



DEVELOPMENT OF A *MASH* TL-3 MEDIAN BARRIER GATE



Research/Test Report 9-1002-2

Cooperative Research Program

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

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
<http://tti.tamu.edu/documents/9-1002-2.pdf>

1. Report No. FHWA/TX-11/9-1002-2		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle DEVELOPMENT OF A MASH TL-3 MEDIAN BARRIER GATE				5. Report Date February 2011 Published June 2011	
				6. Performing Organization Code	
7. Author(s) Roger P. Bligh, Dusty R. Arrington, Chiara Silvestri, and Wanda L. Menges				8. Performing Organization Report No. Test Report 9-1002-2	
9. Performing Organization Name and Address Texas Transportation Institute Proving Ground The Texas A&M University System College Station, Texas 77843-3135				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. Project 9-1002	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080				13. Type of Report and Period Covered Technical/Test Report: September 2008–August 2010	
				14. Sponsoring Agency Code	
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration. Project Title: Roadside Safety Device Crash Testing Program URL: http://tti.tamu.edu/documents/9-1002-2.pdf					
16. Abstract <p>Median barriers are commonly used to separate opposing lanes of traffic on divided highways and to separate managed lanes from general purpose lanes. Concrete median barriers (CMBs) are often preferred on urban freeways with narrow medians due to their minimal deflection and low maintenance. However, long, continuous runs of CMBs limit access of emergency and maintenance vehicles to the other side of a roadway or a managed lane. Implementation of crashworthy median barrier gates at these locations can maintain the desired level of median protection for motorists while offering improved cross-median access for emergency and/or maintenance vehicles.</p> <p>A new median barrier gate was developed and crash tested under this project. The gate spans a 30-ft opening in a concrete median barrier and consists of two vertically stacked 12-inch × 12-inch × ¼-inch steel tubes connected to steel end brackets with 2¼-inch diameter steel pins.</p> <p>The gate is economical to fabricate and install. It can be manually operated by a single person and is designed to accommodate reversible traffic flow on both sides of the median and be operable in both directions on each end. The median barrier gate satisfies <i>MASH</i> Test Level 3 (TL-3) impact performance criteria and is considered suitable for implementation on Texas highways where cross-median access is desired.</p>					
17. Key Words Median Barrier, Gate, Roadside Safety, Crash Test, <i>MASH</i>			18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov		
19. Security Classif.(of this report) Unclassified		20. Security Classif.(of this page) Unclassified		21. No. of Pages 170	22. Price

**DEVELOPMENT OF A *MASH* TL-3
MEDIAN BARRIER GATE**

by

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

Dusty R. Arrington
Engineering Research Associate
Texas Transportation Institute

Chiara Silvestri
Post Doctoral Research Associate
Texas Transportation Institute

and

Wanda L. Menges
Research Specialist
Texas Transportation Institute

Report 9-1002-2
Project 9-1002
Project Title: Roadside Safety Device Crash Testing Program

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

February 2011
Published: June 2011

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


DISCLAIMER


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

TTI PROVING GROUND DISCLAIMER

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




Wanda L. Menges, Research Specialist
Deputy Quality Manager


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

ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the Federal Highway Administration. The TxDOT project director for this research was Rory Meza, P.E. Bobby Dye with the Design Division served as project advisor and was also actively involved in this research. The authors acknowledge and appreciate their guidance and assistance.

TABLE OF CONTENTS

	Page
LIST OF FIGURES	x
LIST OF TABLES	xii
CHAPTER 1. INTRODUCTION	1
1.1 INTRODUCTION	1
1.2 BACKGROUND	1
1.3 OBJECTIVES/SCOPE OF RESEARCH	4
CHAPTER 2. MEDIAN BARRIER GATE DESIGN.....	5
2.1 DESIGN CONSIDERATIONS	5
2.1.1 Snagging	5
2.1.2 Rail Member Selection	6
2.2 FINITE ELEMENT ANALYSIS	7
CHAPTER 3. MEDIAN BARRIER GATE DETAILS.....	13
3.1 TEST ARTICLE DESIGN AND CONSTRUCTION.....	13
3.2 MATERIAL SPECIFICATIONS	14
3.3 SOIL CONDITIONS	14
CHAPTER 4. TEST REQUIREMENTS AND EVALUATION CRITERIA.....	19
4.1 CRASH TEST MATRIX.....	19
4.2 EVALUATION CRITERIA.....	19
CHAPTER 5. CRASH TEST PROCEDURES	21
5.1 TEST FACILITY	21
5.2 VEHICLE TOW AND GUIDANCE PROCEDURES	21
5.3 DATA ACQUISITION SYSTEMS.....	21
5.3.1 Vehicle Instrumentation and Data Processing	21
5.3.2 Anthropomorphic Dummy Instrumentation	22
5.3.3 Photographic Instrumentation and Data Processing	22
CHAPTER 6. CRASH TEST 420020-6 (<i>MASH</i> TEST 3-20).....	23
6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS	23
6.2 TEST VEHICLE.....	23
6.3 WEATHER CONDITIONS.....	23
6.4 TEST DESCRIPTION.....	23
6.5 DAMAGE TO TEST INSTALLATION	26
6.6 VEHICLE DAMAGE.....	26
6.7 OCCUPANT RISK FACTORS.....	26
6.8 ASSESSMENT OF TEST RESULTS	32

TABLE OF CONTENTS (CONTINUED)

	Page
6.8.1 Structural Adequacy.....	32
6.8.2 Occupant Risk.....	32
6.8.3 Vehicle Trajectory	33
CHAPTER 7. CRASH TEST 420020-7 (<i>MASH</i> TEST 3-11).....	35
7.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS	35
7.2 TEST VEHICLE.....	35
7.3 WEATHER CONDITIONS.....	35
7.4 TEST DESCRIPTION.....	35
7.5 DAMAGE TO TEST INSTALLATION.....	38
7.6 VEHICLE DAMAGE.....	38
7.7 OCCUPANT RISK FACTORS.....	38
7.8 ASSESSMENT OF TEST RESULTS.....	44
7.8.1 Structural Adequacy.....	44
7.8.2 Occupant Risk.....	44
7.8.3 Vehicle Trajectory	45
CHAPTER 8. CRASH TEST 420020-8 (<i>MASH</i> TEST 3-21).....	47
8.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS	47
8.2 TEST VEHICLE.....	47
8.3 WEATHER CONDITIONS.....	47
8.4 TEST DESCRIPTION.....	47
8.5 DAMAGE TO TEST INSTALLATION.....	50
8.6 VEHICLE DAMAGE.....	50
8.7 OCCUPANT RISK FACTORS.....	50
8.8 ASSESSMENT OF TEST RESULTS.....	56
8.8.1 Structural Adequacy.....	56
8.8.2 Occupant Risk.....	56
8.8.3 Vehicle Trajectory	57
CHAPTER 9. SUMMARY AND CONCLUSIONS.....	59
CHAPTER 10. IMPLEMENTATION STATEMENT.....	63
REFERENCES	65
APPENDIX A. DETAILS OF THE TXDOT MEDIAN BARRIER GATE.....	67
APPENDIX B. CERTIFICATION DOCUMENTATION.....	83
APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION	95

TABLE OF CONTENTS (CONTINUED)

	Page
APPENDIX D. SEQUENTIAL PHOTOGRAPHS.....	107
APPENDIX E. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS	117
APPENDIX F. RECOMMENDED MEDIAN BARRIER GATE DETAILS.....	138

LIST OF FIGURES

		Page
Figure 1.1.	Emergency Opening System (EOS).....	3
Figure 2.1.	Mid-Span Impact of Pickup Truck into EOS: (a) Initial Impact Conditions and (b) High Vehicle Roll Angle.....	8
Figure 2.2.	Pickup Truck in Relation to Different Rail Geometries Chosen for Evaluation. ...	8
Figure 2.3.	Rail Deformation and Deflection Results.....	9
Figure 2.4.	Vehicle Roll Angle Results.....	10
Figure 2.5.	Predicted Vehicle Roll Outcomes for Different Rail Configurations.....	11
Figure 3.1.	Details of the TxDOT Median Barrier Gate Installation.....	15
Figure 3.2.	Details of the TxDOT Median Barrier Gate.....	16
Figure 3.3.	TxDOT Median Barrier Gate Installation before Testing.....	17
Figure 6.1.	Vehicle/Barrier Geometrics for Test No. 420020-6.....	24
Figure 6.2.	Vehicle before Test No. 420020-6.....	25
Figure 6.3.	Vehicle/Barrier Positions after Test No. 420020-6.....	27
Figure 6.4.	TxDOT Median Barrier Gate after Test No. 420020-6.....	28
Figure 6.5.	Vehicle after Test No. 420020-6.....	29
Figure 6.6.	Interior of Vehicle for Test No. 420020-6.....	30
Figure 6.7.	Summary of Results for <i>MASH</i> Test 3-20 on the TxDOT Median Barrier Gate..	31
Figure 7.1.	Vehicle/Gate Geometrics for Test No. 420020-7.....	36
Figure 7.2.	Vehicle before Test No. 420020-7.....	37
Figure 7.3.	Vehicle/Gate Positions after Test No. 420020-7.....	39
Figure 7.4.	TxDOT Median Barrier Gate after Test No. 420020-7.....	40
Figure 7.5.	Vehicle after Test No. 420020-7.....	41
Figure 7.6.	Interior of Vehicle for Test No. 420020-7.....	42
Figure 7.7.	Summary of Results for <i>MASH</i> Test 3-11 on the TxDOT Median Barrier Gate..	43
Figure 8.1.	Vehicle/Gate Geometrics for Test No. 420020-8.....	48
Figure 8.2.	Vehicle before Test No. 420020-8.....	49
Figure 8.3.	Position of Vehicle/Gate after Test No. 420020-8.....	51
Figure 8.4.	Installation after Test No. 420020-8.....	52
Figure 8.5.	Vehicle after Test No. 420020-8.....	53
Figure 8.6.	Interior of Vehicle for Test No. 420020-8.....	54
Figure 8.7.	Summary of Results for <i>MASH</i> Test 3-21 on the TxDOT Median Barrier Gate..	55
Figure C1.	Vehicle Properties for Test No. 420020-6.....	95
Figure C2.	Vehicle Properties for Test No. 420020-7.....	98
Figure C3.	Vehicle Properties for Test No. 420020-8.....	102
Figure D1.	Sequential Photographs for Test No. 420020-6 (Overhead and Frontal Views).....	107
Figure D2.	Sequential Photographs for Test No. 420020-6 (Rear View).....	109
Figure D3.	Sequential Photographs for Test No. 420020-7 (Overhead and Frontal Views).....	110
Figure D4.	Sequential Photographs for Test No. 420020-7 (Rear View).....	112
Figure D5.	Sequential Photographs for Test No. 420020-8 (Overhead and Frontal Views).....	113

LIST OF FIGURES (CONTINUED)

		Page
Figure D6.	Sequential Photographs for Test No. 420020-8 (Rear View).....	115
Figure E1.	Vehicle Angular Displacements for Test No. 420020-6.....	117
Figure E2.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-6 (Accelerometer Located at Center of Gravity).	118
Figure E3.	Vehicle Lateral Accelerometer Trace for Test No. 420020-6 (Accelerometer Located at Center of Gravity).	119
Figure E4.	Vehicle Vertical Accelerometer Trace for Test No. 420020-6 (Accelerometer Located at Center of Gravity).	120
Figure E5.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-6 (Accelerometer Located over Rear Axle).	121
Figure E6.	Vehicle Lateral Accelerometer Trace for Test No. 420020-6 (Accelerometer Located over Rear Axle).	122
Figure E7.	Vehicle Vertical Accelerometer Trace for Test No. 420020-6 (Accelerometer Located over Rear Axle).	123
Figure E8.	Vehicle Angular Displacements for Test No. 420020-7.....	124
Figure E9.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-7 (Accelerometer Located at Center of Gravity).	125
Figure E10.	Vehicle Lateral Accelerometer Trace for Test No. 420020-7 (Accelerometer Located at Center of Gravity).	126
Figure E11.	Vehicle Vertical Accelerometer Trace for Test No. 420020-7 (Accelerometer Located at Center of Gravity).	127
Figure E12.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-7 (Accelerometer Located over Rear Axle).	128
Figure E13.	Vehicle Lateral Accelerometer Trace for Test No. 420020-7 (Accelerometer Located over Rear Axle).	129
Figure E14.	Vehicle Vertical Accelerometer Trace for Test No. 420020-7 (Accelerometer Located over Rear Axle).	130
Figure E15.	Vehicle Angular Displacements for Test No. 420020-8.....	131
Figure E16.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-8 (Accelerometer Located at Center of Gravity).	132
Figure E17.	Vehicle Lateral Accelerometer Trace for Test No. 420020-8 (Accelerometer Located at Center of Gravity).	133
Figure E18.	Vehicle Vertical Accelerometer Trace for Test No. 420020-8 (Accelerometer Located at Center of Gravity).	134
Figure E19.	Vehicle Longitudinal Accelerometer Trace for Test No. 420020-8 (Accelerometer Located over Rear Axle).	135
Figure E20.	Vehicle Lateral Accelerometer Trace for Test No. 420020-8 (Accelerometer Located over Rear Axle).	136
Figure E21.	Vehicle Vertical Accelerometer Trace for Test No. 420020-8 (Accelerometer Located over Rear Axle).	137

LIST OF TABLES

	Page
Table 2.1. Comparison of Tubular Rail Properties.....	7
Table 9.1. Performance Evaluation Summary for <i>MASH</i> Test 3-20 on the TxDOT Median Barrier Gate.	60
Table 9.2. Performance Evaluation Summary for <i>MASH</i> Test 3-11 on the TxDOT Median Barrier Gate.	61
Table 9.3. Performance Evaluation Summary for <i>MASH</i> Test 3-21 on the TxDOT Median Barrier Gate.	62
Table C1. Exterior Crush Measurements for Test No. 420020-6.....	96
Table C2. Occupant Compartment Measurements for Test No. 420020-6.	97
Table C3. Vehicle Parametric Measurements for Vertical CG for Test No. 420020-7.....	99
Table C4. Exterior Crush Measurements for Test No. 420020-7.....	100
Table C5. Occupant Compartment Measurements for Test No. 420020-7.	101
Table C6. Vehicle Parametric Measurements for Vertical CG for Test No. 420020-7.....	103
Table C7. Exterior Crush Measurements for Test No. 420020-8.....	104
Table C8. Occupant Compartment Measurements for Test No. 420020-8.	105

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.

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

Median barriers are commonly used to separate opposing lanes of traffic on divided highways. Concrete median barriers (CMBs) are often preferred on urban freeways with narrow medians. They are also used along heavily traveled highways to separate managed lanes from general purpose lanes. The rigid nature of concrete barriers results in little or no deflection and makes them relatively maintenance free. This reduces life-cycle cost, congestion due to lane closures, and exposure of maintenance personnel.

However, long, continuous runs of CMBs limit access of emergency and maintenance vehicles to the other side of the roadway or a managed lane. Periodic openings in the barrier can provide needed cross-median access. However, the exposed barrier ends resulting from openings in a concrete median barrier pose an impact hazard for traffic. Even if the exposed barrier ends are safety treated with crash attenuators, median protection is lost along the length of the opening. Implementation of crashworthy median barrier gates at these locations can maintain the desired level of median protection for motorists while offering improved cross-median access for emergency and/or maintenance vehicles.

A median barrier gate must be able to function as a median barrier to contain and redirect errant vehicles impacting along its length, be able to open and close, and be properly transitioned to the CMB on both ends. The Texas Transportation Institute (TTI) developed an emergency opening system (EOS) for the Texas State Department of Highways and Public Transportation (SDHPT) in the early 1980s (*1*). The system was comprised of two tubular steel beams mounted vertically on top of each other with a separation of 3 inches. A W-beam rail was attached to the face of the steel beams and terminated with W-beam end connectors to minimize snagging potential. The beams spanned 30 ft between free-standing CMB sections that were modified to transition from a New Jersey safety shape profile to a vertical face. Steel brackets with three 7/8-inch thick horizontal steel plates were anchored to the ends of the CMB sections using eight 1.5-inch diameter anchor bolts. The steel box beams were pinned to the brackets using a

3.25-inch diameter pin at each end. A jack and caster mechanism was used to raise the beams off of the horizontal bracket plates to permit it to be pushed open.

Three full-scale crash tests were conducted to evaluate the impact performance of the system under *NCHRP Report 230* (2). Two tests were performed to evaluate the transition of the steel beams to the CMB and the effects of vehicle snagging on the concrete barrier ends. One test involved an 1800-lb small passenger car impacting the EOS at a nominal speed of 60 mi/h and a nominal angle of 15 degrees. The other transition test involved a 4500-lb passenger sedan impacting the EOS at nominal speed of 60 mi/h and a nominal angle of 25 degrees. The impact point for both tests was 6 ft upstream of the downstream end of the system.

Another test was conducted 6 ft upstream of the midpoint of the gate to evaluate the strength and maximum deflection of the steel beams. A 4500-lb passenger sedan impacted the EOS at nominal speed of 60 mi/h and a nominal angle of 25 degrees. The crash tests were successful, and the design was implemented by the SDHPT on selected projects along Interstate 45 (1).

As traffic volumes have continued to increase, additional lanes have been added to increase capacity. This has resulted in narrower medians and the use of more concrete median barrier to separate traffic. The use of managed lanes has also increased significantly in recent years as another means of addressing growing congestion problems. Consequently, the need for median barrier gates to provide emergency and other authorized vehicles access to these lanes has also increased.

TTI conducted further testing of both the original and a modified version of the EOS for the TxDOT under research project 0-5210 (3). The objective of the testing was to determine if the EOS complies with the new *Manual for Assessing Safety Hardware (MASH)* that was published by the American Association of State Highway and Transportation Officials (AASHTO) in October 2009 (4). *MASH* has superseded *NCHRP Report 350* (5) as the recommended guidance for the safety performance evaluation of roadside safety features.

MASH test designation 3-10 was performed on the original EOS barrier design with some minor modifications incorporated to reduce the potential for vehicle snagging. The horizontal plates on the steel end bracket were tapered, and the curb protruding from the end of the concrete parapet was constructed with a straight taper rather than a rounded nose. Figure 1 shows the test installation. The test conditions were a 2420 lb vehicle (denoted 1100C) impacting the gate 3.6 ft upstream of the end of the concrete parapet at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively.

The 1100C test vehicle was contained and redirected. However, the gate failed to comply with *MASH* due to excessive occupant compartment deformation inside the vehicle (3).



Figure 1.1. Emergency Opening System (EOS).

Several modifications were made to the end of the EOS to help mitigate the severe vehicle snagging. These changes were developed with retrofit of the existing design as a goal. The horizontal steel plates on the end brackets were replaced with tapered sections of 2 inch \times $\frac{1}{4}$ -inch thick steel tubing. The ends of the tubular steel beams were cut off and tapered sections of tubing were added. These tubes tapered out 2 inches from the sides of the steel beams and then tapered back down to a width that was less than the width of the end of the concrete parapet to reduce snagging potential from a reverse direction impact. When assembled and installed, the tapered sections of tubing on the steel beams and end bracket overlapped each other to resemble

a finger joint. Other details of the median barrier gate, including the concrete parapet details, remained the same as in the previous tests.

MASH test 3-10 was performed on the modified design. Once again, the modified gate did not perform acceptably due to excessive occupant compartment deformation inside the vehicle (3). Further research was needed to develop a median barrier gate that satisfies *MASH* impact performance criteria.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this research was to develop a median barrier gate that meets the Test Level 3 (TL-3) impact performance requirements of *MASH*. TxDOT requested that the gate be designed to accommodate reversible traffic flow on both sides of the median and that the gate be operable in both directions on each end.

The research approach consisted of engineering analysis, finite element simulation, and full-scale crash testing. Three tests were performed to evaluate different aspects of the design. Test 3-11 evaluated the strength of the median barrier gate and its ability to function as a longitudinal barrier. Tests 3-20 and 3-21 assessed the transition of the median barrier gate to the adjacent concrete median barrier.

Reported herein are details of the design and analysis of the TxDOT median barrier gate, descriptions of the tests performed, assessment of the test results, and implementation recommendations.

CHAPTER 2. MEDIAN BARRIER GATE DESIGN

A median barrier gate must function as a median barrier. Adequate strength is necessary to maintain continuity of protection between the sections of concrete median barrier it spans. The gate must be capable of containing and redirecting errant vehicles that impact along its length. Additionally, the stiffness of the gate must be properly transitioned to the adjacent concrete median barrier to prevent excessive vehicle snagging or vehicle “pocketing” into the more flexible gate in advance of the rigid barrier end.

As the name implies, the median barrier gate must also function as a gate. It must be capable of being readily opened and closed from both directions on either end. The gate must be sufficiently light to permit manual operation and the components, including any wheels or casters must be durable and suitable for operation in a highway environment. Key design considerations that must be addressed include vehicle snagging on exposed CMB surfaces, structural adequacy to accommodate the increased impact severity of the design impact conditions prescribed by the AASHTO *MASH*, and stability of the pickup truck design test vehicle.

2.1 DESIGN CONSIDERATIONS*

2.1.1 Snagging

As discussed in Chapter 1, the original EOS failed to comply with *MASH*. Exposed surfaces on the CMB to which the gate was attached permitted severe vehicle snagging to occur. The snagging forces led to excessive occupant compartment deformation inside the vehicle.

Various design features were incorporated into the new median barrier gate to help mitigate snagging potential. The vertical spacing between the rail elements was eliminated. This not only reduced snagging, but also simplified fabrication. Stacking the two rails on top of one another eliminates the need for welded spacers. Thus, the rails can be individually galvanized and assembled with through bolts rather than being welded together with channel spacers and galvanized as a unit.

Additionally, the width of the tubular rail members was increased to match the width of the end of the concrete parapet to which it is attached. This decreases the ability of the vehicle to make direct contact with the end of the concrete parapet. When making this change, it was important to account for the tolerance in the pinned connection and any lateral shift that the connection permits in the rail members. Too much shift could expose the edge of the rail members and result in snagging in a reverse direction impact.

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

Finally, the gap between the ends of the tubular rails and the concrete parapet was minimized. Some offset was required to accommodate the travel arc of the rails as they are opened and closed.

2.1.2 Rail Member Selection

The selection of a rail member to serve as the beams in the median barrier gate involved consideration of several factors. The bending capacity of the rails had to be sufficient to contain and redirect a pickup truck impacting at the design test conditions specified in *MASH*. The EOS was connected to free-standing barrier ends when it was crash tested. The resulting lateral barrier deflection reduced the impact forces compared to a system connected to a rigid barrier. Furthermore, the heavier design test vehicle specified in *MASH* increased the impact severity by 13 percent compared to the nominal test conditions used to evaluate the EOS.

Geometry of the rails was an important consideration in addition to strength. As mentioned in the previous section, it was desirable that the width of the rail match the width of the end of the concrete parapet to which it was attached to reduce snagging potential. Further, several constraints existed on the depth of the rail members. The combined height of the two rail members had to provide sufficient rail height to maintain vehicle stability during redirection while maintaining a clear opening from the ground to the bottom of the lower rail of no more than 11 inches. An empirical relationship between clear opening and post setback distance is presented in Section 13 “Railings” of the 2004 AASHTO *LRFD Bridge Design Specifications* (6). This guidance, which was based on crash test performance, recommends that the clear opening beneath a rail be no more than 11 inches when the post setback distance is zero. In the case of the median barrier gate, the “post” is the end of the concrete parapet and the setback distance is zero (i.e., the edge of the concrete parapet is aligned with the face of the tubular steel rail elements).

Weight, cost, and availability were other important factors in the selection of a rail member for use in the median barrier gate. If the tubular steel rails were too heavy, it would make their use in a manually operated gate impractical. Some districts have found the cost of proprietary gate systems in the market to be prohibitive. One of the design objectives for the new median barrier gate was to keep its cost comparable to that of the existing EOS. The availability of tubular steel members in large sizes can be very limited. Selection of a rail size with very limited availability could adversely affect fabrication and delivery schedules. The researchers contacted several steel suppliers in Texas to obtain cost information and verify availability of the members being considered for use in the median barrier gate system.

Table 2.1 shows the weight, cost, and plastic section modulus for the 8-inch × 8-inch × ½-inch steel tube used in the EOS and other sizes with possible application in the new median barrier gate. Tubular members with a width of 12 inches were selected to match the width of the concrete parapet needed to develop the strength of the barrier gate. The selection of member depth was a function of rail height. Stacked 12-inch × 10-inch steel tubes could provide a maximum height of 31 inches when constrained by a maximum clear opening of 11 inches. The 12-inch × 12-inch section could provide rail heights up to 35 inches.

Several thicknesses were available for these two sizes of steel tubes. The selection of a thickness is based on the required strength. Impact simulations were performed to aid in the selection of a rail height based on vehicle stability and a rail thickness based on strength.

Table 2.1. Comparison of Tubular Rail Properties.

Material Costs (04/2010)					
Section	Thickness	Cost/Foot	Weight/Foot	Cost/lb	Zx
12x12	1/4	\$28.91	39.4	\$0.73	47.6
	5/16	\$33.42	48.8	\$0.68	58.6
	3/8	\$35.90	58	\$0.62	69.2
12x10	1/4	\$38.80	36	\$1.08	42.1
	5/16	N/A	44.6	N/A	51.7
	3/8	\$58.35	52.9	\$1.10	61.1
8x8	1/2	\$38.09	48.7	\$0.78	37.5

2.2 FINITE ELEMENT ANALYSIS[†]

Finite element models were developed for use in impact simulations to determine the optimal rail member size for the new median barrier gate. The objective was to meet strength and crashworthiness requirements while minimizing weight and cost. This was accomplished through a parametric study of the performance of different rail sizes and thicknesses.

The LS-DYNA finite element code was used for the simulations (7). LS-DYNA is a general purpose explicit finite element code capable of simulating complex nonlinear dynamic impact problems. LS-DYNA incorporates state-of-the-art contact algorithms that can be used to model vehicular collisions with roadside objects and is widely used within the roadside safety research community for analyzing the impact performance of roadside safety hardware.

The analyses were performed using the impact conditions of *MASH* test 3-11. This test involves a 5000-lb pickup truck (denoted 2270P) impacting the barrier at a speed of 62 mi/h and an angle of 25 degrees. The impact point was approximately 4 ft upstream of the midpoint of the gate. The vehicle model used in the simulations was a 2007 Chevrolet Silverado 1500, 2-wheel drive (2WD), crew cab, short box, pickup truck (8). This model was developed by the National Crash Analysis Center (NCAC) under sponsorship of the Federal Highway Administration (FHWA) to represent the *MASH* design vehicle.

An initial simulation was performed on the EOS. This system incorporates two 8-inch × 8-inch × ½-inch steel tubes vertically separated 3 inches and mounted at a height of 28.5 inches.

[†] The full-scale crash test reported herein were performed at TTI Proving Ground. TTI Proving Ground is an ISO 17025 accredited laboratory with A2LA Mechanical Testing certificate 2821.01. This certificate does not include simulation analysis.

The pickup truck exhibited a high roll angle as shown in Figure 2.1, and rollover was the predicted outcome. It was concluded from the results of this simulation that the rail height needed to be increased to improve stability of the pickup truck.

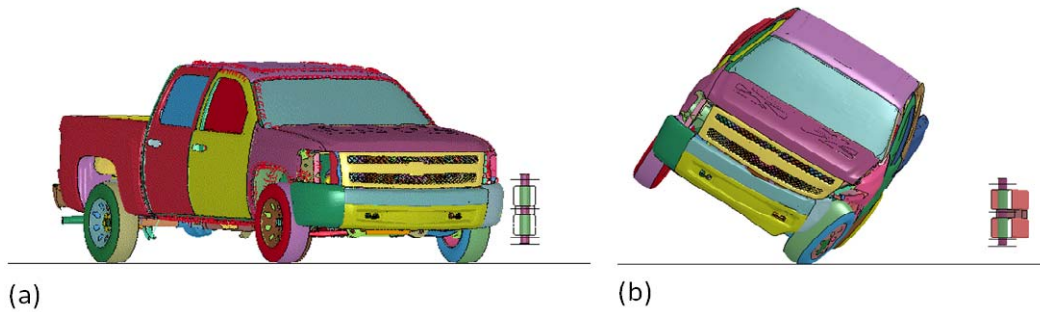


Figure 2.1. Mid-Span Impact of Pickup Truck into EOS: (a) Initial Impact Conditions and (b) High Vehicle Roll Angle.

Additional simulations were performed with the 12-inch \times 10-inch and 12-inch \times 12-inch steel tubes. The lightest sections (i.e., minimum thickness) available were selected for evaluation. The 12-inch \times 10-inch \times 1/4-inch tube was evaluated at a height of 31 inches, which was the maximum height that could be achieved while maintaining a maximum clear opening of 11 inches below the rail. A 12-inch \times 12-inch \times 1/4-inch steel tube was evaluated at heights of 34 inches and 36 inches. Figure 2.2 shows the pickup truck in relation to these rail configurations. As a consequence of these first findings, the barrier design process concentrated in investigating the impact response behavior of the device with alternative heights and sections. At first, various 12-inch wide tube sections were evaluated with different rail heights, as it is shown in Figure 2.2.

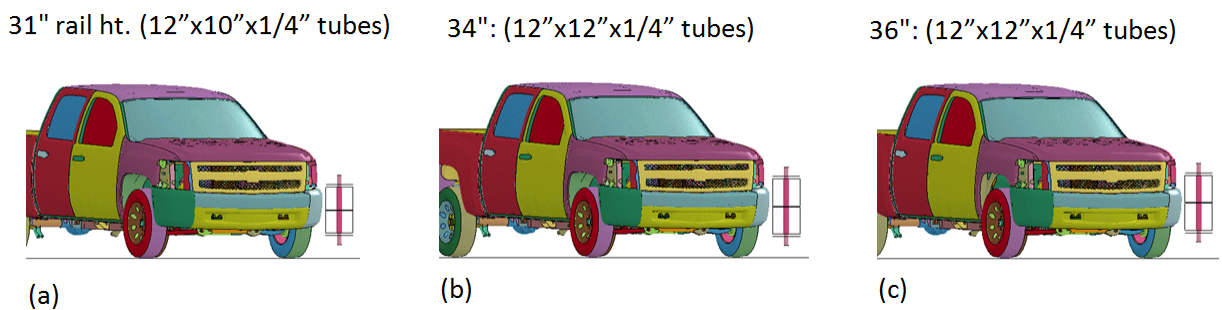


Figure 2.2. Pickup Truck in Relation to Different Rail Geometries Chosen for Evaluation.

As shown in Figure 2.3, the maximum dynamic deflection and permanent deflection was similar for all three rail configurations. Some localized buckling was observed in the 12-inch \times 12-inch \times 1/4-inch tube.

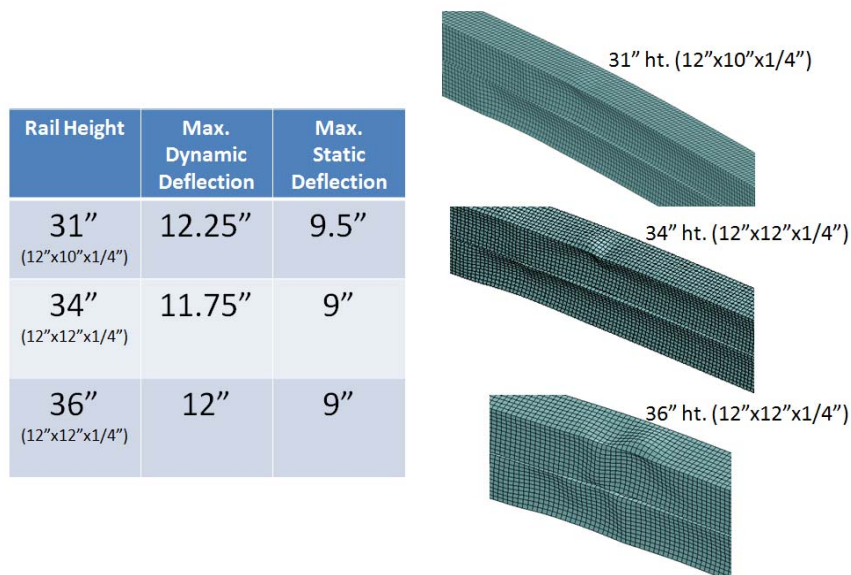


Figure 2.3. Rail Deformation and Deflection Results.

Figure 2.4 shows vehicle roll angle versus time. At time of termination of the simulation runs (0.55 seconds), the vehicle roll angle for the 31 inch rail height was 35 degrees and still increasing. Vehicle rollover for this configuration is likely. The vehicle was very stable in the impact with the 36 inch rail height, with a maximum roll angle of only 17 degrees. The vehicle was also successfully redirected in the simulation with the 34 inch rail height, but the vehicle had a higher roll angle of 27 degrees.

Results showed that a 12-inch × 10-inch tube section was not feasible as a rail member for the new median barrier gate. It was not capable of redirecting the pickup truck in a stable manner at its maximum height of 31 inches. Thus, further evaluation efforts focused on the 12-inch × 12-inch steel tube sections.

Two additional simulations were performed. One simulation evaluated vehicle stability associated with a 35 inch rail height. A 12-inch × 12-inch × -1/4 inch tube was used in this simulation. The final simulation was performed with a thicker 12-inch × 12-inch × 5/16-inch tube at a height of 34 inches. The purpose of this simulation was to evaluate if the local buckling phenomenon observed in the simulation of the thin-walled tube affected vehicle stability. In other words, would the reduced deformation of a thicker, stronger tube improve vehicle stability and enable a lower mounting height to be utilized.

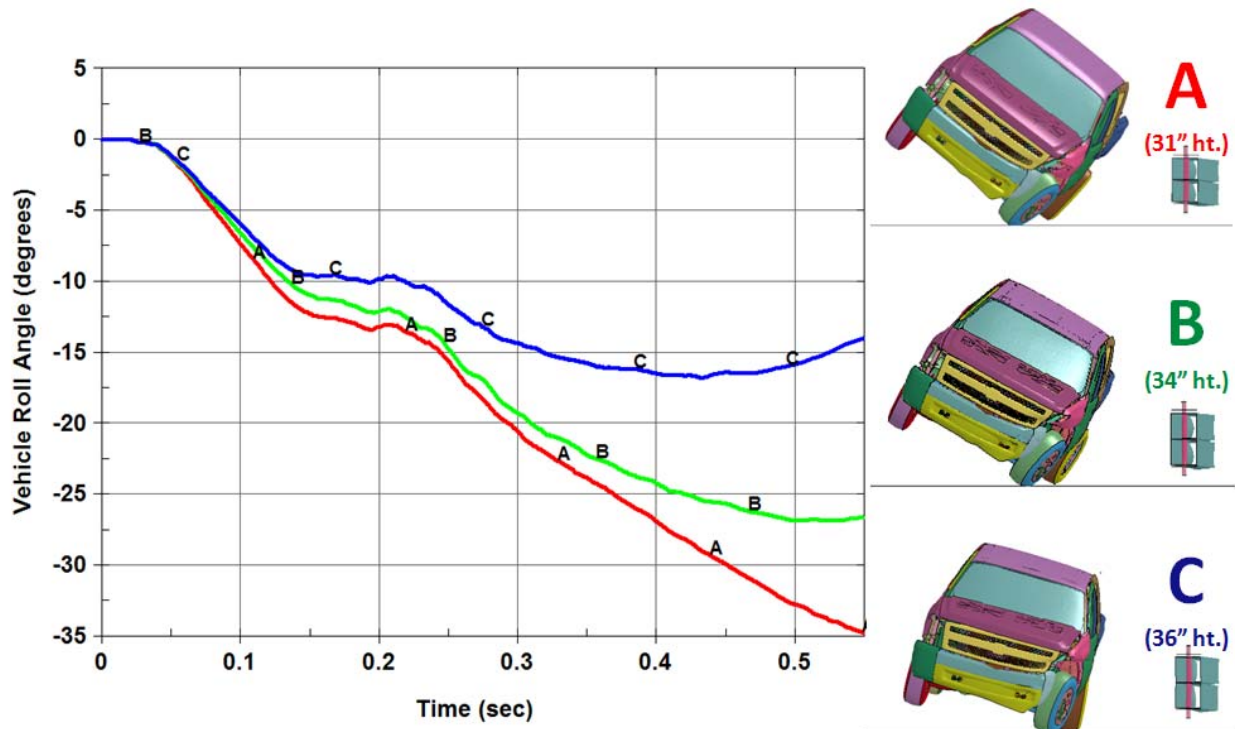


Figure 2.4. Vehicle Roll Angle Results.

Figure 2.5 shows vehicle roll angle versus time for these additional simulations superimposed on the results from the previous simulations. Results from the two cases with different rail thickness (cases B and E) are similar in terms of vehicle roll angle, indicating that the increase in rail thickness did not affect vehicle stability. Consequently, there was no compelling reason to adopt a thicker, heavier, more costly rail section. It was concluded that the 12-inch \times 12-inch \times 1/4-inch tube section was the optimal choice as a rail member for the new median barrier gate. Not only does it provide adequate strength to contain and redirect the pickup truck, it is a lighter and less expensive section than the 8-inch \times 8-inch \times 1/2-inch tube section used in the EOS (refer to Table 2.1).

The rail height selected for the new median barrier gate was 35 inches. The pickup truck was stably redirected at this rail height as shown in Figure 2.5. Further, this is the maximum height that can be achieved with the stacked 12-inch \times 12-inch \times 1/4-tubes when constrained by a maximum clear opening of 11 inches between the ground and bottom of the rail to reduce potential for vehicle snagging.

The impact forces derived from the simulation of the selected rail configuration were used to size the connection pins, design the steel anchor bracket, and engineer the reinforcement in the concrete parapet ends. The design recommendations were reviewed and approved by TxDOT. Full-scale crash tests were performed to verify the impact performance of the median barrier gate. Details of the median barrier gate and crash tests are described in the following sections of this report.

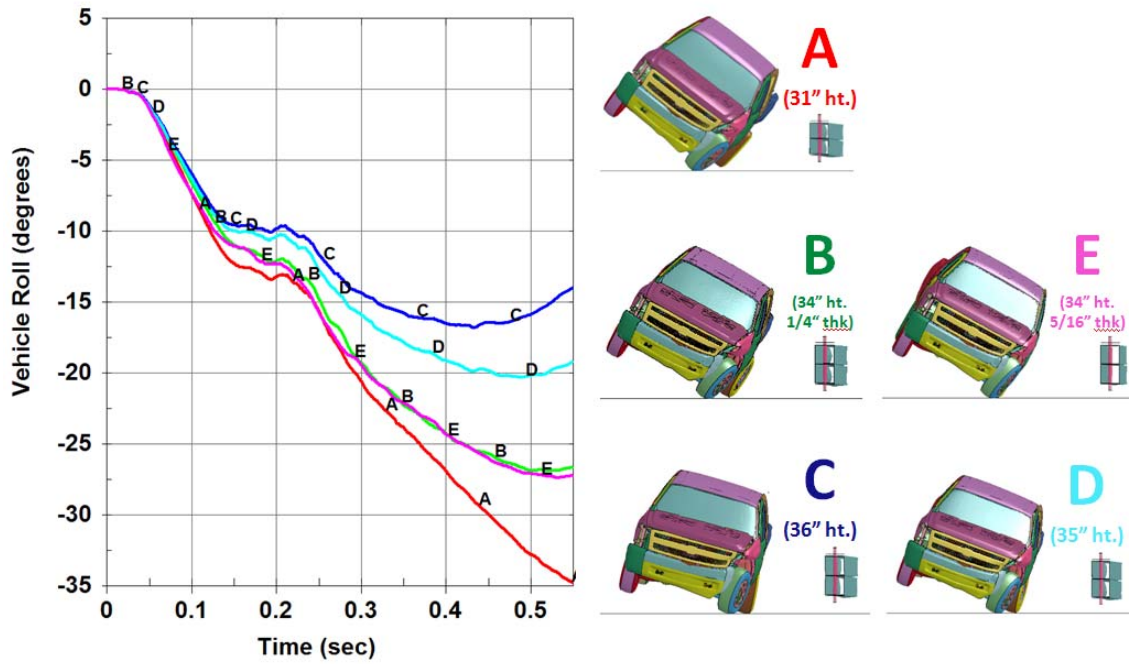


Figure 2.5. Predicted Vehicle Roll Outcomes for Different Rail Configurations.

CHAPTER 3. MEDIAN BARRIER GATE DETAILS

3.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The total length of the installation was 50 ft-0 inch and was comprised of two 10 ft cast-in-place concrete barrier sections with a 30 ft long median barrier gate spanning between them. The concrete parapets were cast in place on top of a 6-inch thick reinforced concrete slab. They were tied to the slab using fourteen #5 stirrups spaced at 8 inches, followed by three #5 stirrups spaced at 4 inches at the gate end of the parapet. The concrete parapets transitioned from a 32-inch tall F-shape that was 9½ inches wide on top and 24 inches wide on bottom to a vertical wall that was 36½ inches tall and 12 inches wide over a distance of 5 ft. A 9½-inch tall curb protruded 16 inches out from the end of the concrete parapet to support the steel end bracket and steel connection pin.

Horizontal reinforcement in the F-shape portion of the concrete parapets consisted of four pairs of #5 bars located 5 inches, 10 inches, 16 inches, and 30½ inches from the bottom of the parapet. These bars were symmetric about the vertical centerline of the parapet and followed its profile. In the transition section, the horizontal reinforcement included two pairs of #5 bars located 5 inches and 10 inches from the bottom of the parapet, and three pairs of #7 Richmond anchors located 14 inches, 20½ inches, and 25½ inches from the bottom of the parapet. Another set of #7 Richmond anchors were bent to follow the vertical taper of the transition and terminated at a height of 31 inches from the bottom of the parapet. The Richmond anchors formed a rectangular bolt pattern to which the steel anchor brackets were attached.

The vertical reinforcement in the 5-ft transition section of the parapet near the gate connection was comprised of pairs of #5 U-bars that created closed stirrups spaced on 4-inch centers. This was followed by four more pairs of U-bars spaced at 8 inches. These U-bars were positioned between #5 open stirrups that were bent to match the profile of the F-shape barrier and spaced on 8-inch centers along the 5-ft length of F-shape barrier.

A 16-inch long, 9½-inch high curb was cast on the inside face of each concrete parapet. A 9½-inch long section of 3-inch schedule 40 pipe that was cast inside the curb and reinforced with two #5 U-bars that extended out of the end of the parapet. The steel end brackets rested on top of the curb, and the connecting pins extended into the embedded pipe section.

The median barrier gate itself was comprised of two 29-ft long, 12-inch × 12-inch × ¼-inch A500 Grade B steel tubes. The tubes were stacked vertically on top of one another and bolted together using three ¾-inch diameter × 26-inch long ASTM A325 or equivalent grade bolts spaced on 80-inch centers. A 2½-inch schedule 40 pipe section was welded inside the ends of the tubes for the connecting pins. The ends of the tubes were reinforced with a tubing support bracket fabricated from ASTM A36 steel plate. The tubing support bracket slides into the end of the tubes around the pipe inserts and is secured in place using two ¾-inch diameter × 26-inch long ASTM A325 or equivalent grade bolts.

Steel end brackets were fabricated from ASTM A36 steel plate. The vertical plate of the end bracket that connected to the end of the concrete parapet was 12 inches wide and 2 inches thick. Two 1-inch thick tapered horizontal steel plates were welded to the top and bottom of the end plate. A 2½-inch × 3-inch slot was cut into each plate to accept the connecting pin.

The end brackets were bolted to the ends of the concrete parapets using eight 1-inch diameter × 3¾-inch long ASTM A325 high-strength bolts. The bolts threaded into the Richmond anchors that were cast inside the concrete parapet.

The median barrier gate was connected to the end brackets using 2¼-inch diameter × 32-inch long ASTM A36 cold rolled steel pins. The pins passed through the horizontal plates in the end bracket, the pipe sections inside the tubular steel rails, and inserted into the pipe sleeve embedded in the parapet curb.

The median barrier was supported by a heavy duty 8-inch diameter swivel caster wheel. The wheel provides a mounting height of 35 inches to the top of the upper steel tube. Figure 3.1, Figure 3.2, and Appendix A show details of the median barrier gate installation. Figure 3.3 presents photographs of the completed test installation.

3.2 MATERIAL SPECIFICATIONS

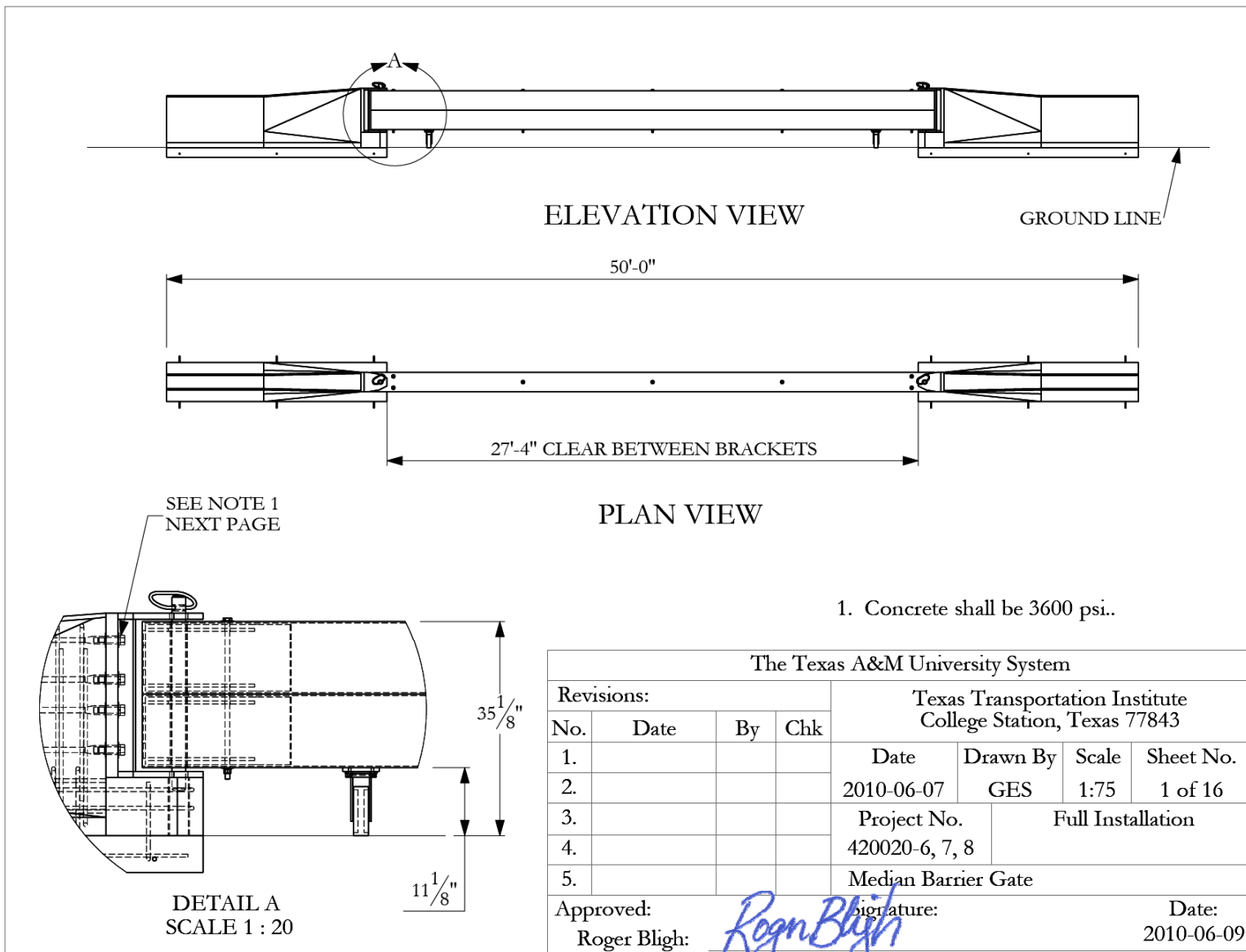
Concrete used for parapet portion of the barrier was specified to have a 28-day unconfined compressive strength of 3600 psi. All reinforcing steel was grade 60.

The rails that comprised the gate were ASTM A500 Grade B steel tubes. The end bracket, tubing support bracket, and caster mounting plate were fabricated from ASTM A36 steel plate.

The bolts used to connect the end bracket to the concrete parapet, secure the tubing support bracket inside the tubes, connect the tubes together, and connect the swivel caster were all ASTM A325 or equivalent grade. The connecting pin was specified to be ASTM A36 cold rolled steel. The handle on the pin was fabricated from ASTM A36 steel rod. Appendix B presents materials certifications related to the materials used to construct the median barrier gate.

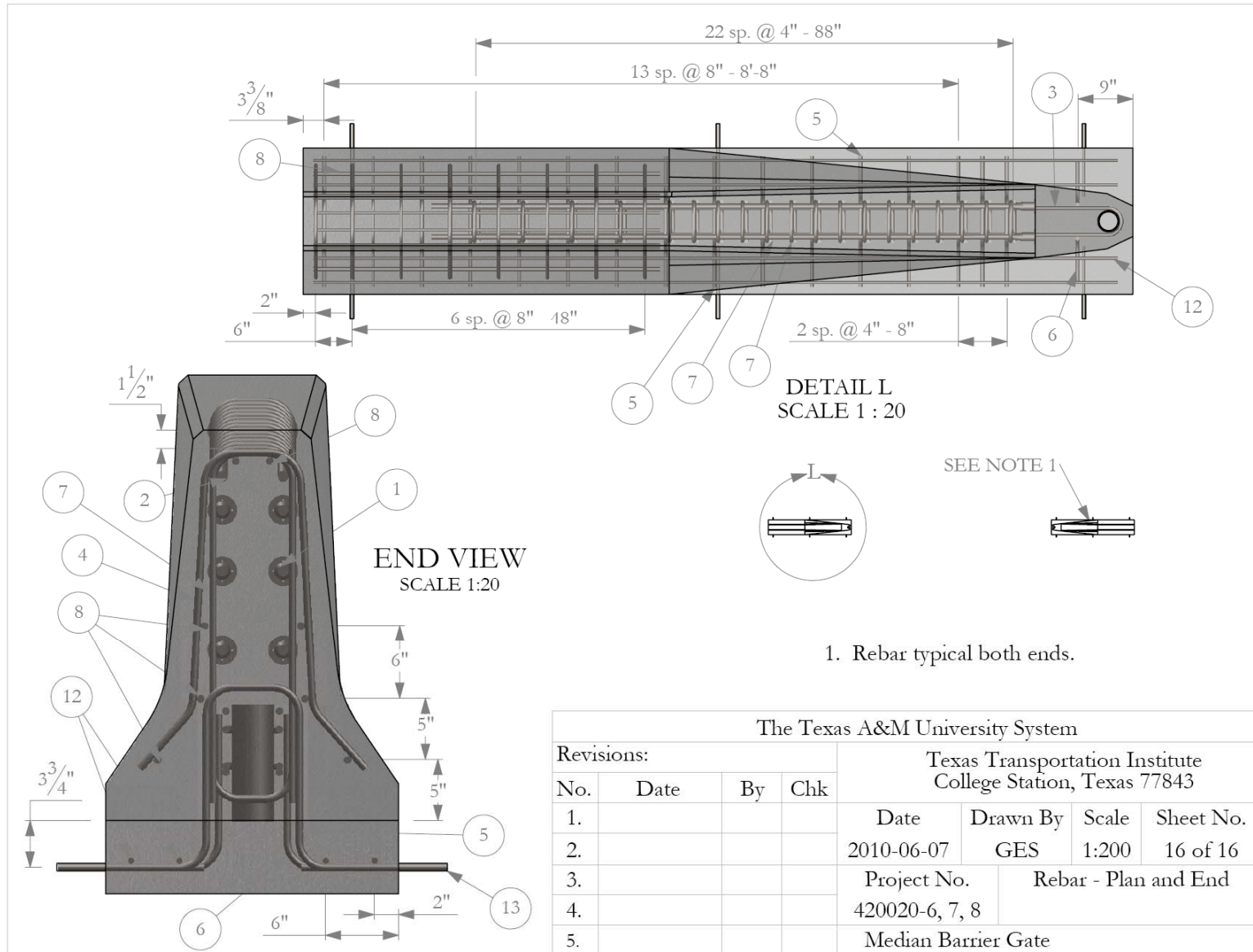
3.3 SOIL CONDITIONS

The test installation was installed on an existing concrete apron.



T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Final Design\Drawings\Median Barrier Gate Drawing

Figure 3.1. Details of the TxDOT Median Barrier Gate Installation.



The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:200	16 of 16
2.				Project No.		Rebar - Plan and End	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							

Figure 3.2. Details of the TxDOT Median Barrier Gate.

T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Final Design\Drawings\Median Barrier Gate Drawing



Figure 3.3. TxDOT Median Barrier Gate Installation before Testing.

CHAPTER 4. TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1 CRASH TEST MATRIX

Three full-scale crash tests were performed to evaluate the impact performance of the TxDOT median barrier gate and assess its compliance with *MASH* guidelines. The first test performed on the TxDOT median barrier gate was *MASH* test 3-20. This test involves a 2420-lb passenger car (denoted 1100C) impacting the median barrier gate upstream of its connection to the rigid concrete parapet at a nominal speed of 62 mi/h and an angle of 25 degrees. The intent of this test is to evaluate the transition of the median barrier gate to the concrete parapet and assesses the potential for vehicle snagging. The critical impact point (CIP) for this test was determined to be 3.6 ft upstream of the concrete parapet end.

The second test was *MASH* test 3-11. This test involves a 5000 lb pickup truck (denoted 2270P) impacting the CIP of the length of need (LON) of the median barrier at a nominal impact speed and angle of 62 mi/h and 25 degrees, respectively. This is a strength test that verifies the structural adequacy of the median barrier gate for impacts involving light trucks and sport utility vehicles (SUVs). Vehicle stability is also a primary evaluation criterion for this test. The CIP for this test was selected to be 4.3 ft upstream of the midpoint of the median barrier gate.

The third test performed on the median barrier gate was *MASH* test 3-21. This test involves a 5000 lb pickup truck impacting the median barrier gate upstream of its connection to the rigid concrete parapet at a nominal speed of 62 mi/h and angle 25 degrees. The purpose of this test is to evaluate the strength of the connection between the median barrier gate and concrete parapet as well as the potential for vehicle snagging in the transition section. The critical impact point (CIP) for this test was determined to be 4.3 ft upstream of the concrete parapet end.

The crash test and data analysis procedures followed for these tests were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

4.2 EVALUATION CRITERIA

The crash tests were evaluated in accordance with the criteria presented in *MASH*. The performance of the TxDOT median barrier gate was judged on the basis of three factors: structural adequacy, occupant risk, and post impact vehicle trajectory. Structural adequacy criteria assess the median barrier gate's ability 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 evaluated to determine potential for secondary impact with other vehicles or fixed objects that may create 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 herein. These criteria are described in further detail for each crash test.

CHAPTER 5. CRASH TEST PROCEDURES

5.1 TEST FACILITY

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

The Texas Transportation Institute Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing. The site selected for construction and testing of the TxDOT median barrier gate evaluated under this project was on the surface of an out-of-service concrete apron. The apron consists of unreinforced jointed-concrete pavement in 12.5-ft by 15-ft blocks nominally 8 to 12 inches deep. The apron is over 50 years old, and the joints have some displacement, but are otherwise flat and level.

5.2 VEHICLE TOW AND GUIDANCE PROCEDURES

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

5.3 DATA ACQUISITION SYSTEMS

5.3.1 Vehicle Instrumentation and Data Processing

The test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro produced by Diversified Technical Systems, Inc. The accelerometers, that measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra small size, solid state units 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 recorded, the data are backed up inside the unit by internal batteries should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark as well as initiating the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The raw data are then processed by the Test Risk Assessment Program (TRAP) software to produce detailed reports of the test results. Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology.

TRAP uses the data from the TDAS Pro to compute occupant/compartiment impact velocities, time of occupant/compartiment 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.

5.3.2 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 tests with the 2270P vehicle.

5.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of the test included three high-speed cameras: one overhead with a field of view perpendicular to the ground and directly over the impact point; one placed behind the installation at an angle; and a third placed to have a field of view parallel to and aligned with the installation at the downstream end. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The footage from these high-speed cameras was 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 median barrier gate installation before and after the test.

CHAPTER 6. CRASH TEST 420020-6 (MASH TEST 3-20)

6.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

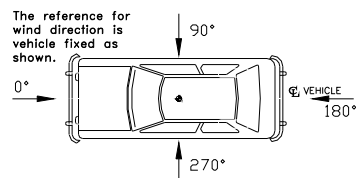
MASH test 3-20 involves an 1100C vehicle weighing 2420 lb \pm 55 lb impacting the median barrier gate at a speed of 62.2 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. The target impact point was 3.6 ft upstream of the end of the concrete parapet. The 2003 Kia Rio used in the test weighed 2424 lb and the actual impact speed and angle were 62.6 mi/h and 24.6 degrees, respectively. The actual impact point was 4.1 ft upstream of the end of the concrete parapet.

6.2 TEST VEHICLE

A 2003 Kia Rio, shown in Figures 6.1 and 6.2, was used for the crash test. Test inertial weight of the vehicle was 2424 lb, and its gross static weight was 2592 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. Figure 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.

6.3 WEATHER CONDITIONS

The test was performed on the morning of July 15, 2010. Eight days prior to test date, a total of 0.17 inch of rainfall was recorded. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 184 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 88°F, relative humidity: 66 percent.



6.4 TEST DESCRIPTION

The 2003 Kia Rio, traveling at a speed of 62.6 mi/h, impacted the TxDOT median barrier gate 49 inches upstream of the end of the concrete parapet at an angle of 24.6 degrees. At approximately 0.009 s after impact, the left front tire of the vehicle contacted the downstream caster wheel of the gate, and at 0.026 s, the left front tire contacted the toe of the concrete barrier. The vehicle began to redirect 0.037 s after impact. At 0.167 s, the vehicle was traveling parallel with the median barrier gate and traveling at a speed of 45.6 mi/h. The rear of the vehicle contacted the barrier 0.199 s after impact. At 0.300 s, the vehicle lost contact with the barrier and was traveling at an exit speed and angle of 49.3 mi/h and 11.6 degrees, respectively. Brakes on the vehicle were applied at 1.4 s after impact, and the vehicle subsequently came to rest 183 ft downstream of impact and 27 ft toward traffic lanes. Figures D1 and D2 in Appendix D show sequential photographs of the test period.



Figure 6.1. Vehicle/Barrier Geometries for Test No. 420020-6.



Figure 6.2. Vehicle before Test No. 420020-6.

6.5 DAMAGE TO TEST INSTALLATION

Damage to the gate itself was only cosmetic and consisted of scuff marks as shown in Figures 6.3 and 6.4. The end of the upstream concrete parapet sustained two thin stress cracks on the field side. Minor concrete spalling was observed on the field side of the end of the downstream concrete parapet. No rebar was exposed and the spall was considered to be cosmetic in nature. The vehicle was in contact with the installation 10.2 ft. No measurable dynamic or permanent deflection was noted.

6.6 VEHICLE DAMAGE

As shown in Figure 6.5, the vehicle sustained damage to the front and left side. The left front strut, strut tower, and A-post were deformed. Also damaged were the front bumper, hood, grill, radiator and support, left front fender, left front tire and wheel rim, left front door and glass, the left rear door, and left rear quarter panel. The roof was deformed and the windshield sustained stress cracking. Maximum exterior crush to the vehicle was 12.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 3.0 inches in the firewall area near the toe pan on the driver side. Figure 6.6 shows photographs of the interior of the vehicle. Exterior crush and occupant compartment deformation measurements are provided in Appendix C, Tables C1 and C2.

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 26.6 ft/s at 0.078 s, the highest 0.010-s occupant ridedown acceleration was -4.0 Gs from 0.221 to 0.231 s, and the maximum 0.050-s average acceleration was -14.9 Gs between 0.032 and 0.082 s. In the lateral direction, the occupant impact velocity was 31.2 ft/s at 0.078 s, the highest 0.010-s occupant ridedown acceleration was 6.4 Gs from 0.217 to 0.227 s, and the maximum 0.050-s average acceleration was 17.6 Gs between 0.023 and 0.073 s. Theoretical Head Impact Velocity (THIV) was 43.1 km/h or 12.0 m/s at 0.076 s; Post-Impact Head Decelerations (PHD) was 7.1 Gs between 0.218 and 0.228 s; and Acceleration Severity Index (ASI) was 2.28 between 0.028 and 0.078 s. Figure 6.7 summarizes these data and other pertinent information from the test. Vehicle angular displacements and accelerations versus time traces are presented in Appendix E, Figures E1 through E7.



Figure 6.3. Vehicle/Barrier Positions after Test No. 420020-6.



Figure 6.4. TxDOT Median Barrier Gate after Test No. 420020-6.



Figure 6.5. Vehicle after Test No. 420020-6.

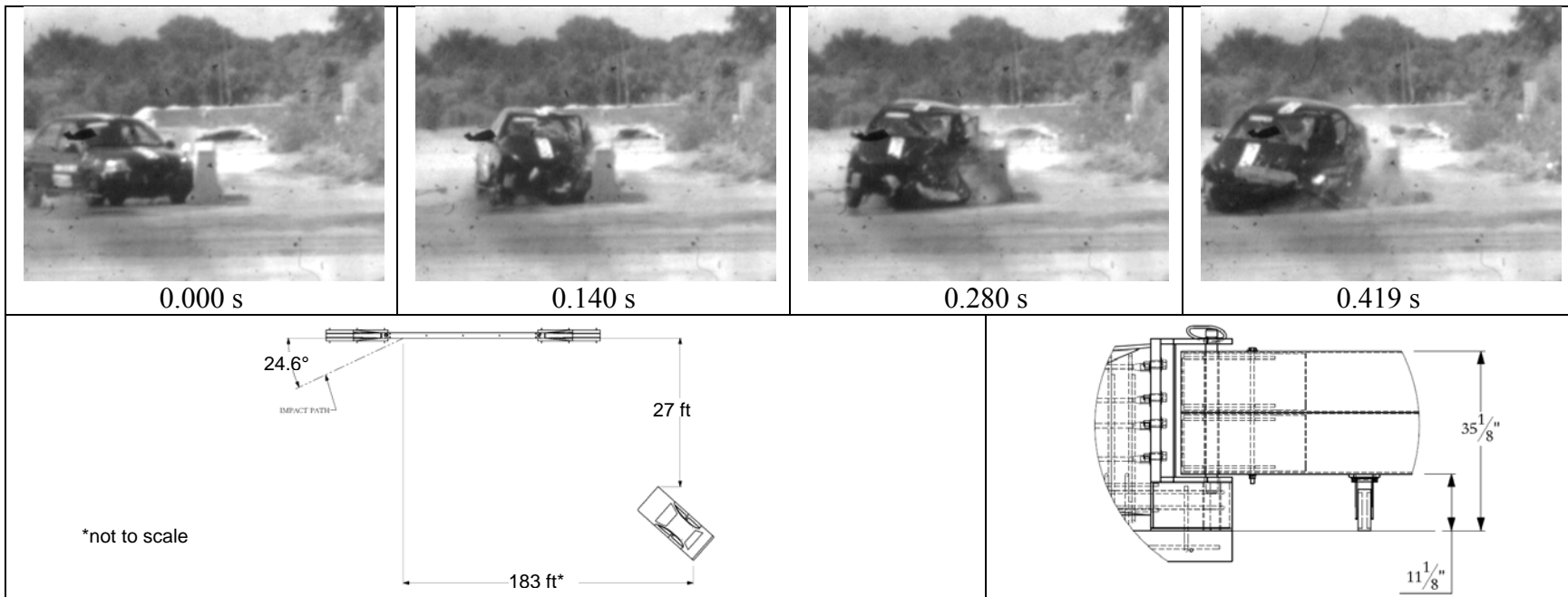


Before Test



After Test

Figure 6.6. Interior of Vehicle for Test No. 420020-6.



General Information

Test Agency..... Texas Transportation Institute (TTI)
 Test Standard Test No. MASH Test 3-20
 TTI Test No. 420020-6
 Date 2010-07-15

Test Article

Type..... Median Barrier Gate
 Name TxDOT Median Barrier Gate
 Installation Length 50 ft
 Material or Key Elements 12-inch x 12-inch x 1/4-inch steel tubes connected to concrete parapets using 2 1/4-inch steel pins

Soil Type and Condition

..... Anchored to existing concrete

Test Vehicle

Type/Designation..... 1100C
 Make and Model 2003 Kia Rio
 Curb 2357 lb
 Test Inertial..... 2424 lb
 Dummy 168 lb
 Gross Static..... 2592 lb

Impact Conditions

Speed62.6 mi/h
 Angle24.6 degrees
 Location/Orientation4.1 ft upstrm of

Exit Conditions

parapet end
 Speed49.3 mi/h
 Angle11.6 degrees

Occupant Risk Values

Impact Velocity
 Longitudinal26.6 ft/s
 Lateral31.2 ft/s
 Ridedown Accelerations
 Longitudinal-4.0 G
 Lateral 6.4 G
 THIV43.1 km/h
 PHD7.1 G
 ASI0.11
 Max. 0.050-s Average
 Longitudinal-14.9 G
 Lateral 17.6 G
 Vertical -3.9 G

Post-Impact Trajectory

Stopping Distance 183 ft dwnstr
 27 ft twd traffic

Vehicle Stability

Maximum Yaw Angle..... -184 degrees
 Maximum Pitch Angle..... 10 degrees
 Maximum Roll Angle -12 degrees
 Vehicle Snagging No
 Vehicle Pocketing..... No

Test Article Deflections

Dynamic Nil
 Permanent..... Nil
 Working Width Nil

Vehicle Damage

VDS 11LFQ6
 CDC..... 11FDEW4
 Max. Exterior Deformation 12.0 inches
 OCDI LS1020120
 Max. Occupant Compartment
 Deformation 3.0 inches

Figure 6.7. Summary of Results for MASH Test 3-20 on the TxDOT Median Barrier Gate.

6.8 ASSESSMENT OF TEST RESULTS

An assessment of the test based on 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 median barrier gate contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or over the installation. No measureable deformation was noted. (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 ≤ 102 mm (4.0 inches); windshield = ≤ 76 mm (3.0 inches); side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤ 229 mm (9.0 inches); forward of A-pillar ≤ 305 mm (12.0 inches); front side door area above seat ≤ 229 mm (9.0 inches); front side door below seat ≤ 305 mm (12.0 inches); floor pan/transmission tunnel area ≤ 305 mm (12.0 inches))

Results: No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the 1100C vehicle, nor to present hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 3.0 inches in the firewall area near the toe pan on the driver side. (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 -12 degrees and 10 degrees, respectively. (PASS)

- H. *Occupant impact velocities should satisfy the following:*

<u>Longitudinal and Lateral Occupant Impact Velocity</u>	
<u>Preferred</u>	<u>Maximum</u>
30 ft/s	40 ft/s

Results: Longitudinal occupant impact velocity was 26.6 ft/s, and lateral occupant impact velocity was 31.2 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations

<u><i>Preferred</i></u>	<u><i>Maximum</i></u>
<i>15.0 Gs</i>	<i>20.49 Gs</i>

Results: Longitudinal ridedown acceleration was -4.0 G, and lateral ridedown acceleration was 6.4 G. (PASS)

6.8.3 Vehicle Trajectory

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

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

CHAPTER 7. CRASH TEST 420020-7 (MASH TEST 3-11)

7.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

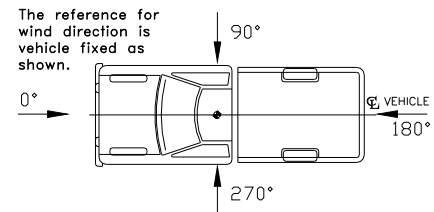
MASH test 3-11 involves a 2270P vehicle weighing 5000 lb \pm 100 lb impacting the TxDOT median barrier gate at a speed of 62.2 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. The target impact point was 4.3 ft upstream of the mid-span of the gate. The 2003 Dodge Ram 1500 Quad-Cab pickup used in the test weighed 5015 lb and the actual impact speed and angle were 63.1 mi/h and 24.7 degrees, respectively. The actual impact point was 4.8 ft upstream of the mid-span of the gate.

7.2 TEST VEHICLE

A 2003 Dodge Ram 1500 Quad-Cab pickup, shown in Figures 7.1 and 7.2, was used for the crash test. Test inertia weight of the vehicle was 5015 lb, and its gross static weight was 5015 lb. The height to the lower edge of the vehicle bumper was 13.5 inches, and it was 26.0 inches to the upper edge of the bumper. The vertical center of gravity (CG) height of the pickup truck was measured to be 28.12 inches. Figure C2 and Table C3 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.

7.3 WEATHER CONDITIONS

The test was performed on the morning of July 19, 2010. No rainfall was recorded for the 10 days prior to the test date. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 218 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 87°F, relative humidity: 69 percent.



7.4 TEST DESCRIPTION

The 2003 Dodge Ram 1500 Quad-Cab pickup, traveling at a speed of 63.1 mi/h, impacted the TxDOT median barrier gate 4.8 ft upstream of the mid-span of the gate at an angle of 24.7 degrees. At approximately 0.021 s, the left front tire contacted the gate and the left front tire aired out. The gate began to deflect 0.025 s after impact, and the vehicle began to redirect at 0.042 s. At 0.169 s after impact, the vehicle was traveling parallel with the barrier at a speed of 55.1 mi/h. Maximum deflection of the barrier of 1.1 ft occurred 0.223 s after impact. At 0.311 s, the 2270P vehicle lost contact with the barrier and was traveling at an exit speed and angle of 50.1 mi/h and 12.2 degrees, respectively. Brakes on the vehicle were applied at 1.2 s after impact, and the vehicle subsequently came to rest 100 ft downstream of impact and 25 ft toward traffic lanes. Figures D3 and D4 in Appendix D show sequential photographs of the test period.



Figure 7.1. Vehicle/Gate Geometrics for Test No. 420020-7.



Figure 7.2. Vehicle before Test No. 420020-7.

7.5 DAMAGE TO TEST INSTALLATION

The steel barrier gate sustained moderate damage as shown in Figures 7.3 and 7.4. The traffic faces of the steel tubes were deformed inward and the tubular rails were buckled near mid-span. There was no damage noted to the concrete parapets. The vehicle was in contact with the installation a distance of 14.9 ft. Working width was 1.1 ft. Maximum dynamic deflection of the median barrier gate during the test was 1.1 ft, and maximum permanent deformation was 0.8 ft.

7.6 VEHICLE DAMAGE

As shown in Figure 7.5, the majority of the damage sustained by the 2270P vehicle was to the left front corner and above the top wheel line along the left side. The left upper A-arm was deformed. Also damaged were the front bumper, grill, left front fender, left front tire and wheel rim, left front and rear doors, rear of the cab, left exterior bed, left rear wheel rim (no loss of air in the tire), rear bumper, and tailgate. Maximum exterior crush to the vehicle was 12.0 inches in the side plane in the left front corner at bumper height. Maximum occupant compartment deformation was 0.5 inches across the cab at hip level on the driver side. Figure 7.6 shows photographs of the interior of the vehicle. Exterior crush measurements and occupant compartment deformation are provided in Appendix C, Tables C4 and C5.

7.7 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 11.5 ft/s at 0.090 s, the highest 0.010-s occupant ridedown acceleration was -7.4 Gs from 0.101 to 0.111 s, and the maximum 0.050-s average acceleration was -5.0 Gs between 0.015 and 0.065 s. In the lateral direction, the occupant impact velocity was 27.2 ft/s at 0.090 s, the highest 0.010-s occupant ridedown acceleration was 12.8 Gs from 0.104 to 0.114 s, and the maximum 0.050-s average acceleration was 12.9 Gs between 0.032 and 0.082 s. THIV was 32.2 km/h or 8.9 m/s at 0.088 s; PHD was 14.2 Gs between 0.103 and 0.113 s; and ASI was 1.49 between 0.028 and 0.078 s. Figure 7.7 summarizes these data and other pertinent information from the test. Vehicle angular displacements and accelerations versus time traces are presented in Appendix E, Figures E8 through E14.



Figure 7.3. Vehicle/Gate Positions after Test No. 420020-7.



Figure 7.4. TxDOT Median Barrier Gate after Test No. 420020-7.



Figure 7.5. Vehicle after Test No. 420020-7.

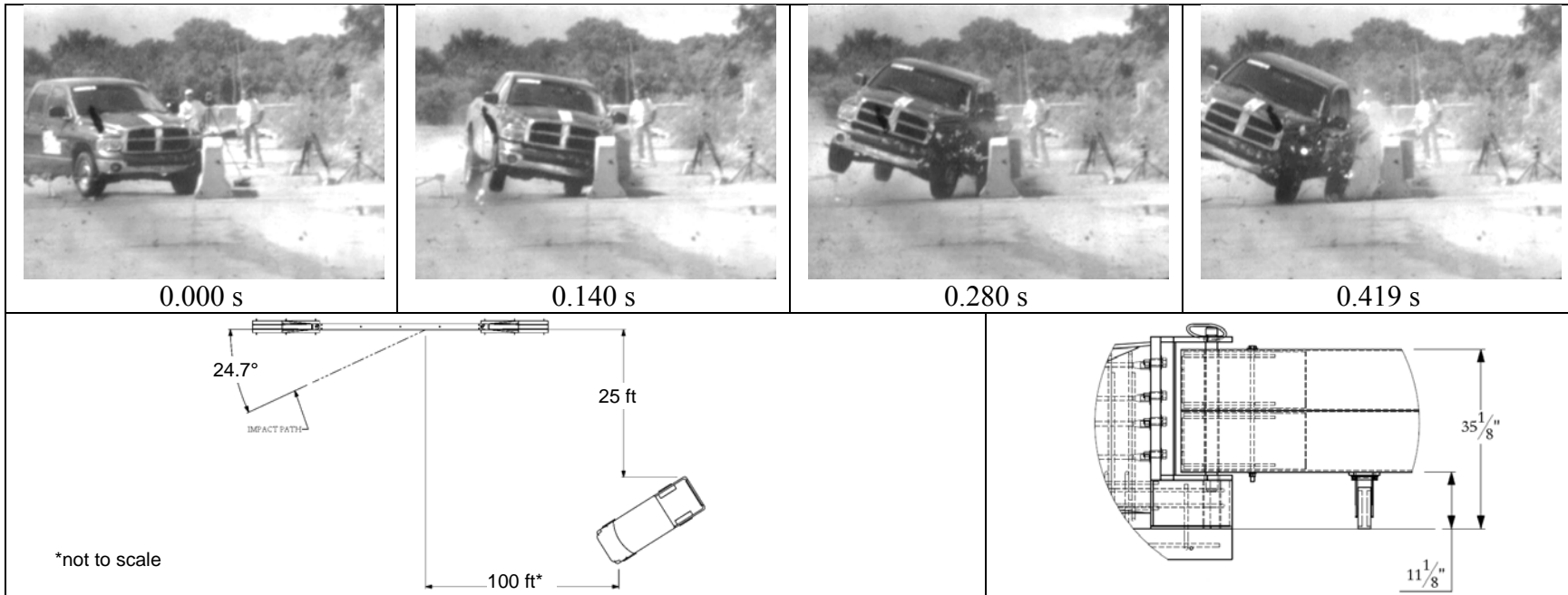
Before Test



After Test



Figure 7.6. Interior of Vehicle for Test No. 420020-7.



43

General Information

Test Agency..... Texas Transportation Institute (TTI)
 Test Standard Test No. MASH Test 3-11
 TTI Test No. 420020-7
 Date 2010-07-19

Test Article

Type..... Median Barrier Gate
 Name TxDOT Median Barrier Gate
 Installation Length 50.0 ft
 Material or Key Elements 12-inch x 12-inch x 1/4-inch steel tubes connected to concrete parapets using 2 1/4-inch steel pins

Soil Type and Condition

..... Anchored on existing concrete apron

Test Vehicle

Type/Designation..... 2270P
 Make and Model 2003 Dodge Ram 1500 Quad-Cab
 Curb 4699 lb
 Test Inertial..... 5015 lb
 Dummy No dummy
 Gross Static..... 5015 lb

Impact Conditions

Speed63.1 mi/h
 Angle24.7 degrees
 Location/Orientation4.8 ft upstream

Exit Conditions

Speed50.1 mi/h
 Angle12.2 degrees

Occupant Risk Values

Impact Velocity
 Longitudinal11.5 ft/s
 Lateral27.2 ft/s
 Ridedown Accelerations
 Longitudinal-7.4 G
 Lateral12.8 G
 THIV32.2 kmh
 PHD14.2 G
 ASI1.49
 Max. 0.050-s Average
 Longitudinal -5.0 G
 Lateral12.9 G
 Vertical -3.7 G

Post-Impact Trajectory

Stopping Distance 100 ft dwnstrm
 25 ft twd traffic

Vehicle Stability

Maximum Yaw Angle..... 38 degrees
 Maximum Pitch Angle..... 6 degrees
 Maximum Roll Angle-21 degrees
 Vehicle Snagging No
 Vehicle Pocketing..... No

Test Article Deflections

Dynamic 1.1 ft
 Permanent..... 0.8 ft
 Working Width 1.1 ft

Vehicle Damage

VDS 11LFQ4
 CDC..... 11FLEW3
 Max. Exterior Deformation 12.0 inches
 OCDI LS000000
 Max. Occupant Compartment
 Deformation 0.5 inches

Figure 7.7. Summary of Results for MASH Test 3-11 on the TxDOT Median Barrier Gate.

7.8 ASSESSMENT OF TEST RESULTS

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

7.8.1 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 median barrier gate contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.1 ft. (PASS)

7.8.2 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 ≤ 102 mm (4.0 inches); windshield = ≤ 76 mm (3.0 inches); side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤ 229 mm (9.0 inches); forward of A-pillar ≤ 305 mm (12.0 inches); front side door area above seat ≤ 229 mm (9.0 inches); front side door below seat ≤ 305 mm (12.0 inches); floor pan/transmission tunnel area ≤ 305 mm (12.0 inches))

Results: No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area. (PASS)
Maximum occupant compartment deformation was 0.5 inches at the hip level on the driver side. (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 -21 degrees and 6 degrees, respectively. (PASS)

- H. *Occupant impact velocities should satisfy the following:*
Longitudinal and Lateral Occupant Impact Velocity

<u>Preferred</u>	<u>Maximum</u>
30 ft/s	40 ft/s

Results: Longitudinal occupant impact velocity was 11.5 ft/s, and lateral occupant impact velocity was 27.2 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*
Longitudinal and Lateral Occupant Ridedown Accelerations

<u>Preferred</u>	<u>Maximum</u>
15.0 Gs	20.49 Gs

Results: Longitudinal ridedown acceleration was -7.4 G, and lateral ridedown acceleration was 12.8 G. (PASS)

7.8.3 Vehicle Trajectory

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

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

CHAPTER 8. CRASH TEST 420020-8 (MASH TEST 3-21)

8.1 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

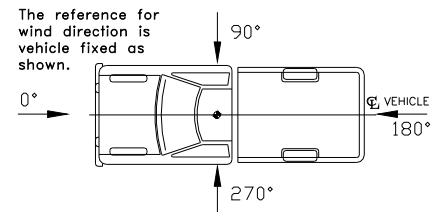
MASH test 3-21 involves a 2270P vehicle weighing 5000 lb \pm 100 lb impacting the TxDOT median barrier gate at a speed of 62.2 mi/h \pm 2.5 mi/h and an angle of 25 degrees \pm 1.5 degrees. The target impact point was 4.3 ft upstream of the end of the concrete parapet. The 2003 Dodge Ram 1500 Quad-Cab pickup used in the test weighed 5008 lb and the actual impact speed and angle were 63.1 mi/h and 25.5 degrees, respectively. The actual impact point was 3.9 ft upstream of the end of the concrete parapet.

8.2 TEST VEHICLE

A 2003 Dodge Ram 1500 Quad-Cab pickup, shown in Figures 8.1 and 8.2, was used for the crash test. Test inertia weight of the vehicle was 5008 lb, and its gross static weight was 5008 lb. The height to the lower edge of the vehicle bumper was 13.5 inches, and it was 26.0 inches to the upper edge of the bumper. The vertical CG height of the pickup truck was 28.25 inches. Figure C3 and Table C6 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.

8.3 WEATHER CONDITIONS

The test was performed on the morning of July 21, 2010. Three days prior to the test date 0.41 inch of rain was recorded. Weather conditions at the time of testing were as follows: Wind speed: 5 mi/h; wind direction: 88 degrees with respect to the vehicle (vehicle was traveling in a southwesterly direction); temperature: 90°F, relative humidity: 65 percent.



8.4 TEST DESCRIPTION

The 2003 Dodge Ram 1500 Quad-Cab pickup, traveling at a speed of 63.1 mi/h, impacted the TxDOT median barrier gate 3.9 ft upstream of the end of the concrete parapet at an angle of 25.5 degrees. At approximately 0.49 s after impact, the right front corner of the vehicle contacted the concrete parapet, and at 0.054 s, the vehicle began to redirect. The caster wheel under the gate separated from the gate at 0.059 s. At 0.184 s after impact, the vehicle was traveling parallel with the barrier at a speed of 49.4 mi/h. The rear of the vehicle contacted the gate at 0.199 s after impact, and then the concrete barrier at 0.263 s. At 0.344 s, the vehicle lost contact with the barrier and was traveling at an exit speed and angle of 46.3 mi/h and 6.6 degrees, respectively. Brakes on the vehicle were applied 1.2 s after impact, and the vehicle subsequently came to rest 190 ft downstream of impact with the rear toward the field side of the installation. Figures D5 and D6 in Appendix D show sequential photographs of the test period.



Figure 8.1. Vehicle/Gate Geometrics for Test No. 420020-8.



Figure 8.2. Vehicle before Test No. 420020-8.

8.5 DAMAGE TO TEST INSTALLATION

The lower toe and end of the concrete barrier sustained significant damage, as shown in Figures 8.3 and 8.4. The concrete was cracked and fell away from the reinforcement in the toe of the concrete barrier and also from the field side of the barrier. The concrete on the end of the traffic face of the barrier was cracked, but remained in place. The end bracket was pushed toward the field side 1.0 inch. Tire marks were present along the traffic face of the steel gate and traffic face of the concrete barrier for a distance of 11.75 ft. Working width, maximum dynamic deflection, and maximum permanent deformation were 1.25 inches.

8.6 VEHICLE DAMAGE

Figure 8.5 shows the damage to the vehicle, which was mostly in the right front quarter in the side plane. The right upper and lower ball joint, right tie rod end, right frame rail, right front upper and lower A-arms, drive shaft, rear axle, and rear U-bolts and springs were damaged. Also damaged were the front bumper, hood, grill, right front fender, right front tire and wheel rim, right front and rear doors, right rear cab, right rear exterior bed, right rear tire and wheel rim, rear bumper, and tailgate. The windshield sustained stress cracks. Maximum exterior crush to the vehicle was 19 inches in the side plane at the right front corner at bumper height. Maximum occupant compartment deformation was 5.25 inches in the right firewall area near the toe pan on the front passenger side. Figure 8.6 shows photographs of the interior of the vehicle. Exterior crush and occupant compartment deformation are provided in Appendix C, Tables C7 and C8.

8.7 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 22.6 ft/s at 0.091 s, the highest 0.010-s occupant ridedown acceleration was -6.5 Gs from 0.103 to 0.113 s, and the maximum 0.050-s average acceleration was -11.8 Gs between 0.045 and 0.095 s. In the lateral direction, the occupant impact velocity was 27.9 ft/s at 0.091 s, the highest 0.010-s occupant ridedown acceleration was -9.4 Gs from 0.104 to 0.114 s, and the maximum 0.050-s average acceleration was -14.9 Gs between 0.034 and 0.084 s. THIV was 38.8 km/h or 10.8 m/s at 0.089 s; PHD was 11.1 Gs between 0.104 and 0.114 s; and ASI was 1.92 between 0.044 and 0.094 s. Figure 8.7 summarizes these data and other pertinent information from the test. Vehicle angular displacements and accelerations versus time traces are presented in Appendix E, Figures E15 through E21.



Figure 8.3. Position of Vehicle/Gate after Test No. 420020-8.



Rear of barrier

Figure 8.4. Installation after Test No. 420020-8.



Figure 8.5. Vehicle after Test No. 420020-8.

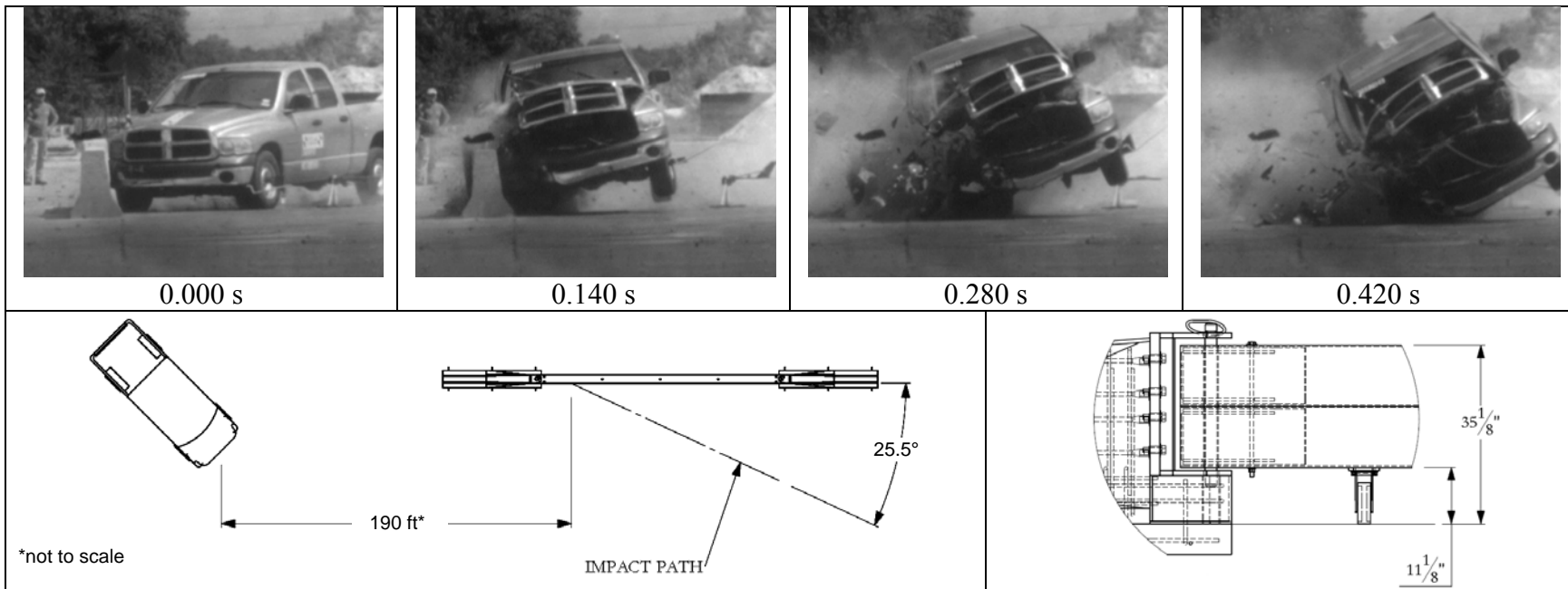


Before Test



After Test

Figure 8.6. Interior of Vehicle for Test No. 420020-8.



55

General Information

Test Agency..... Texas Transportation Institute (TTI)
 Test Standard Test No. *MASH* Test 3-21
 TTI Test No. 420020-8
 Date 2010-07-21

Test Article

Type..... Median Barrier Gate
 Name TxDOT Median Barrier Gate
 Installation Length 50.0 ft
 Material or Key Elements 12-inch x 12-inch x 1/4-inch steel tubes connected to concrete parapets using 2 1/4-inch steel pins

Soil Type and Condition.....

Anchored on existing concrete apron

Test Vehicle

Type/Designation..... 2270P
 Make and Model 2003 Dodge Ram 1500 Quad-Cab
 Curb 4765 lb
 Test Inertial 5008 lb
 Dummy No dummy
 Gross Static 5008 lb

Impact Conditions

Speed63.1 mi/h
 Angle25.5 degrees
 Location/Orientation

Exit Conditions

Speed46.3 mi/h
 Angle6.6 degrees

Occupant Risk Values

Impact Velocity
 Longitudinal22.6 ft/s
 Lateral27.9 ft/s
 Ridedown Accelerations
 Longitudinal-6.5 G
 Lateral-9.4 G
 THIV38.8 km/h
 PHD11.1 G
 ASI1.92
 Max. 0.050-s Average
 Longitudinal-11.8 G
 Lateral-14.9 G
 Vertical -4.9 G

Post-Impact Trajectory

Stopping Distance 190 ft dwnstrm

Vehicle Stability

Maximum Yaw Angle..... -32 degrees
 Maximum Pitch Angle..... -8 degrees
 Maximum Roll Angle 20 degrees
 Vehicle Snagging Yes
 Vehicle Pocketing..... No

Test Article Deflections

Dynamic 1.25 inches
 Permanent..... 1.25 inches
 Working Width 1.25 inches

Vehicle Damage

VDS02RFQ5
 CDC.....02RFEW4
 Max. Exterior Deformation 19.0 inches
 OCDI RF0030000
 Max. Occupant Compartment
 Deformation 5.25 inches

Figure 8.7. Summary of Results for *MASH* Test 3-21 on the TxDOT Median Barrier Gate.

8.8 ASSESSMENT OF TEST RESULTS

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

8.8.1 Structural Adequacy

- B. 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 median barrier gate contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.25 inches. (PASS)

8.8.2 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 ≤ 102 mm (4.0 inches); windshield = ≤ 76 mm (3.0 inches); side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤ 229 mm (9.0 inches); forward of A-pillar ≤ 305 mm (12.0 inches); front side door area above seat ≤ 229 mm (9.0 inches); front side door below seat ≤ 305 mm (12.0 inches); floor pan/transmission tunnel area ≤ 305 mm (12.0 inches))

Results: The toe and end of the concrete parapet cracked and pieces of concrete fell off in small pieces. This debris did not penetrate or show potential to penetrate the occupant compartment, nor to present undue hazard to others in the area. (PASS)

Maximum occupant compartment deformation was 5.25 inches in the firewall area near the toe pan on the front passenger side. (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 20 degrees and -8 degrees, respectively. (PASS)

H. *Occupant impact velocities should satisfy the following:*
Longitudinal and Lateral Occupant Impact Velocity

<u>Preferred</u>	<u>Maximum</u>
9.0 m/s (30 ft/s)	12.2 m/s (40 ft/s)

Results: Longitudinal occupant impact velocity was 22.6 ft/s, and lateral occupant impact velocity was 27.9 ft/s. (PASS)

I. *Occupant ridedown accelerations should satisfy the following:*
Longitudinal and Lateral Occupant Ridedown Accelerations

<u>Preferred</u>	<u>Maximum</u>
15.0 Gs	20.49 Gs

Results: Longitudinal ridedown acceleration was -6.5 G, and lateral ridedown acceleration was -9.4 G. (PASS)

8.8.3 Vehicle Trajectory

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

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

CHAPTER 9. SUMMARY AND CONCLUSIONS

Concrete median barrier is commonly used to separate opposing lanes of traffic on high-speed, urban freeways with high average daily traffic (ADT) and narrow medians. The resulting long, continuous runs of CMBs limit access of emergency and maintenance vehicles to the other side of the roadway or managed lane. Periodic implementation of crashworthy median barrier gates can maintain the desired level of median protection for motorists while offering improved cross-median access for authorized vehicles.

TxDOT has been using an Emergency Opening System developed in the early 1980s to satisfy this need. The EOS was recently crash tested in accordance with the latest guidelines for the impact performance of roadside safety features contained in the AASHTO *Manual for Assessing Safety Hardware*. The gate failed to comply with *MASH* due to excessive occupant compartment deformation inside the vehicle.

A new crashworthy median barrier gate was developed to replace the EOS and meet the continuing needs of TxDOT. Three crash tests were performed to evaluate the impact performance of different aspects of the median barrier gate. Test 3-11 evaluated the strength of the median barrier gate and its ability to function as a longitudinal barrier. Tests 3-20 and 3-21 assessed the transition of the median barrier gate to the adjacent concrete median barrier. As summarized in Table 9.1 through Table 9.3, the new median barrier gate passed all of the required evaluation criteria for each test and meets the Test Level 3 (TL-3) impact performance requirements of *MASH*.

Table 9.1. Performance Evaluation Summary for MASH Test 3-20 on the TxDOT Median Barrier Gate.

Test Agency: Texas Transportation Institute

Test No.: 420020-5

Test Date: 2010-07-15

MASH Test 3-10 Evaluation Criteria	Test Results	Assessment
<p>Structural Adequacy</p> <p><i>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</i></p>	<p>The TxDOT median barrier gate contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or over the installation. No measureable deformation was noted.</p>	<p>Pass</p>
<p>Occupant Risk</p> <p><i>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.</i></p>	<p>No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the 1100C vehicle, nor to present hazard to others in the area.</p>	<p>Pass</p>
<p><i>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</i></p>	<p>Maximum occupant compartment deformation was 3.0 inches in the firewall area near the toe pan on the driver side.</p>	<p>Pass</p>
<p><i>F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i></p>	<p>The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were -12 degrees and 10 degrees, respectively.</p>	<p>Pass</p>
<p><i>H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.</i></p>	<p>Longitudinal occupant impact velocity was 26.6 ft/s, and lateral occupant impact velocity was 31.2 ft/s.</p>	<p>Pass</p>
<p><i>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.</i></p>	<p>Maximum longitudinal ridedown acceleration was -4.0 G, and maximum lateral ridedown acceleration was 6.4 G.</p>	<p>Pass</p>
<p>Vehicle Trajectory</p>		
<p><i>For redirective devices, the vehicle shall exit the barrier within the exit box.</i></p>	<p>The vehicle exited within the exit box.</p>	<p>Pass</p>

Table 9.2. Performance Evaluation Summary for MASH Test 3-11 on the TxDOT Median Barrier Gate.

Test Agency: Texas Transportation Institute

Test No.: 420020-7

Test Date: 2010-07-19

MASH Test 3-11 Evaluation Criteria	Test Results	Assessment
<p>Structural Adequacy <i>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</i></p>	<p>The TxDOT median barrier gate contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.1 ft.</p>	<p>Pass</p>
<p>Occupant Risk <i>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.</i></p>	<p>No detached elements, fragments, or other debris was present to penetrate or to show potential for penetrating the occupant compartment, nor to present undue hazard to others in the area.</p>	<p>Pass</p>
<p><i>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</i></p>	<p>Maximum occupant compartment deformation was 0.5 inches at the hip level on the driver side.</p>	<p>Pass</p>
<p><i>F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i></p>	<p>The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were -21 degrees and 6 degrees, respectively.</p>	<p>Pass</p>
<p><i>H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.</i></p>	<p>Longitudinal occupant impact velocity was 11.5 ft/s, and lateral occupant impact velocity was 27.2 ft/s.</p>	<p>Pass</p>
<p><i>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.</i></p>	<p>Longitudinal ridedown acceleration was -7.4 G, and lateral ridedown acceleration was 12.8 G.</p>	<p>Pass</p>
<p>Vehicle Trajectory</p>		
<p><i>For redirective devices, the vehicle shall exit the barrier within the exit box.</i></p>	<p>The 2270P vehicle exited within the exit box.</p>	<p>Pass</p>

Table 9.3. Performance Evaluation Summary for MASH Test 3-21 on the TxDOT Median Barrier Gate.

Test Agency: Texas Transportation Institute

Test No.: 420020-8

Test Date: 2010-07-21

MASH Test 3-21 Evaluation Criteria	Test Results	Assessment
Structural Adequacy <i>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</i>	The TxDOT median barrier gate contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.25 inches.	Pass
Occupant Risk <i>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.</i>	The toe and end of the concrete parapet cracked and pieces of concrete fell off in small pieces. This debris did not penetrate or show potential to penetrate the occupant compartment, nor to present undue hazard to others in the area.	Pass
<i>Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</i>	Maximum occupant compartment deformation was 5.25 inches in the firewall area near the toe pan on the front passenger side.	Pass
<i>F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</i>	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 20 degrees and -8 degrees, respectively.	Pass
<i>H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.</i>	Longitudinal occupant impact velocity was 22.6 ft/s, and lateral occupant impact velocity was 27.9 ft/s.	Pass
<i>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.</i>	Longitudinal ridedown acceleration was -6.5 G, and lateral ridedown acceleration was -9.4 G.	Pass
Vehicle Trajectory		
<i>For redirective devices, the vehicle shall exit the barrier within the exit box.</i>	The vehicle exited within the exit box.	Pass

CHAPTER 10. IMPLEMENTATION STATEMENT[‡]

A new median barrier gate was developed and crash tested. The gate spans a 30-ft opening in a concrete median barrier. The gate consists of two vertically stacked 12-inch × 12-inch × ¼-inch steel tubes connected to steel and brackets with 2¼-inch diameter steel pins.

The 35-inch rail height dramatically improves vehicle stability during impacts along the length of the gate. The 12-inch width of the tubular steel rails matches the width of the concrete parapet to which the gate is attached. This significantly reduces snagging potential on the end of the rigid concrete parapet.

The weight and material cost of the tubular steel rails are less than those used in the existing EOS. Thus, it will be more economical to deploy and easier to operate. Testing with a prototype built for the full-scale crash test program demonstrated that the gate can be readily operated by one person. Bolted connections are used to reduce welding and decrease fabrication cost. It also permits the rail members and components to be individually galvanized and assembled rather than as a complete unit.

The gate is designed to accommodate reversible traffic flow on both sides of the median and be operable in both directions on each end. This versatility enables the gate to be used in the median of a divided highway or as a means of separating main lanes from managed lanes with changing traffic direction. The heavy duty swivel caster wheels support the weight of the gate and eliminate the need for a jack to raise and lower the gate as part of the operation sequence. This will expedite operations for authorized vehicles requiring access through the gate.

The median barrier gate satisfies *MASH* Test Level 3 (TL-3) impact performance criteria and is suitable for immediate implementation on Texas highways where cross-median access is desired. Statewide implementation can be achieved through the development and issuance of a standard detail sheet by the Design Division.

A few design changes and options are recommended for consideration. It is recommended to increase the height of the fabricated steel end bracket by 1 inch. This modification will provide an additional ½-inch tolerance between the upper and lower horizontal plates and the tubular steel rail members for gate operation.

A design option is the use of a fabricated steel curb rather than a concrete curb beneath the fabricated steel end bracket. Steel plates can be welded to the bottom of the lower horizontal plate of the end bracket to form a curb. If this option is used, the end bracket can be attached to the Richmond anchors and used as an end form for the concrete parapet. It eliminates the need to separately form, reinforce and cast a concrete curb, and eliminates the need for the pipe sleeve in the curb.

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

Finally, an optional pry bar can be included in the design. During installation and operation, it is possible for the rails to shift longitudinally against the connecting pins. The resulting bearing pressure can make it difficult to extract the pin to operate the gate. A pry bar can be used between the end plate and the tubular steel rails to shift the rail and release the bearing pressure on the pin. This can be easily accomplished by a single person if necessary. The pry bar design option calls for the incorporation of a pry bar in the system that will be available to the gate operator if needed. The pry bar is stowed by inserting it vertically into prefabricated holes in the steel rails. Appendix F provides these recommended design changes and options.

REFERENCES

1. Strybos, J. W., Morgan, J. R., and Ross, Jr., H. E., "Emergency Opening System for an Authorized Vehicle Lane," Research Report TX-84/105-1F, Texas Transportation Institute, College Station, TX, March 1984.
2. Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," *NCHRP Report 230*, Transportation Research Board, National Research Council, Washington, D.C., March 1981.
3. Bligh, R. P. and Menges, W. L., "Median Barrier Gate, Technical Memorandum #0-5210-9," Texas Transportation Institute, College Station, TX, June 2010.
4. AASHTO, *Manual for Assessing Safety Hardware*, Washington, D.C., American Association of State Highway and Transportation Officials, 2009.
5. Ross, Jr., H.E., Sicking, D.L., Zimmer, R.A. and Michie, J.D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," National Cooperative Highway Research Program *Report 350*, Transportation Research Board, National Research Council, Washington, D.C., 1993.
6. AASHTO, *LRFD Bridge Design Specifications*, Washington, D.C., American Association of State Highway and Transportation Officials, 2004.
7. Hallquist, J. O., *LS-DYNA: Keyword User's Manual*, Version 971, Livermore Software Technology Corporation (LSTC), Livermore, California, 2007.
8. National Crash Analysis Center (NCAC) website for Silverado truck model: <http://www.ncac.gwu.edu/vml/archive/ncac/vehicle/silverado-v2.pdf>, Accessed February 7, 2011.

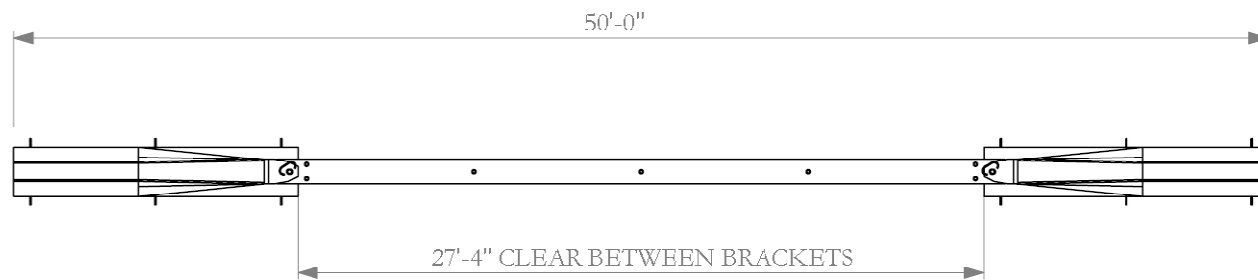
APPENDIX A. DETAILS OF THE TXDOT MEDIAN BARRIER GATE

T:\2009-2010\20020 TxDOT\Median Barrier\Solidworks\Final Design\Drawings\Median Barrier Gate Drawing



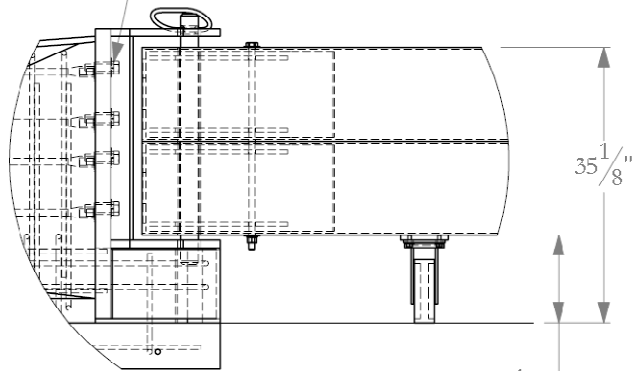
ELEVATION VIEW

GROUND LINE



PLAN VIEW

SEE NOTE 1
NEXT PAGE

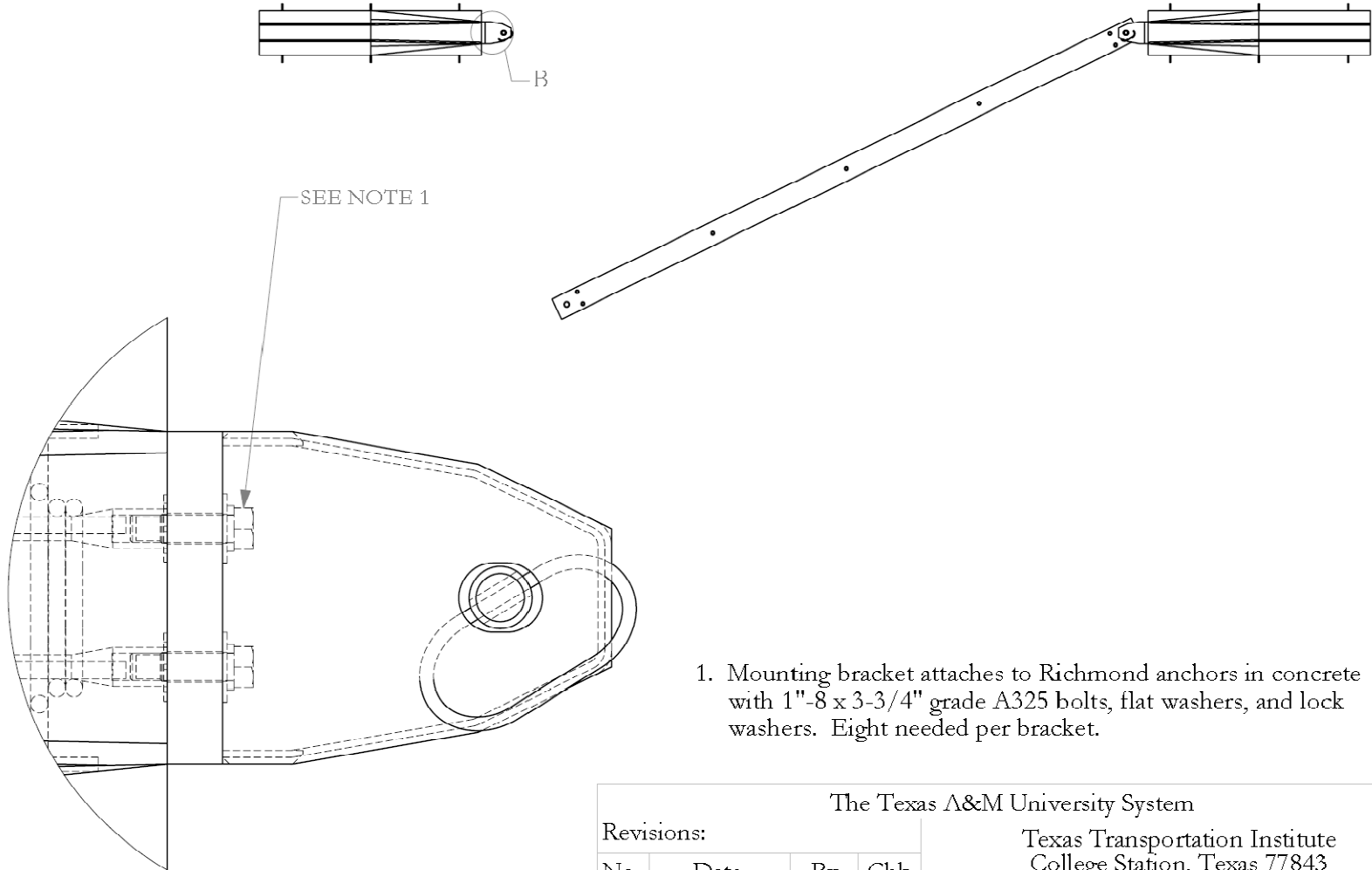


DETAIL A
SCALE 1 : 20

1. Concrete shall be 3600 psi.

The Texas A&M University System

Revisions:				Texas Transportation Institute College Station, Texas 77843				
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.	
1.				2010-06-07	GHS	1:75	1 of 16	
2.								
3.				Project No.		Full Installation		
4.				420020-6, 7, 8				
5.				Median Barrier Gate				
Approved: Roger Bligh:				Signature: <i>Rogn Bligh</i>			Date: 2010-06-09	

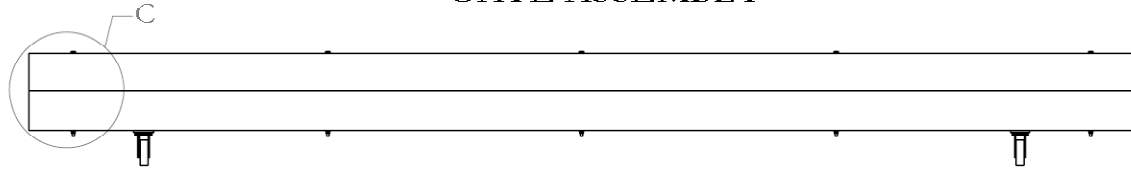


DETAIL B
SCALE 1 : 5

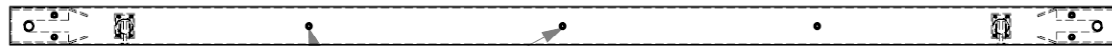
1. Mounting bracket attaches to Richmond anchors in concrete with 1"-8 x 3-3/4" grade A325 bolts, flat washers, and lock washers. Eight needed per bracket.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:75	2 of 16
2.							
3.				Project No.		Open	
4.				420020-6, 7, 8			
5.				Median Barrier Gate			

GATE ASSEMBLY

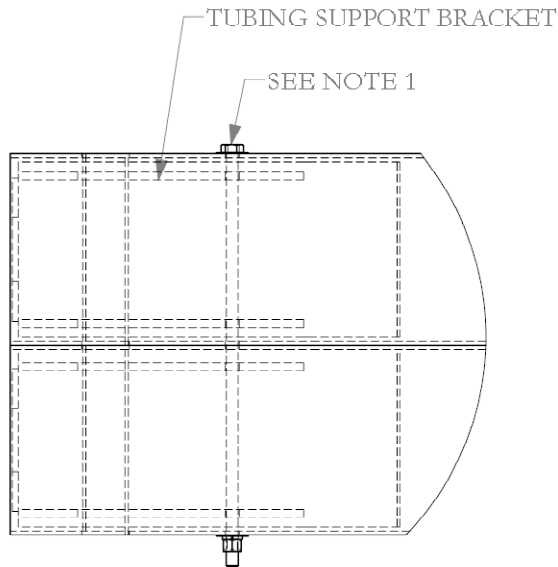


ELEVATION VIEW



PLAN VIEW

SEE NOTE 1



DETAIL C
SCALE 1 : 10

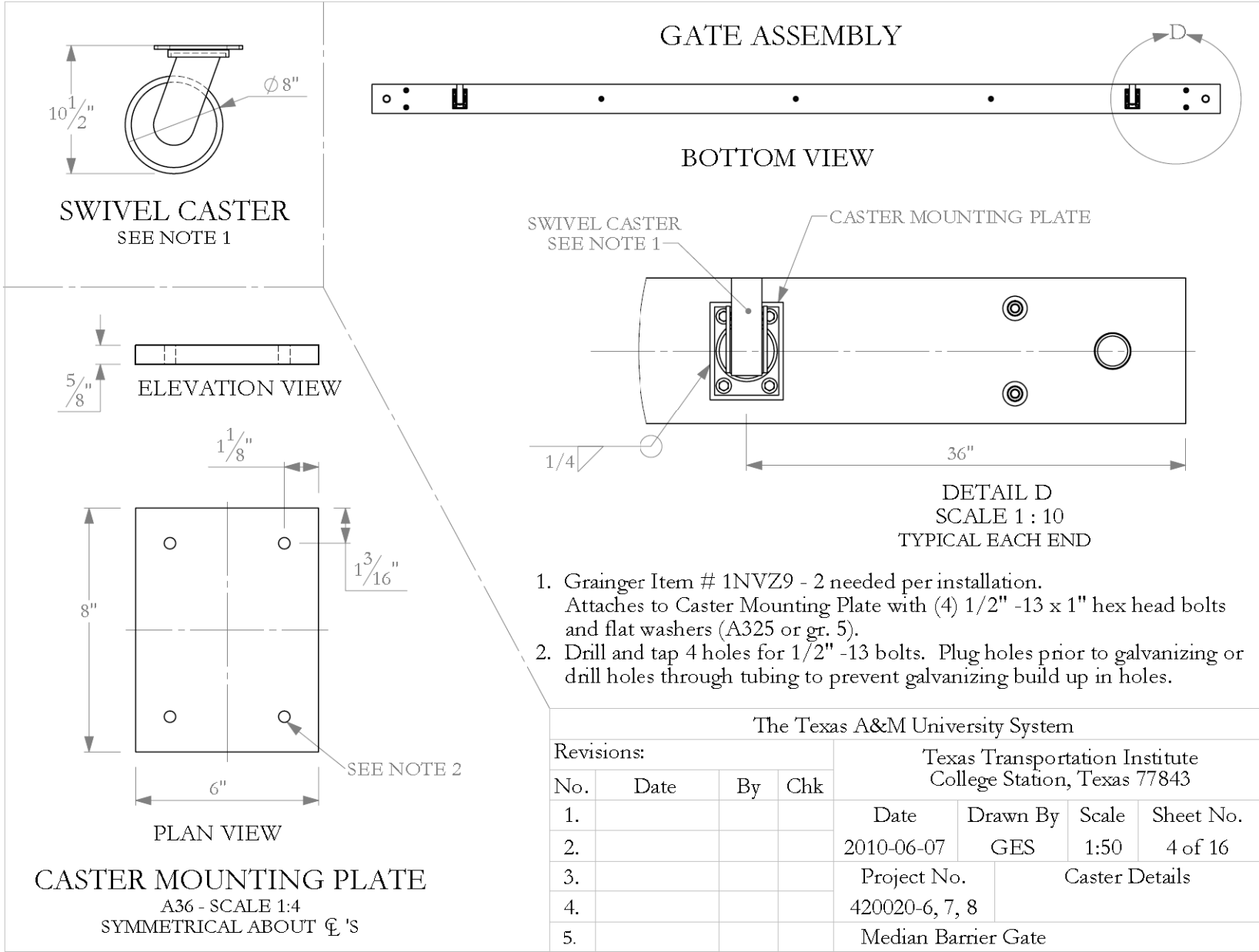
1. 3/4" -10 x 26" hex head bolt, A325 or grade 5, 2 flat washers, lock washer, and hex nut. 7 needed per installation. Bolts attach Tubes together and hold Support Brackets in Tubes

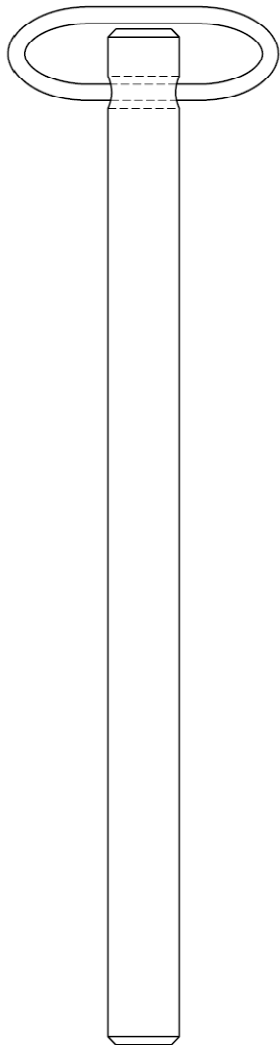
The Texas A&M University System

Texas Transportation Institute
College Station, Texas 77843

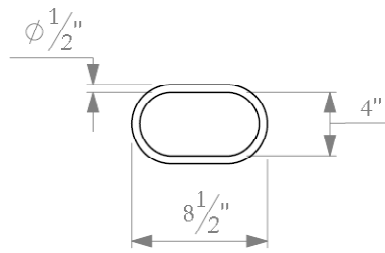
Revisions:

No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:50	3 of 16
2.				Project No.		Gate Assembly	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							

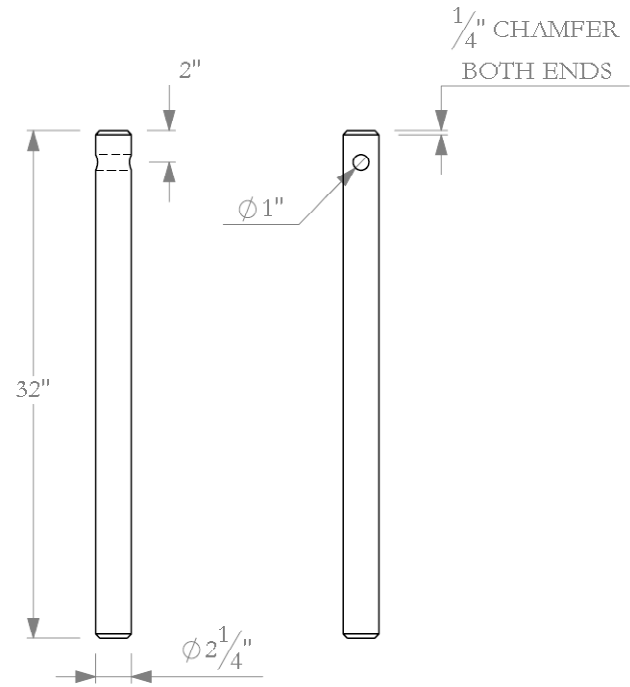




PIN ASSEMBLY
2 NEEDED PER INSTALLATION



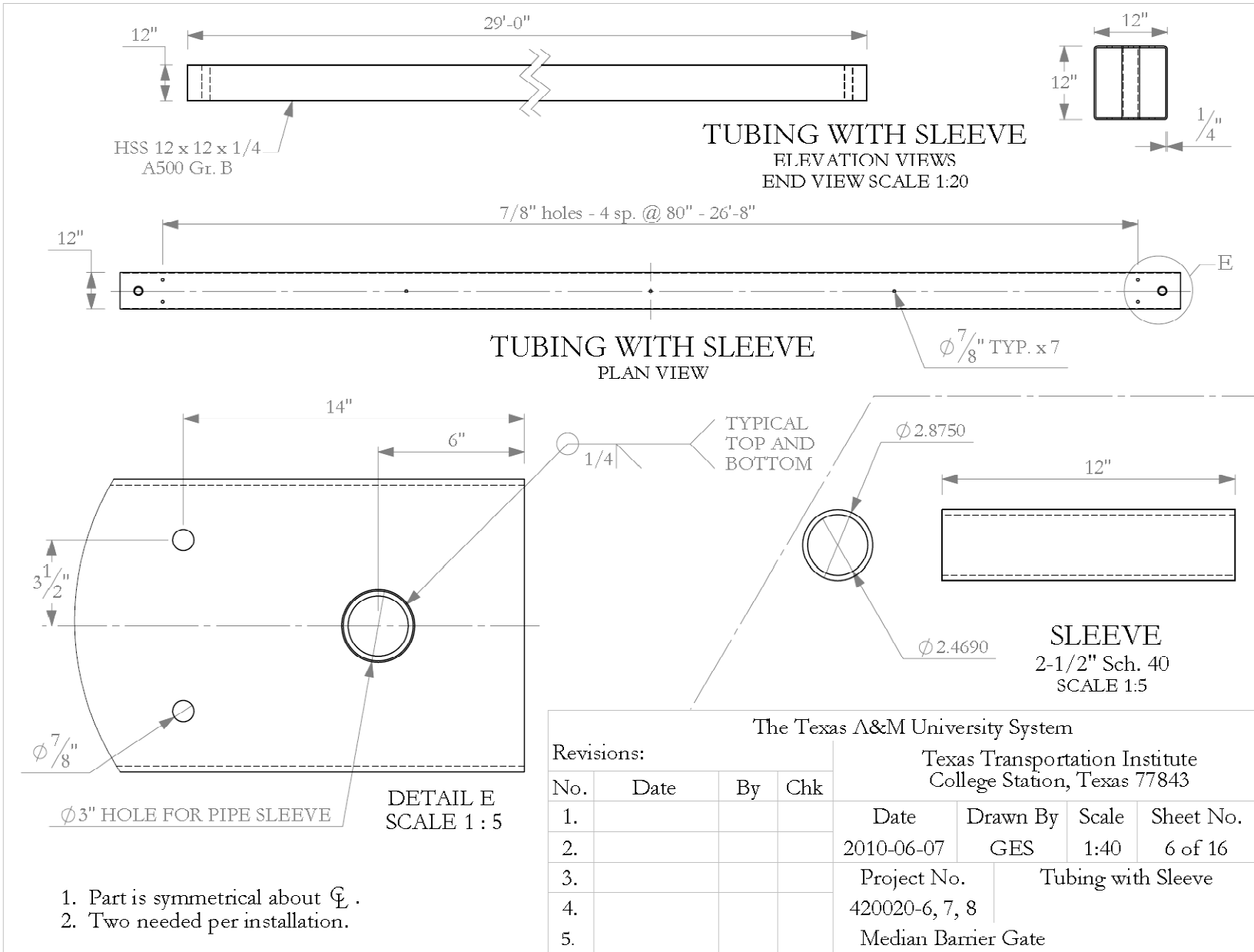
HANDLE
A36



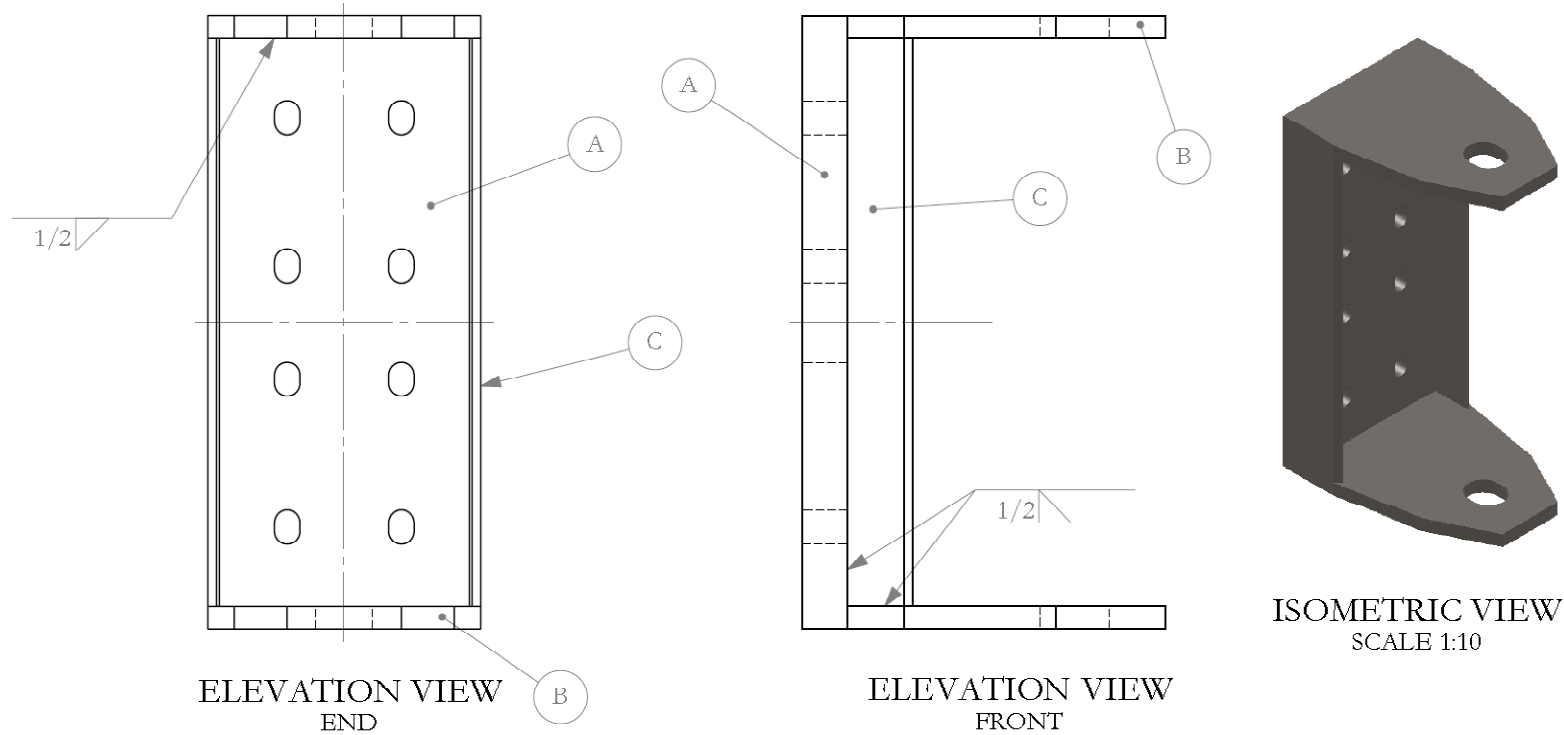
PIN
A36 HOT ROLLED

The Texas A&M University System

Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:5	5 of 16
2.				Project No.		Pin	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							
Approved: Roger Bligh:				Signature:		Date: 2010-06-09	



T:\2009-2010\420020 Median Barrier Solidworks\Final Design\Drawings\Median Barrier Gate Drawing



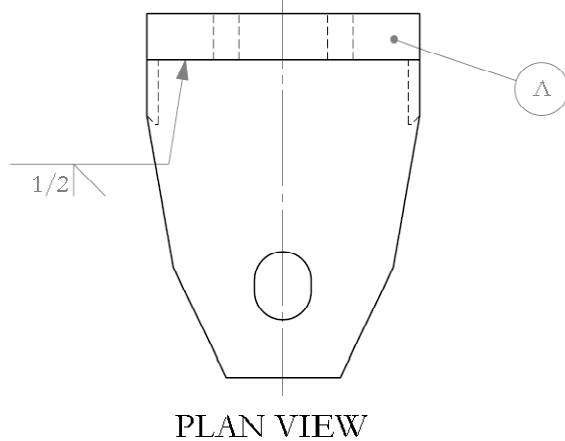
ELEVATION VIEW
END

ELEVATION VIEW
FRONT

ISOMETRIC VIEW
SCALE 1:10

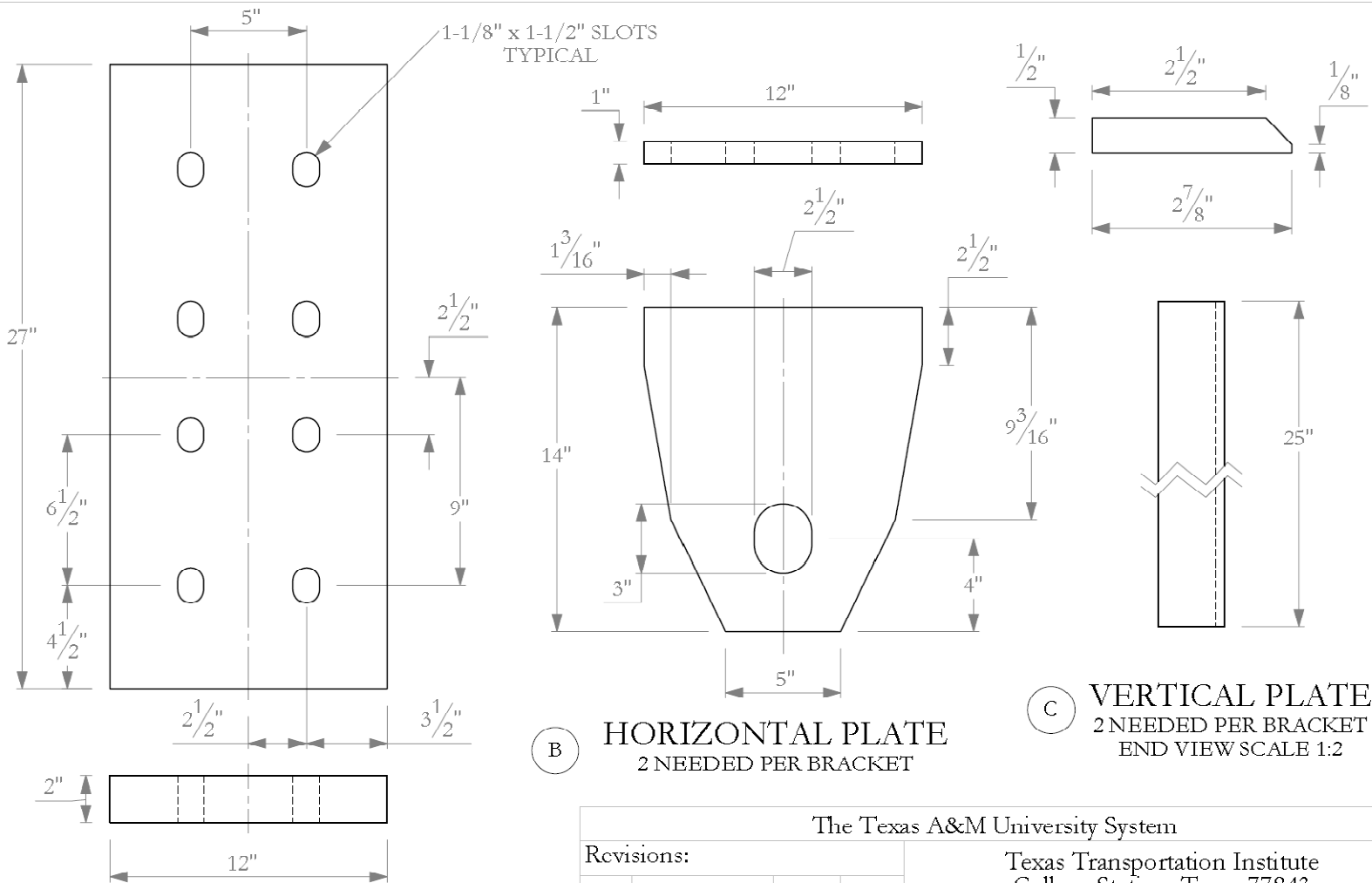
MOUNTING BRACKET

1. Part is symmetrical about Φ , 's.
2. Two needed per installation.



PLAN VIEW

Revisions:				The Texas A&M University System			
No.	Date	By	Chk	Texas Transportation Institute College Station, Texas 77843			
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-06-07	GES	1:7	7 of 16
3.				Project No.		Mounting Bracket	
4.				420020-6, 7, 8			
5.				Median Barrier Gate			



(A) BACK PLATE
1 NEEDED PER BRACKET

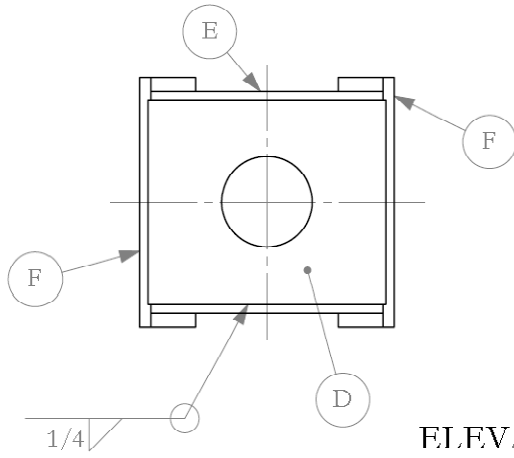
(B) HORIZONTAL PLATE
2 NEEDED PER BRACKET

(C) VERTICAL PLATE
2 NEEDED PER BRACKET
END VIEW SCALE 1:2

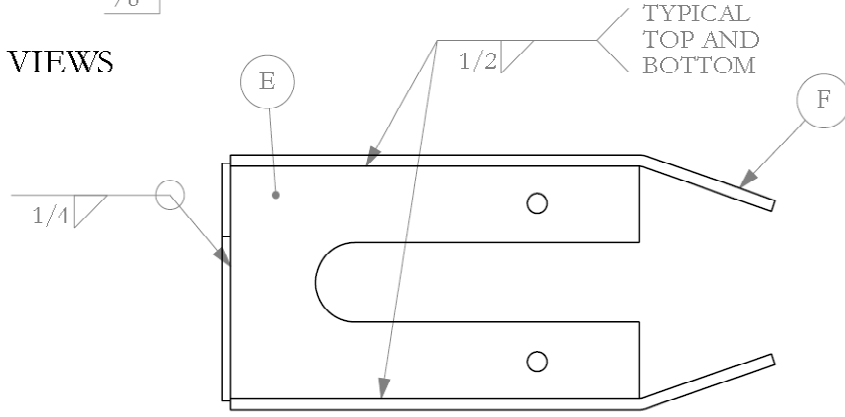
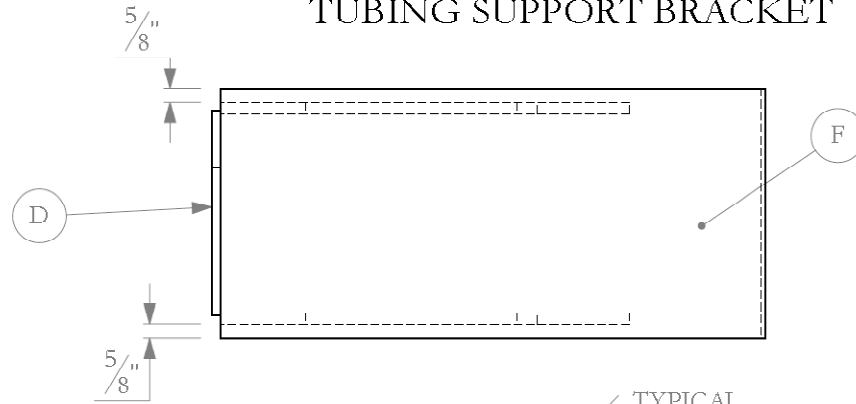
1. All parts are A36 steel.
2. Parts A and B are symmetrical about ϕ 's.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:6	8 of 16
2.							
3.							
4.				Project No. 420020-6, 7, 8		Mounting Bracket Parts	
5.				Median Barrier Gate			

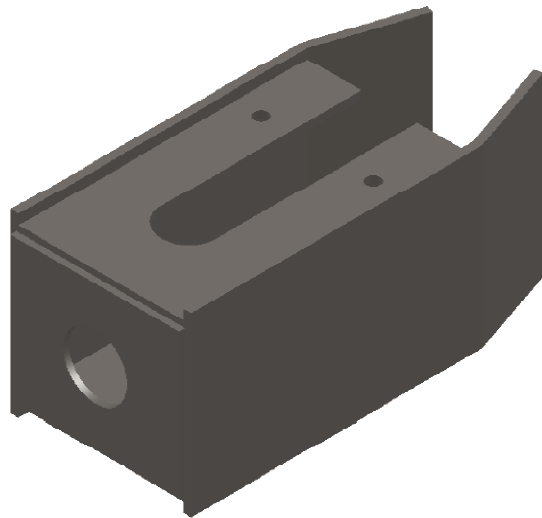
TUBING SUPPORT BRACKET



ELEVATION VIEWS

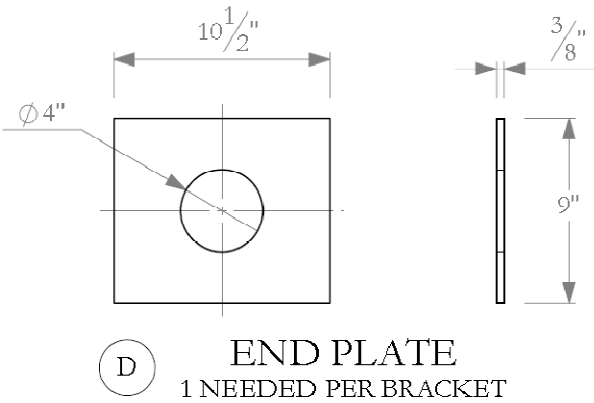
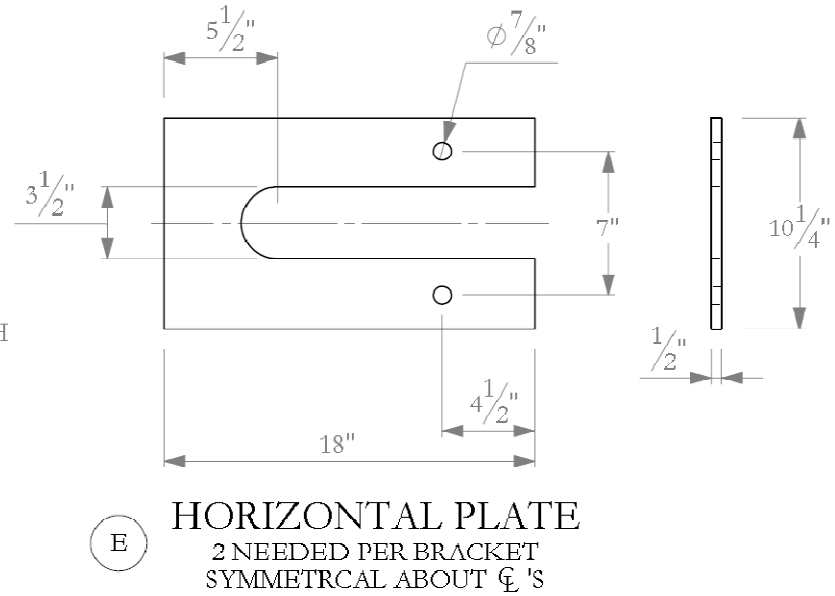
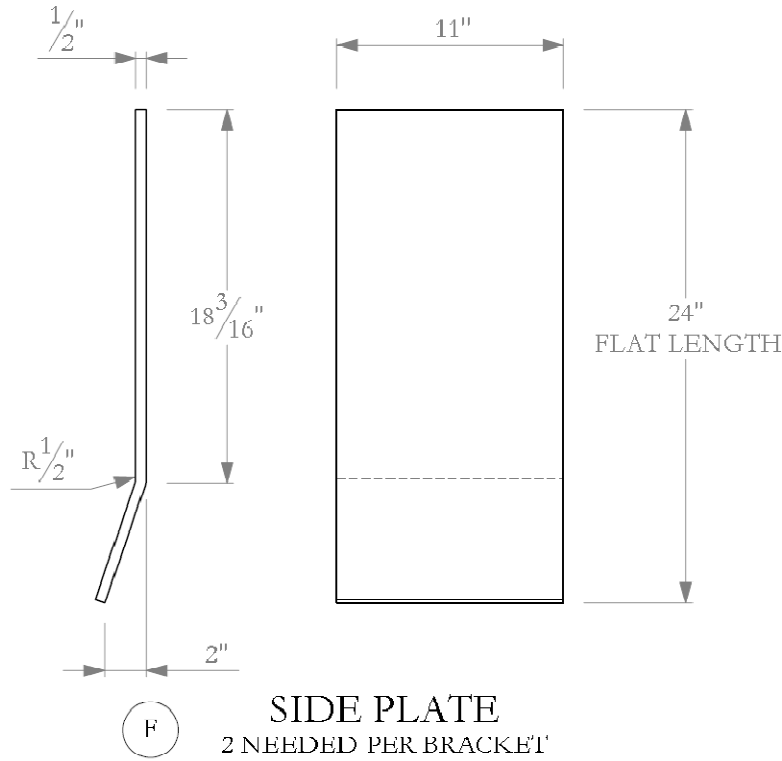


PLAN VIEW



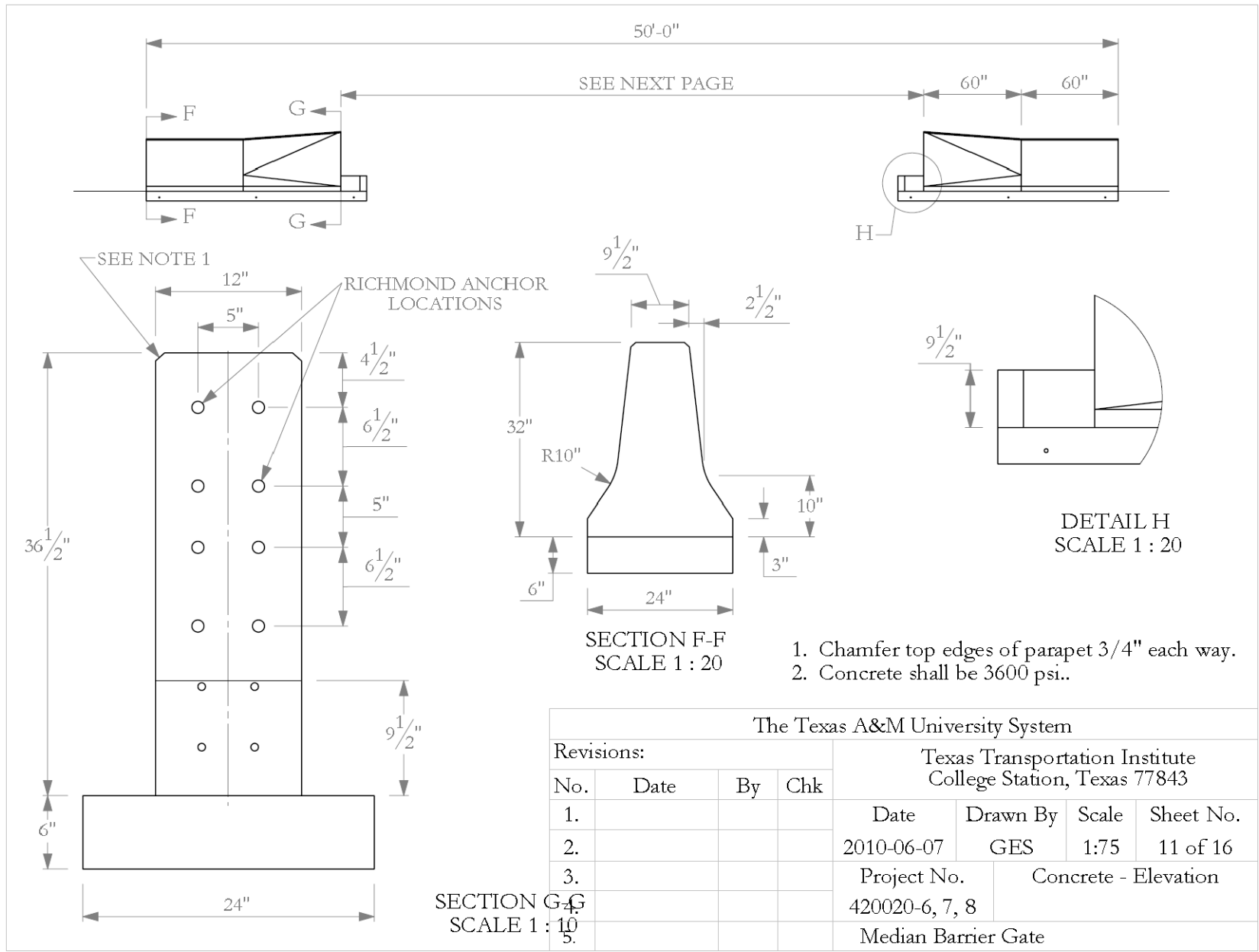
ISOMETRIC VIEW

Revisions:				The Texas A&M University System			
No.	Date	By	Chk	Texas Transportation Institute College Station, Texas 77843			
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-06-07	GES	1:7	9 of 16
3.				Project No.		Tubing Support Bracket	
4.				420020-6, 7, 8			
5.				Median Barrier Gate			



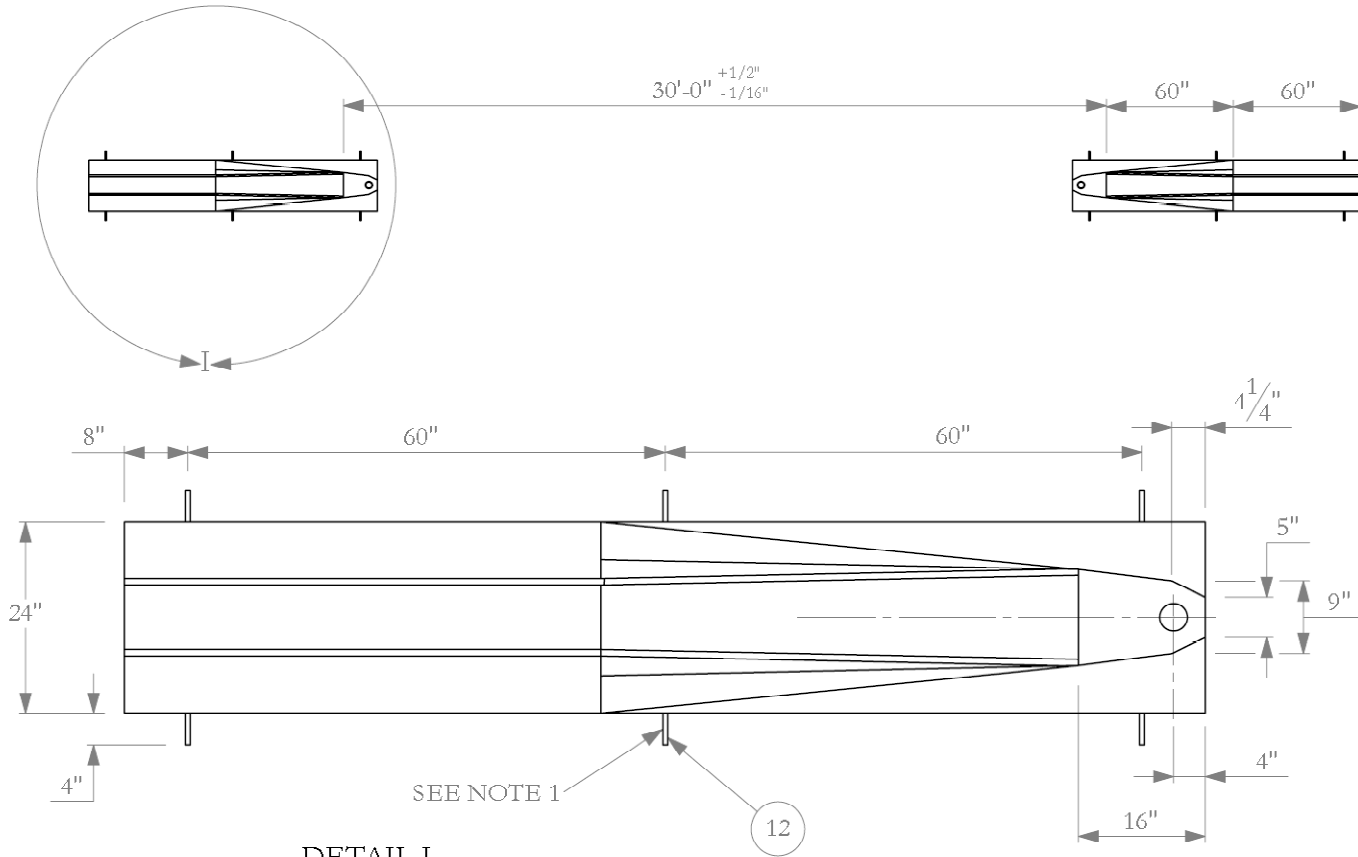
1. All parts are A36 steel.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:8	10 of 16
2.				Project No.		Support Bracket Parts	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							



The Texas A&M University System

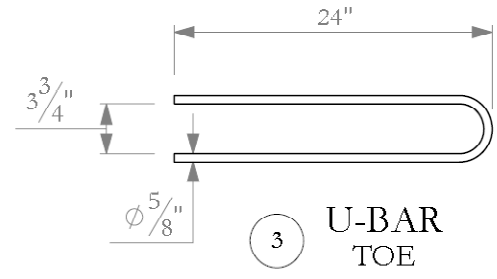
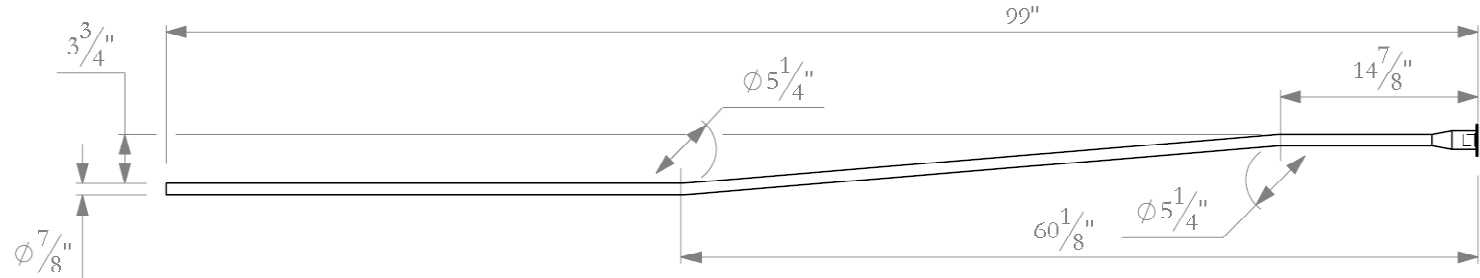
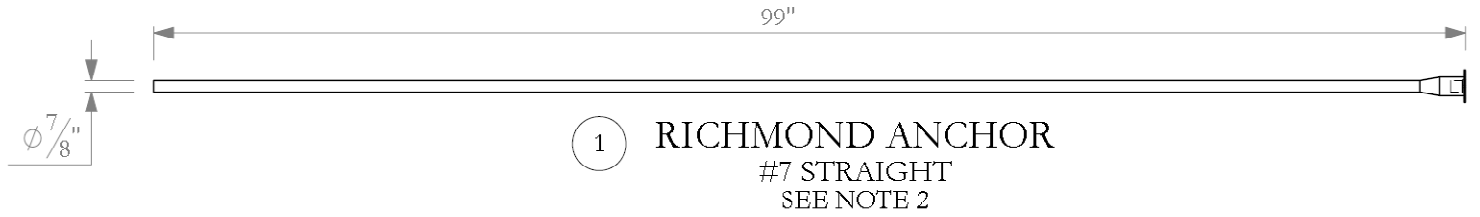
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:75	11 of 16
2.				Project No.		Concrete - Elevation	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							



DETAIL I
SCALE 1 : 20

1. Drill into existing concrete and insert #5 x 12" rebars.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:75	12 of 16
2.				Project No.		Concrete - Plan	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							

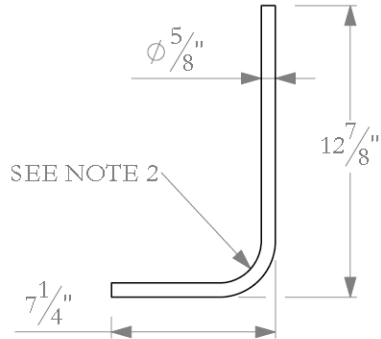


#	PART NUMBER	QTY.
1	Richmond Anchor, #7 straight	12
2	Richmond Anchor, #7 bent	4
3	U-bar, toe	4
4	Stirrup, parapet	16
5	Stirrup, foundation	32
6	L-bar, toe	4
7	U-bar, parapet	76
8	Rebar, #5 x 57"	16
9	Rebar, #5 x 93"	8
10	Pipe, 3" sch. 40 x 9-1/2"	2
11	Rebar, #4 x 11'	8
12	Rebar, #5 x 12"	12

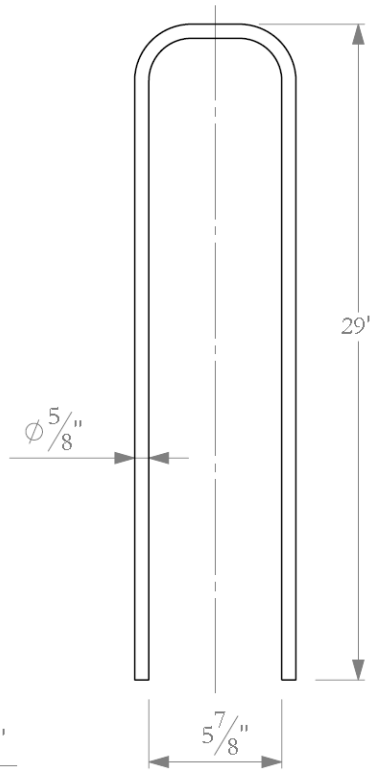
1. All rebar is grade 60.
2. Dayton Superior D-101-A Dowel Bar Splicers, #7 rebar.

Revisions:				The Texas A&M University System			
No.	Date	By	Chk	Texas Transportation Institute College Station, Texas 77843			
1.				Date	Drawn By	Scale	Sheet No.
2.				2010-06-07	GES	1:12	13 of 16
3.				Project No.		Rebar List	
4.				420020-6, 7, 8			
5.				Median Barrier Gate			

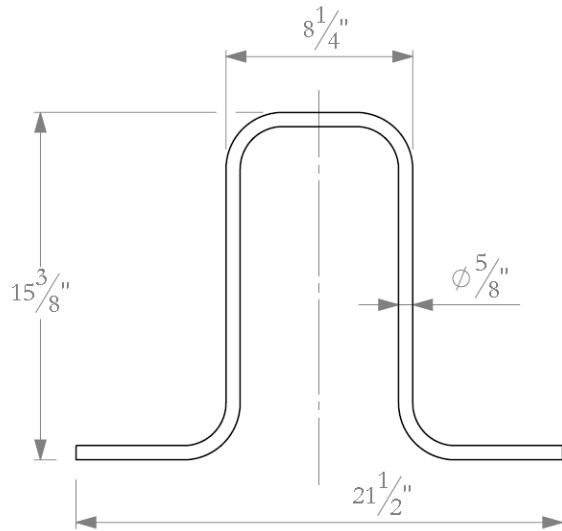
T:\2009-2010\420020 Tx.DCT\Median Barrier\Solidworks\Fina. Design\Drawings\Median Barrier Gate Drawing



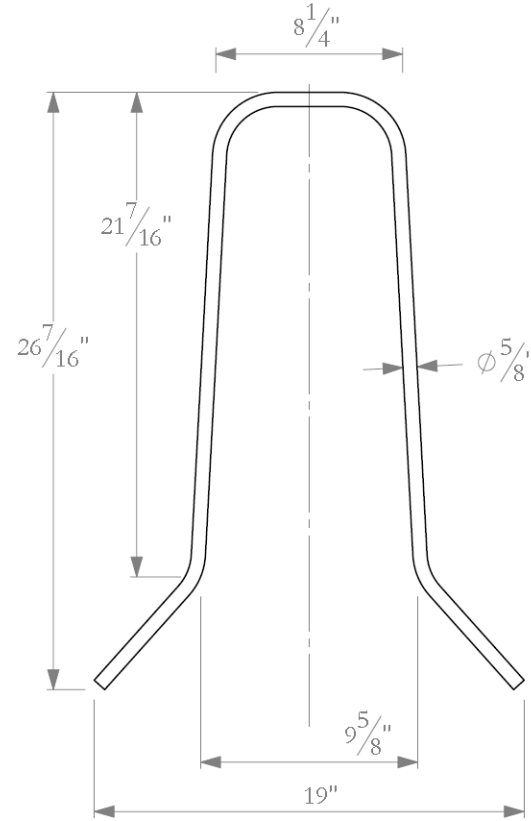
6 L-BAR



7 U-BAR



5 STIRRUP FOUNDATION



4 STIRRUP PARAPET

1. All rebar is grade 60.
2. Bends are ϕ 3-3/4" (R 1-7/8") for all #5 stirrups.
3. Bars 4, 5, and 7 are symmetrical about ϕ 's.

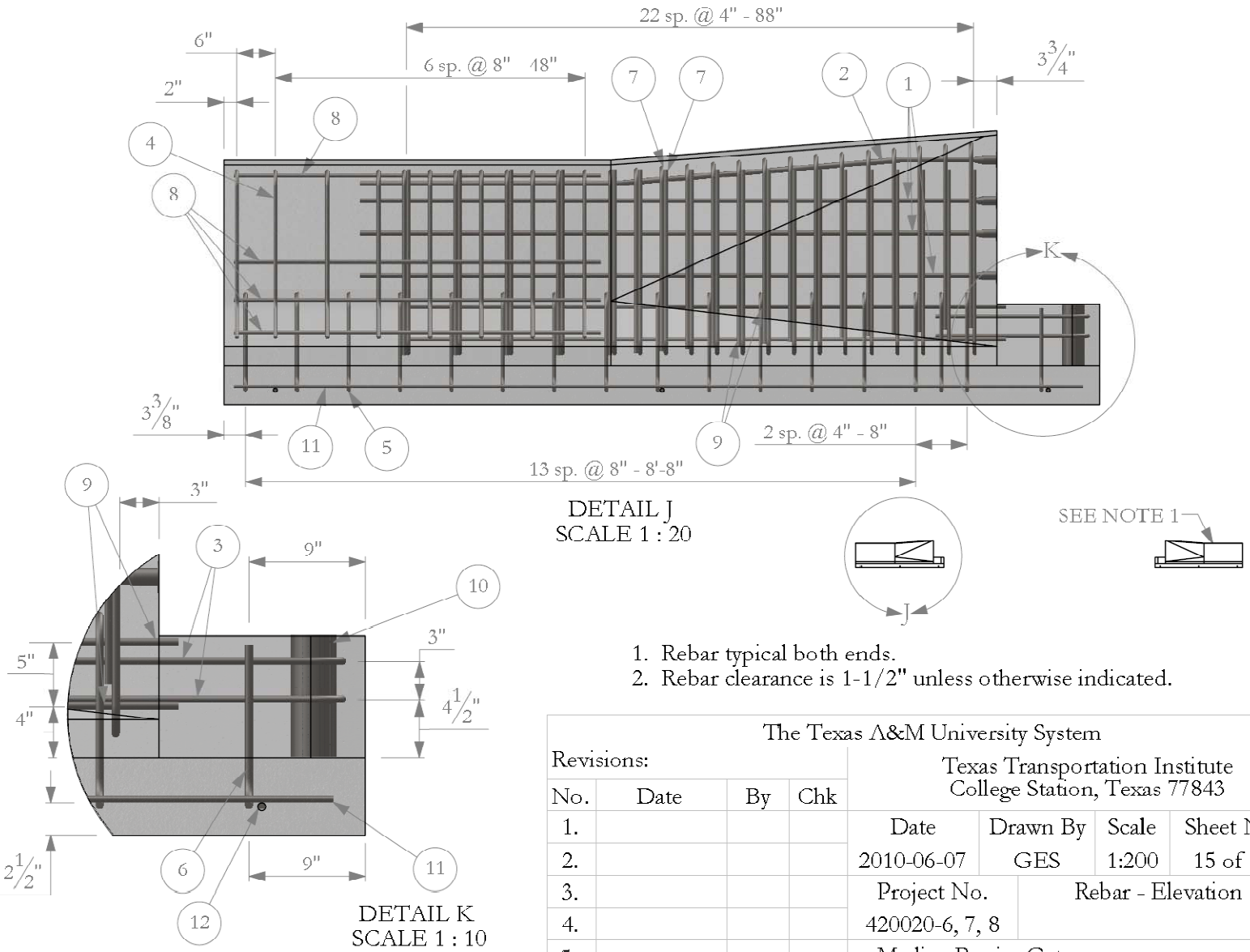
The Texas A&M University System

Revisions:

No.	Date	By	Chk
1.			
2.			
3.			
4.			
5.			

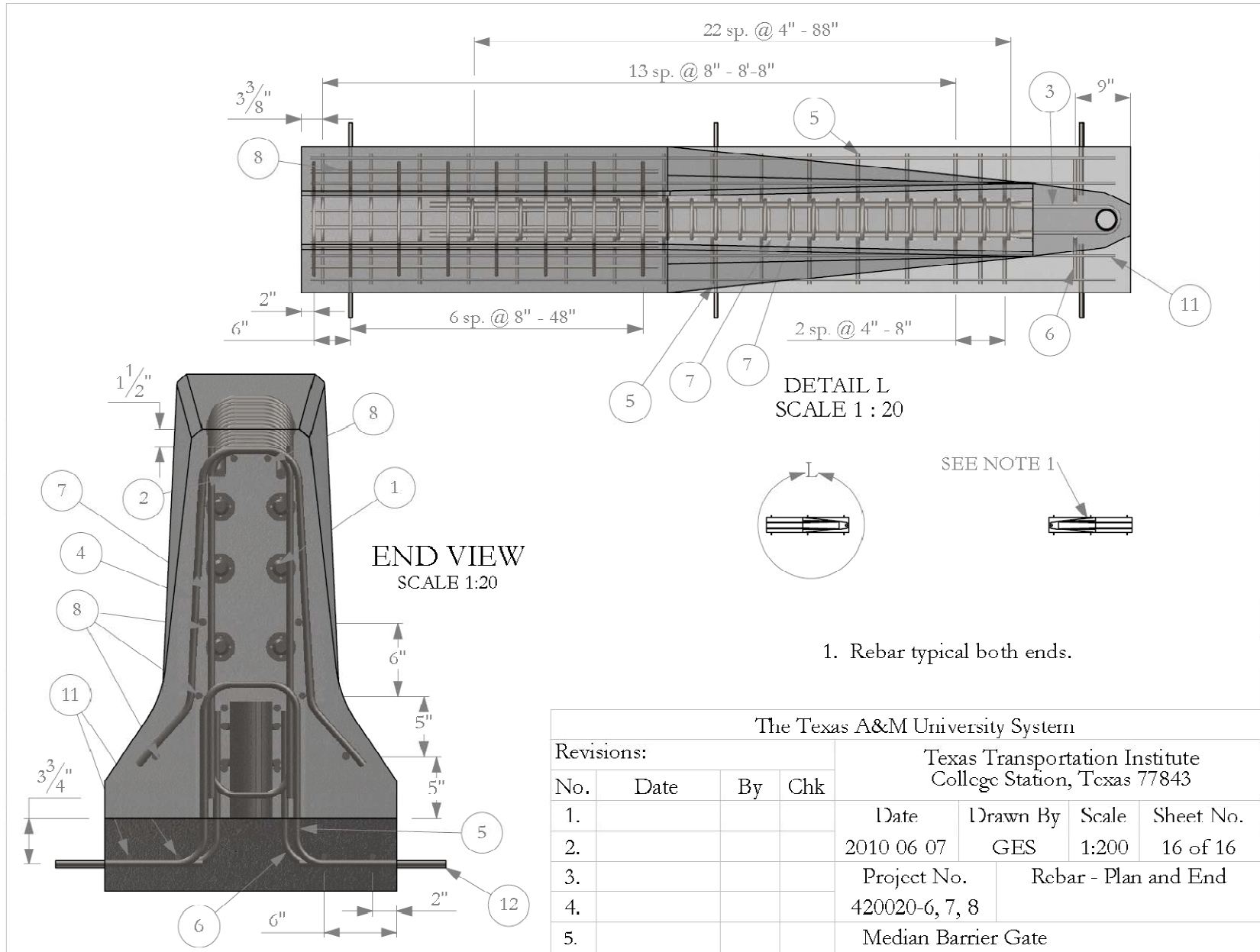
Texas Transportation Institute
College Station, Texas 77843

Date	Drawn By	Scale	Sheet No.
2010-06-07	GES	1:7	14 of 16
Project No.		Rebar Details	
420020-6, 7, 8			
Median Barrier Gate			



1. Rebar typical both ends.
2. Rebar clearance is 1-1/2" unless otherwise indicated.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2010-06-07	GES	1:200	15 of 16
2.				Project No.		Rebar - Elevation	
3.				420020-6, 7, 8			
4.				Median Barrier Gate			
5.							



APPENDIX B. CERTIFICATION DOCUMENTATION

		MATERIAL USED		
TEST NUMBER	420020-7	420020-6	420020-8	
DATE	2010-07-15	2010-07-19	2010-07-21	
DATE RECEIVED	ITEM NUMBER	DESCRIPTION	SUPPLIER	HEAT #
2010-06-08	Rebar 05-10	5/8" x 20' grd 60	CMC-Sheplers	3016376
2010-06-08	Rich Anchor-1	#7 x 99" Richmond Anchor	CMC-Sheplers	
2010-07-07	Parts-7	Median Barrier Gate Parts	Brazos Industries	see file



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.:3016376 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-09b Gr 420/60 ROLL DATE: 05/02/2010 MELT DATE: 04/30/2010	S O L D T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	S H I P T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 80315040 BOL#: 70106603 CUST PO#: VERBAL CUST P/N: DLVRY LBS / HEAT: 39420.000 LB DLVRY PCS / HEAT: 1890 EA
--	----------------------------	--	----------------------------	--	---

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.38%				
Mn	1.05%				
P	0.011%				
S	0.035%				
Si	0.26%				
Cu	0.39%				
Cr	0.16%				
Ni	0.21%				
Mo	0.061%				
V	0.001%				
Cb	0.002%				
Sn	0.013%				
Al	0.002%				
Yield Strength test 1	65.5ksi				
Tensile Strength test 1	105.5ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
Bend Test	Passed				

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

REMARKS :

05/28/2010 04:16:11

Page 1 OF 1

O - PAUL
ustries inc



MILL TEST CERTIFICATE
EN10204 3.1

Certificate No G0030835 K 2 Date 29.01.2010

Shipment:307076968
Product description: ERW-STEEL PIPES

Standard:ASTM A83
Customer name: SUNBELT GROUP, INC.

Delivery Coe.
Contract No: 2010

Material :ASTMA 83 GRA
Order No: 002465
Customer: 19,029

No	OD (Inch)	WT (Inch)	Length (Feet)	Pieces	Feet	Pipe Type	HT Psi	HT Sec	BD	DE	FB	NDT	VD	EL	NP	C
1	1 1/4"	0,140	21	252	5.291,34	GPE	1200	5	0	OK	OK	OK	OK	0,00	0	OK
2	1 1/2"	0,145	21	144	3.023,52	GPE	1200	5	0	OK	OK	OK	OK	0,00	0	OK
3	2"	0,154	21	130	2.729,86	GPE	2300	5	0	OK	OK	OK	OK	0,00	0	OK
4	2"	0,154	24	286	6.888,50	GPE	2300	5	0	OK	OK	OK	OK	0,00	0	OK
5	2 1/2"	0,203	24	180	4.322,83	GPE	2500	5	0	OK	OK	OK	OK	0,00	0	OK
6	4"	0,237	21	150	3.149,51	GPE	1900	5	0	OK	OK	OK	OK	0,00	0	OK
7	3"	0,218	21	42	881,89	GPE	2220	5	0	OK	OK	OK	OK	0,00	0	OK
8	2 1/2"	0,203	18	54	974,41	GPE	2500	5	0	OK	OK	OK	OK	0,00	0	OK
9	6"	0,280	24	42	1.008,86	GPE	1520	5	0	OK	OK	OK	OK	0,00	0	OK

No	Heat No	C	Si	Mn	P	S	Al	V	Ti	Mo	Cr	Ni	Cu	N	Ce
1	922686	2,8	1,1	30,2	25,1	20,5	61,9	0,3	1,4	0,5	26,4	16,1	55,8	4,8	89,1
2	318006	13,2	2,4	49,7	10,9	18,0	32,3	8,1	1,2	1,9	19,1	30,9	62,3	0,0	226,5
3	117843	9,5	0,8	44,9	14,5	14,0	30,2	0,1	0,9	0,3	14,7	15,5	18,8	6,7	175,6
3	217873	11,9	3,6	44,0	5,1	7,8	46,8	2,2	1,1	1,2	19,9	28,6	55,7	0,0	202,3
4	1219570	2,1	0,0	25,7	7,8	18,8	7,1	0,2	0,9	2,2	18,6	23,3	40,5	0,0	72,6
4	193781	3,0	0,0	25,6	4,2	15,4	21,8	0,0	0,6	1,1	7,9	17,8	28,0	0,0	77,8
4	229745	2,8	0,0	25,4	6,5	17,3	7,7	0,0	0,9	1,6	17,8	22,7	37,9	0,0	77,9
5	220691	9,2	1,9	47,8	8,3	16,5	46,5	1,7	1,0	4,5	30,4	63,4	83,6	0,8	188,7
5	220703	7,0	1,9	46,3	9,3	17,8	43,4	1,5	1,3	4,9	30,0	70,7	89,7	4,7	165,1
6	118517	13,2	3,6	47,9	12,2	10,4	37,2	4,0	1,7	2,3	33,9	46,6	122,6	0,8	231,4
6	192473	2,9	0,0	26,8	2,5	10,1	11,4	0,7	13,2	1,5	16,7	13,9	21,3	0,0	79,9
6	192483	5,5	0,0	27,3	7,8	21,5	19,6	0,0	0,8	0,0	14,1	11,9	20,4	0,0	105,1
6	821694	8,9	0,4	37,1	16,6	18,1	49,4	0,1	1,0	7,2	24,3	17,4	20,9	0,0	169,5
7	318523	14,1	2,5	48,9	15,8	13,3	34,6	6,1	1,0	2,3	23,2	27,6	72,0	0,0	234,1
8	220703	7,0	1,9	46,3	9,3	17,8	43,4	1,5	1,3	4,9	30,0	70,7	89,7	4,7	165,1
9	118228	17,0	2,1	53,7	10,1	15,1	43,6	4,4	1,0	1,0	25,9	35,0	66,7	1,7	272,2

No	Heat No	Re Psi	Rm Psi	A %
1	922686	39.011	54.455	33

Description



[Signature]
BORUSAN MANNESMANN BORU
GENELİK KALİTE
Hisar Mah. Gemsaz Mevki

PO # 6271114

Order-Line - 5199743 / 8
Heat - 220703

85



ALTA HORNOS DE MEXICO

MILL TEST CERTIFICATE

AHMSA:QUALITY WITH THE STRENGTH OF STEEL

B007490

CUSTOMER	BENSON INTERNATIONAL	DATE OF ISSUE	31.08.2009	PAGE	1	WE HEREBY THAT CHEMICAL AND T OR TEST SHOW IN THIS REPORT ARE CORRECT AS CONTAINED THE RECORDS OF THE COMPANY. ING. EDUARDO VILLANUEVA MET. LAB. MANAGER
ADDRESS	5711 Breakwater Dr.					
PRODUCT	HOT ROLLED STEEL IN COILS.					

HEAT	SPECIFICATION	C	Mn	P	S	Si	Cr	Ni	Mo	Al	V	Nb	Ti
195070	ASTM A 1011 SS 36 TIPO 2.	0.180	0.584	0.019	0.006	0.1056	0.039	0.028	0.026	0.007	0.031	0.004	0.005
195422	ASTM A 1011 SS 36 TIPO 2.	0.180	0.580	0.015	0.006	0.1106	0.020	0.030	0.020	0.005	0.034	0.003	0.002
295299	ASTM A 1011 SS 36 TIPO 2.	0.176	0.587	0.009	0.008	0.1156	0.038	0.023	0.024	0.007	0.035	0.003	0.003
HEAT	M2												
195070	0.0056												
195422	0.0052												
295299	0.0040												

HEAT	COIL NO.	SLAB	THICKNESS(Inch)	T. STRENGTH	T. STRENGTH	VELON.	T. ELONG.
195070	1059101	5020	0.2350	50.747(KSI)	69.501(KSI)	46(%)	2
195070	1059102	6020	0.2410	51.351(KSI)	69.729(KSI)	44(%)	2
195422	1091048	6040	0.4850	52.041(KSI)	71.145(KSI)	41(%)	2
295299	1091043	6050	0.2350	49.191(KSI)	68.191(KSI)	40(%)	2

HEAT	COIL NO.	THICKNESS(Inch)	WIDTH(Inch)	ORDER	ITEM	DELIVERY	CUSTOMER ORD.	STANDARD
195070	1059101	0.2350	49.0000	0000106824	000050	1001227796	500481-SEP	A568/A635
195070	1059103	0.2350	49.0000	0000106824	000050	1001227796	500481-SXP	A568/A635
195070	1059102	0.2350	48.0000	0000106824	000050	1001227796	500481-SEP	A568/A635
195422	1091048	0.4850	60.0000	0000106824	000080	1001227796	500481-SEP	A568/A635
295299	1091043	0.2350	60.0000	0000106824	000060	1001227796	500481-SEP	A568/A635

END OF DATA

M-5179
P.O. 6247374

HR 1/2 x 60

MAVERICK STEEL
281-741-0160

ISSUED : 50550133

AHMSA'S COMPROMISE IS ONLY WITH THE CUSTOMER MENTIONED IN THIS CERTIFICATE, AHMSA WILL ONLY ACCEPT THE ORIGINAL DOCUMENT.

CC-03-F-61-A

86

FROM : MAVERICK STEEL ENTERPRISES FAX NO. : 281-741-1002 Jan. 29 2010 04:43PM PS

J. PAUL

Order-Line - 5199743/3

sties Inc

Heat - 195422

10Jun10 14:33 TEST CERTIFICATE No: HD 175340

Sold By:					
CARGILL STEEL SERVICE CENTERS		P/O No	AUS 6271157		
DEPARTMENT OF CARGILL, INCORPORATED		Rel			
8807 LIBERTY RD		S/O No	HD 135262-004		
HOUSTON TX 77028-5730		B/L No	HD 117162-006	Shp	10Jun10
Tel: 713-672-4200 Fax: 713 672-4292		Inv No		Inv	

Sold To: (20847)	Ship To: (011)
NAMASCO	NAMASCO
ATTN: A/P	SOUTH LOOP 4
SUITE 500	BUDA TX 78610
500 COLONIAL CENTER PKWY	
ROSWELL GA 30076	

Tel: 678-259-8800 Fax: 866 598-1572

CERTIFICATE of ANALYSIS and TESTS	Cert. No: HD 175340
	10Jun10

Part No		Pcs	Wgt
HR PLATE SHEET ASTM-A36/ASME SA-36		30	19,604
1/2 X 48.0000" X 96.0000"			

Heat Number	Tag No	Pcs	Wgt
101815	152703	15	9,802
	YIELD=47.42-47.56/TENS=66.17-66.53/ELONG=45-46/MILL=<AHMSA>		
	VESSL=<UP242205>/CNTRY=<MEXICO>		
101815	152704	15	9,802
	YIELD=47.42-47.56/TENS=66.17-66.53/ELONG=45-46/MILL=<AHMSA>		
	VESSL=<UP242205>/CNTRY=<MEXICO>		

Heat Number	*** Chemical Analysis ***
101815	**<*> C=0.1610 Mn=0.5610 P=0.0140 S=0.0060 Si=0.1000 Cu=0.0200
	Al=0.0290 Ti=0.0030 V=0.0040 Nb=0.0020 Mo=0.0070 Cr=0.0230
	Ni=0.0240

ELEMENTS NOT LISTED TEST BELOW DETECTABLE LEVELS
ALL ASTM PLATE PRODUCTS ARE PRODUCED FROM COIL
CENTER TESTS AVAILABLE AT CARGILL

THIS IS TO CERTIFY THAT THE PRODUCT DESCRIBED
HEREIN WAS SAMPLED AND TESTED IN ACCORDANCE
WITH THE SPECIFICATION, TO OUR KNOWLEDGE,
AND FULFILLS REQUIREMENTS IN SUCH RESPECT.

Украина
Ukraine



ОАО "ММК имени ИЛЬИЧА"
OSC "ILYICH IRON & STEEL WORKS OF MARIUPOL"

СЕРТИФИКАТ КАЧЕСТВА N
QUALITY CERTIFICATE No 32177 От 12.10.2008 Лист 1 Из 1 Листов Sheets

Сертифицирован ТМ Норд ГмбХ и Ко.КГ по АД 2000 W0 и по Директиве 97/23/ЕС для сосудов высокого давления; регистрационный номер сертификата/номер паспорта 0045
Approved acc. to AD 2000 - Merkblatt W0 and certified acc. to Pressure Equipment Directive 97/23/EC by TÜV NORD Systems GmbH & Co.KG/notified body; reg-no, 0045

87504, г. Мариуполь, ул. Левченко, 1. Телекс 115157 DEPO SU
Levchenko str. 1, Mariupol, 87504, Telex 115157 DEPO SU

Свидетельство о приемочных испытаниях
Inspection certificate EN 10204-3.1
Контракт N 12EXP/001-07
Contract No UF700101322
Заводской заказ N UF7-001013220327
Manufacturer's works order No

Клиент
Customer
Ворон N 56113921
Specification N 322UF
Lot N 1

Наименование товара Прокат толстолистовой
Description of goods Heavy plates
Марка стали
Grade of steel
Стандарты ASTM A6/A6M-02
Standards ASME/ASTM SA/A36/SA36M-01
ASME/ASTM SA/A36

Состояние поставки Горячекатаный лист
Delivery condition Hot Rolled Plate
Маркировка Trade mark, Made in Ukraine, Grade of steel, Cast No,
Marking Test No, Lot 1, Dimensions in, Boston, PO8699, One colour stroke white at both ends of the plate

Клеймо Trade Mark, Grade of steel, Cast No
Hard stamp

Позиция Item No	Плавка N Cast No	Партия N Test No	Размеры, дюйм Dimensions, inch			Кол-во, шт. Quantity, pcs	Теоретическая масса, тн Theoretical mass, tn
			Толщина Thickness	Ширина Width	Длина Length		
	285947	21245	1/2	96	240	18	26.676
	285952	21246	1/2	96	240	25	37.050
						43	63.726

Выплавка Конвертерный способ производства
Steelmaking process Made by the BOF Process

Плавка Cast No	Химический состав, % Chemical composition, %																			
	C	Mn	Si	S	P	Cr	Ni	Cu	Ti	Al	As	N	Mo	V	Nb	Ca	B	Coq	Pcm	
	x100		x1000		x100							x1000							x100	
285947	16	102	19	12	18	4	1	1	4	33	2	5	1	7	6	-	-	33	-	
285952	14	101	18	14	19	4	1	1	2	37	2	5	2	7	7	-	-	31	-	

Результаты испытаний
Test results

Партия N Test No	Номер изделия Product No	Размеры обр. Dimensions		Направление обр. Direction	Темп. испытания Test temperature	Предел текучести yield point	Предел прочности Tensile strength	Отк. удлинение Elongation	Отк. сужения Reduction of area	Тип надреза Notch type	Энергия удара KV/KU	Impact energy KV/KU	Энергия удара KV/KU	Impact energy KV/KU	Энергия удара KV/KU	Impact energy KV/KU	Среднее значение KV/KU Average value KV/KU	Катод	Кол-во вкл. сост. Shear area
		Толщина/диаметр Thickness/diameter	Ширина Width																
21245	1-1	12,7	40	T	+20	353	468	24	-	-	-	-	-	-	-	-	-	-	-
21245	2-1	12,7	40	T	+20	354	471	26	-	-	-	-	-	-	-	-	-	-	-
21246	1-1	12,7	40	T	+20	352	470	28	-	-	-	-	-	-	-	-	-	-	-
21246	2-1	12,7	40	T	+20	326	458	28	-	-	-	-	-	-	-	-	-	-	-

S-начало полосы/strip start; E-конец полосы/strip end; L, l-продольное/Longitudinal;
T, t-поперечное/Transverse; d-диаметр/diameter;
Примечание / Note

Поставка соответствует условиям заказа. Осмотр поверхности без замечаний. Размеры проката в пределах допусков. Delivery conforms to conditions of the order. Surface examination without remarks. Rolled product dimensions within the tolerance limit. It is hereby certified that the quality of goods mentioned in this certificate is in conformity with the standards and specifications.

Указанный в настоящем сертификате товар соответствует по качеству действующим стандартам и техническим условиям.

ВАТ "Марьупольский"

металлургический комбинат

И. Ивченко

Подпись
Signature

Печатный штамп
Receiving agent's stamp

Д. ФОНТОРОГО

Mill Test Report

Issuing Date : 05/27/2010 B/L No. : 263099 Load No. : 264806 Our Order No. : 81782/3 Cust. Order No. : 9525
 Vehicle No: TTPX 80247
 Specification : 1.0000" x 96.000" x 240.000"
 ASTM A36-08/ASTM A709 Grade 36-09a/ASME SA36-03a .05 Max Si

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
0503684	0.18	0.83	0.017	0.001	0.03	0.25	0.08	0.11	0.02	0.024	0.005	0.001	0.001		0.0032	0.0001	0.012	0.36	0.24

Plate Serial No	Tensile Test								Charpy Impacts												
	Places	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % In 2"	Elongation % In 8"		Dir.	1	(%) shear	2	(%) shear	3	(%) shear	Ave.	(%) shear	Size	Temp	Min Ave.	
0503684-02	4	13.06	T	43,300	70,100																
			T	43,700	70,400																
0503684-03	12	39.20	T	43,300	70,100																
			T	43,700	70,400																
0503684-04	9	29.40	T	43,300	70,100																
			T	43,700	70,400																

89

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.

Yield by 0.5EUL method unless otherwise specified. $Ceq = C + (Mn/5) + ((Cr + Mo + V)/5) + ((Cu + Ni)/15)$

$Pcm = C + (Si/30) + (Mn/20) + (Cu/20) + (Ni/60) + (Cr/20) + (Mo/15) + (V/10) + 5B$

Melted and manufactured in the USA. ISO 9001-2000 certified (#006461) by SRI Quality System Registrar (#0985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.B/EN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 06-MMPQA-383

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

T. A. Depretis

T. A. Depretis, Metallurgist

05/28/2010 9:53:28 AM

Issuing Date : 04/15/2010 B/L No. : 258864 Load No. : 260706 Our Order No. : 810087 Cust. Order No. : 9480
 Vehicle No: LW 62023 Sold To : Ship To :
 Specification : 2.0000" x 96.000" x 240.000"
 ASTM A36-08/ASTM A709 Grade 36-09a/AASHTO M270 Grade 36/ASME
 SA36-03a 2009 Addenda AASHTO M270 36

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	CEQ	PCM
0502639	0.19	0.86	0.024	0.001	0.18	0.29	0.07	0.12	0.01	0.005	0.006	0.003	0.001		0.0015	0.0001	0.015	0.38	0.26

Plate Serial No	Tensile Test								Charpy Impacts								
	Places	Tons	Dir.	(psi) Yield	(psi) Tensile	Elongation % In 2"	Elongation % In 8"	Dir.	1 (%) shear	2 (%) shear	3 (%) shear	Ave.	(%) shear	Size	Temp	Min Ave.	
0502639-02	2	13.06	T	43,600	72,900												
			T	42,600	73,100												
0502639-03	6	39.20	T	43,600	72,900												
			T	42,600	73,100												
0502639-04	5	32.67	T	43,600	72,900												
			T	42,600	73,100												

06

Manufactured to fully killed practice by Electric Arc Furnace. Welding or weld repair was not performed on this material. Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification.

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

Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+(Cu+Ni)/15

PCM = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+SB

Melted and manufactured in the USA. ISO 9001-2000 certified (#006461) by SRI Quality System Registrar (#0985-09). PED 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. DIN 50049 3.1.BEN 10204 3.1B(2004), DIN EN 10204 3.1(2005) compliant. For ABS grades only, Quality Assurance certificate 06-MMPQA-383

T. A. Depretis
T. A. Depretis, Metallurgist

04/19/2010 11:15:56 AM



P. O. Box 911
Seguin, Texas 78156-0911
(830) 372-8200

CERTIFIED MILL TEST REPORT
For additional copies call
(830) 372-8485

are accurate and conform to the reported grade.

Daniel J. Schacht
Daniel J. Schacht
Quality Assurance Manager

HEAT NO.: 248838	S O L D T O	NORTH SHORE SUPPLY CO	S H I P T O	NORTH SHORE SUPPLY CO	SHIP#: 101810/30
SECTION: RD 2-1/4x20"0"		P O BOX 9940		12929 MARKET ST.	BOL #: 429361
RD 57.15mm x6.096		HOUSTON, TX 77213-		HOUSTON, TX 77015-	INV #:
GRADE: ASTM A38-04					CUST PO#: 120201
					CUST P/N:

CHEMICAL ANALYSIS		PROPERTIES						
	%	MECHANICAL	TEST I		TEST		TEST	
			IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	METRIC
C	0.20	Yield Strength	48.0 KSI	331.0 MPA				
Mn	0.80		Tensile Strength	74.6 KSI	514.4 MPA			
P	0.009	Elongation	32 %	32 %				
S	0.026		Gauge Length	8 INS	203 MM			
Si	0.20	Reduction of Area	42 %	42 %				
Cu	0.31		Bend Test					
Cr	0.09	Diameter						
Ni	0.08		Charpy Impact					
Mo	0.023	Test Temp						
Cb	0.002		Sample Size					
V	0.002	Orientation						
Sn	0.012		Hardness	146	EBN			
B	0.0003							
Ti	0.001							
C.Eq.	0.38							

JOMINY RESULTS - Rockwell C hardness at 1/16th inch increments												GRAIN SIZE	INCLUSION RATING										
1	2	3	4	5	6	7	8	9	10	11	12	METHOD	METHOD										
												RESULT	TYPE										
												SIZE	T H			T H			T H				

100% MELTED AND MANUFACTURED IN THE USA AND FREE OF MERCURY CONTAMINATION IN THE PROCESS
REMARKS:

01Jul10 9: 1 TEST CERTIFICATE No: DCR 696282

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

P/O No 6273761
Rel
S/O No DCR 23853-001
B/L No DCR 16103-008 Shp 29Jun10
Inv No Inv

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

Ship To: (21)
NAMASCO-BUDA
2560 SOUTH LOOP 4
BUDA, TX

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

CERTIFICATE of ANALYSIS and TESTS

Cert. No: DCR 696282
29Jun10

Part No 001
TUBING A500 GRADE B(C)
12" SQ X 1/4" X 30'

Pcs Wgt
4 4,732

Heat Number Tag No
U81836 652592

Pcs Wgt
4 4,732

YLD=58500/TEN=72000/ELG=39.7

Heat Number
U81836

*** Chemical Analysis ***
C=0.2100 Mn=0.6900 P=0.0070 S=0.0120 Si=0.0130 Al=0.0410
Cu=0.0300

T/R FAX

: 

Test Report Clerk
MELTED IN U.S.A.

WE PROUDLY MANUFACTURE ALL OF OUR HSS IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED,
AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.

CURRENT STANDARDS:

..... A500/A500M-07
..... A513-07
..... A252-98 (2002)

SOLD DAYTON SUPERIOR CORP (DIP)
55 N PINE ST
TO: TREMONT, PA 17981-

NUCOR
BAR MILL GROUP
NUCOR STEEL AUBURN, INC.

CERTIFIED MILL TEST REPORT

Ship from:
Nucor Steel - Auburn
25 Quarry Road
Auburn, NY 13021
315-253-4561

SHIP DAYTON SUPERIOR CORP (DIP)
55 N PINE ST
TO: TREMONT, PA 17981-

Date: 5-Oct-2009
B.L. Number: 368296
Load Number: 117644

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

NBMG-08 March 24, 2008

HEAT NUM. *	DESCRIPTION	PHYSICAL TESTS					CHEMICAL TESTS												
		YIELD P.S.I.	TENSILE P.S.I.	ELONG % IN 8"	BEND	WT% DEF	C	Ni	Mn	Cr	P	Mo	S	V	Si	Co	Cu	Sn	C.E.
PO# =>	81775																		
AU0910019501	Nucor Steel - Auburn Inc	80,600	113,600	13.2%	OK	.35		1.10		.011		.030		.20		.36			
AU09100195	22/#7 Rebar 20 A615 Gr60 92K min tensile ASTM A615/A615M-08b GR 60[420]	556MPa	783MPa			.12		.14		.040		.026		.001					
PO# =>	81775																		
AU0910089701	Nucor Steel - Auburn Inc	70,700	97,700	15.4%	OK	.33		1.14		.017		.040		.24		.37			
AU09100897	22/#7 Rebar 20 A615 Gr60 92K min tensile ASTM A615/A615M-08b GR 60[420]	487MPa	674MPa			.10		.16		.029		.028		.001					
PO# =>	81775																		
AU0910163201	Nucor Steel - Auburn Inc	70,500	100,600	13.8%	OK	.34		1.06		.011		.035		.21		.36			
AU09101632	22/#7 Rebar 20 A615 Gr60 92K min tensile ASTM A615/A615M-08b GR 60[420]	486MPa	694MPa			.13		.16		.033		.032		.002					
PO# =>	81773																		
AU0910170701	Nucor Steel - Auburn Inc	72,100	99,700	18.3%	OK	.34		1.01		.018		.045		.22		.38			
AU09101707	25/#8 Rebar 20 A615 Gr60 92K min tensile ASTM A615/A615M-08b GR 60[420]	497MPa	687MPa			.15		.25		.045		.028		.001					

93

I HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE CORPORATION.

ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN THE UNITED STATES. ALL PRODUCTS PRODUCED ARE WELD FREE. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.

QUALITY ASSURANCE: Jim Biernat



APPENDIX C. TEST VEHICLE PROPERTIES AND INFORMATION

Date: 2010-07-15 Test No.: 420020-5 VIN No.: KNADC125736268923

Year: 2003 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 120942 Tire Size: P175/65R14

Describe any damage to the vehicle prior to test: _____

• Denotes accelerometer location.

NOTES: _____

Engine Type: 4 cylinder

Engine CID: 1.6 Liter

Transmission Type: _____

 Auto or x Manual

 x FWD RWD 4WD

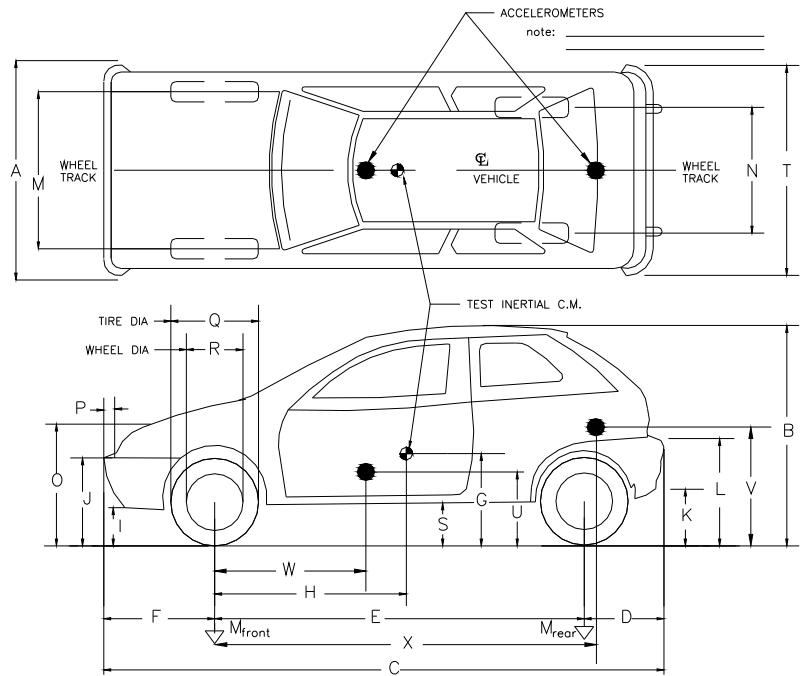
Optional Equipment: _____

Dummy Data: _____

Type: 50th percentile male

Mass: 168 lb

Seat Position: Frt Passenger Seat



Geometry: inches

A	<u>62.50</u>	F	<u>32.00</u>	K	<u>12.00</u>	P	<u>3.25</u>	U	<u>15.50</u>
B	<u>56.12</u>	G	<u> </u>	L	<u>24.25</u>	Q	<u>22.50</u>	V	<u>20.00</u>
C	<u>164.25</u>	H	<u>36.27</u>	M	<u>56.50</u>	R	<u>15.50</u>	W	<u>39.50</u>
D	<u>37.00</u>	I	<u>8.50</u>	N	<u>57.00</u>	S	<u>8.62</u>	X	<u>103.25</u>
E	<u>95.25</u>	J	<u>22.75</u>	O	<u>28.00</u>	T	<u>63.00</u>		

Wheel Center Ht Front 10.75 Wheel Center Ht Rear 11.12

RANGE LIMIT: A = 65 ±3 inches; C = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches;
O = 24 ±4 inches; M+N/2 = 56 ±2 inches

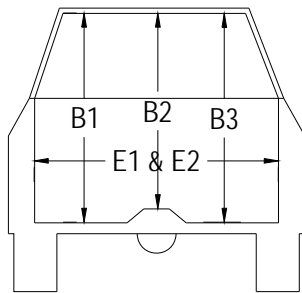
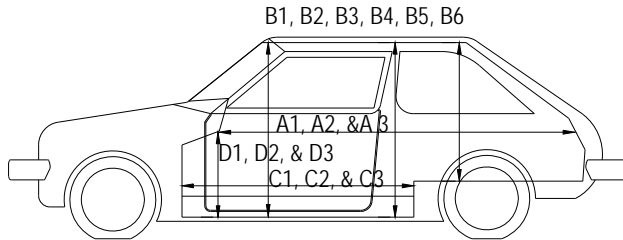
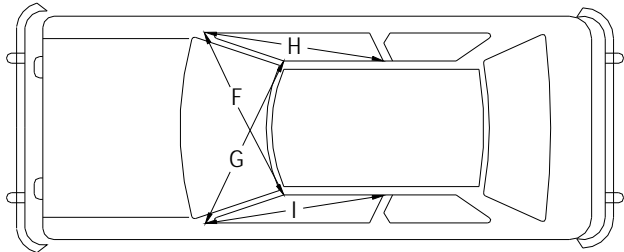
GVWR Ratings:	Mass: lb	Curb	Test Inertial	Gross Static
Front <u>1808</u>	M_{front}	<u>1475</u>	<u>1501</u> Allowable	<u>1586</u> Allowable
Back <u>1742</u>	M_{rear}	<u>882</u>	<u>923</u> Range	<u>1006</u> Range =
Total <u>3379</u>	M_{Total}	<u>2357</u>	<u>2424</u> 2420 ±55 lb	<u>2592</u> 2585 ±55 lb

Mass Distribution:
lb LF: 780 RF: 721 LR: 445 RR: 478

Figure C1. Vehicle Properties for Test No. 420020-6.

Table C2. Occupant Compartment Measurements for Test No. 420020-6.

Date: 2010-07-15 Test No.: 420020-5 VIN No.: KNADC125736268923
 Year: 2003 Make: Kia Model: Rio



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.25	64.50
A2	64.50	63.50
A3	62.25	62.25
B1	39.12	43.12
B2	36.00	35.50
B3	39.12	39.50
B4	34.75	34.75
B5	34.75	34.75
B6	34.75	34.75
C1	27.00	24.00
C2	----	----
C3	27.00	27.00
D1	9.88	10.75
D2	5.88	6.00
D3	9.12	9.25
E1	49.50	52.00
E2	51.00	53.00
F	50.00	45.00
G	50.00	50.75
H	36.50	34.00
I	36.50	36.50
J*	50.50	48.00

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

Date: 2010-07-19 Test No.: 420020-7 VIN No.: 1D7HA18N43525276

Year: 2003 Make: Dodge Model: Ram 1500 Quad-Cab

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

Tread Type: Highway Odometer: 147224

Note any damage to the vehicle prior to test: _____

- Denotes accelerometer location.

NOTES: _____

Engine Type: V8

Engine CID: 4.7 Liter

Transmission Type:

Auto or Manual
 FWD RWD 4WD

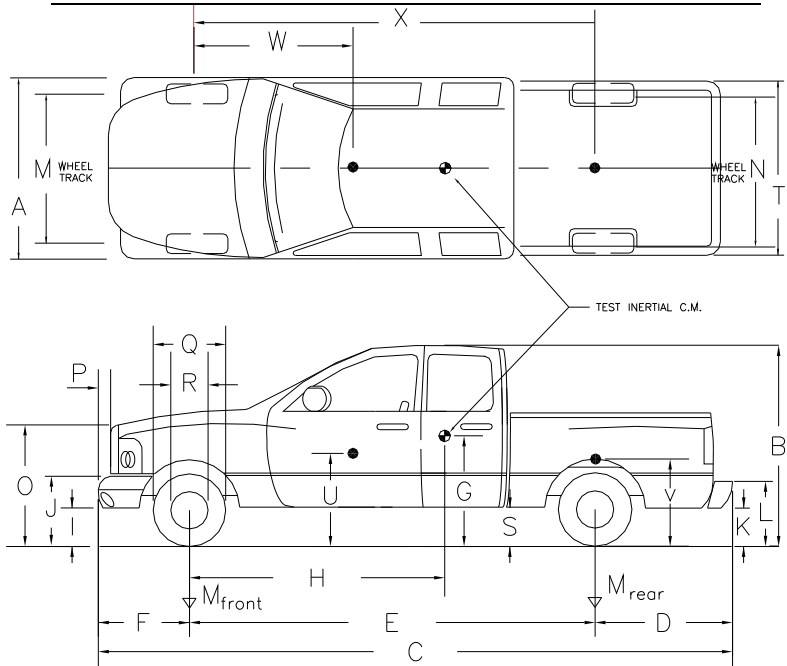
Optional Equipment: _____

Dummy Data:

Type: No dummy

Mass: _____

Seat Position: _____



Geometry: inches

A	<u>77.00</u>	F	<u>39.00</u>	K	<u>20.50</u>	P	<u>3.00</u>	U	<u>27.50</u>
B	<u>73.25</u>	G	<u>28.12</u>	L	<u>28.75</u>	Q	<u>29.50</u>	V	<u>34.00</u>
C	<u>227.00</u>	H	<u>63.23</u>	M	<u>68.25</u>	R	<u>18.50</u>	W	<u>59.50</u>
D	<u>47.50</u>	I	<u>13.5</u>	N	<u>67.25</u>	S	<u>14.25</u>	X	<u>140.50</u>
E	<u>140.50</u>	J	<u>26.00</u>	O	<u>44.75</u>	T	<u>75.50</u>		

Wheel Center Ht Front 14.12 Wheel Well Clearance (FR) 6.12 Frame Ht (FR) 16.62

Wheel Center Ht Rear 14.25 Wheel Well Clearance (RR) 11.25 Frame Ht (RR) 24.25

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

GVWR Ratings:	Mass: lb	Curb	Test Inertial	Gross Static
Front <u>3650</u>	M_{front}	<u>2750</u>	<u>2758</u> Allowable	Allowable
Back <u>3900</u>	M_{rear}	<u>1949</u>	<u>2257</u> Range	Range
Total <u>6650</u>	M_{Total}	<u>4699</u>	<u>5015</u> 5000 ±110 lb	5000 ±110 lb

Mass Distribution:

lb LF: 1380 RF: 1378 LR: 1110 RR: 1147

Figure C2. Vehicle Properties for Test No. 420020-7.

Table C3. Vehicle Parametric Measurements for Vertical CG for Test No. 420020-7.

Date: 2010-07-19 Test No.: 420020-7 VIN: 1D7HA18N43525276

Year: 2003 Make: Dodge Model: Ra, 1500

Body Style: Quad Cab Mileage: 147224

Engine: 4.7 liter Transmission: Automatic

Fuel Level: Empty Ballast: 235 + 418 lb at front of bed (440 lb max)

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

Measured Vehicle Weights: (lb)

LF: 1400 RF: 1334 Front Axle: 2734

LR: 1114 RR: 1122 Rear Axle: 2236

Left: 2514 Right: 2456 Total: 4970

5000 ±110 lb allowed

Wheel Base: 140.5 inches Track: F: 68.25 inches R: 67.25 inches

148 ±12 inches allowed

Track = (F+R)/2 = 67 ±1.5 inches allowed

Center of Gravity, SAE J874 Suspension Method

X: 63.21 in Rear of Front Axle (63 ±4 inches allowed)

Y: -0.40 in Left - Right + of Vehicle Centerline

Z: 28.125 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 44.75 inches Front Bumper Height: 26.0 inches

43 ±4 inches allowed

Front Overhang: 39.0 inches Rear Bumper Height: 28.75 inches

39 ±3 inches allowed

Overall Length: 227.0 inches

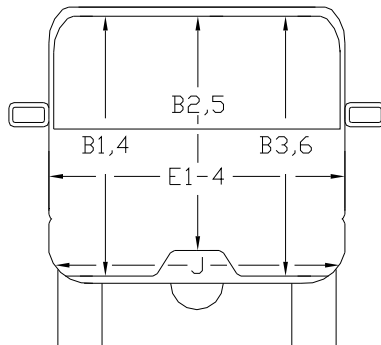
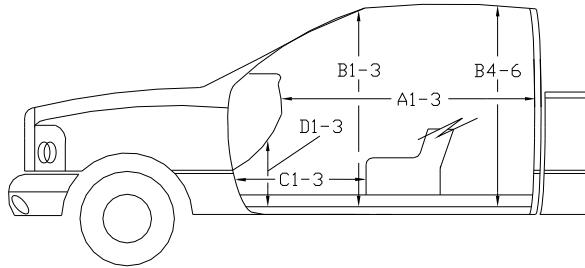
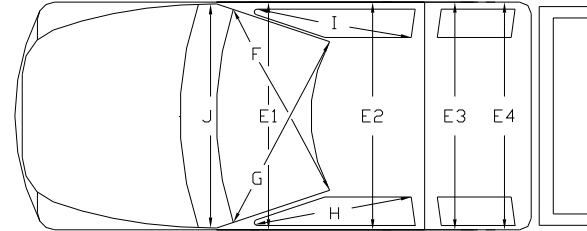
237 ±13 inches allowed

Table C5. Occupant Compartment Measurements for Test No. 420020-7.

Date: 2010-07-19 Test No.: 420020-7 VIN No.: 1D7HA18N43525276

Year: 2003 Make: Dodge Model: Ram 1500 Quad-Cab

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT



	Before (inches)	After (inches)
A1	64.25	64.25
A2	64.50	64.50
A3	65.25	65.25
B1	44.75	44.75
B2	39.25	39.25
B3	45.50	45.50
B4	42.12	42.12
B5	42.50	42.50
B6	42.12	42.12
C1	29.50	29.50
C2	----	----
C3	27.25	27.25
D1	12.62	12.62
D2	2.50	2.50
D3	11.50	11.50
E1	62.50	62.38
E2	64.50	64.50
E3	63.88	63.88
E4	64.00	64.00
F	60.00	60.00
G	60.00	60.00
H	39.75	39.75
I	39.75	39.75
J*	62.50	62.50

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

Date: 2010-07-21 Test No.: 420020-8 VIN No.: 1D7HA18N235509534

Year: 2003 Make: Dodge Model: Ram 1500 Quad-Cab

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

Tread Type: Highway Odometer: 153319

Note any damage to the vehicle prior to test: _____

● Denotes accelerometer location.

NOTES: _____

Engine Type: V8

Engine CID: 4.7 Liter

Transmission Type:

Auto or Manual
 FWD RWD 4WD

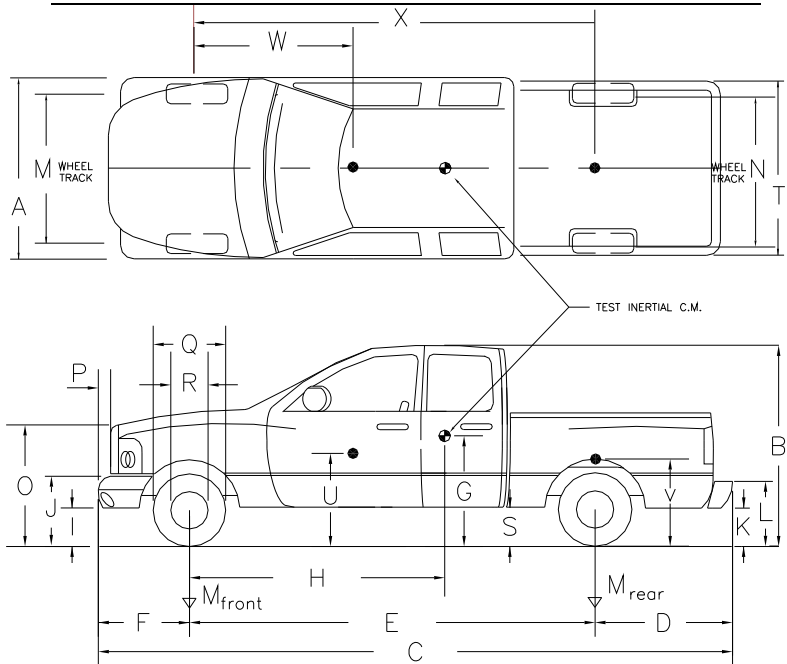
Optional Equipment: _____

Dummy Data:

Type: No dummy

Mass: _____

Seat Position: _____



Geometry: inches

A	<u>77.00</u>	F	<u>39.00</u>	K	<u>20.50</u>	P	<u>3.00</u>	U	<u>27.50</u>
B	<u>73.25</u>	G	<u>28.25</u>	L	<u>28.75</u>	Q	<u>29.50</u>	V	<u>34.00</u>
C	<u>227.00</u>	H	<u>62.34</u>	M	<u>68.25</u>	R	<u>18.50</u>	W	<u>59.50</u>
D	<u>47.50</u>	I	<u>13.5</u>	N	<u>67.25</u>	S	<u>14.25</u>	X	<u>140.50</u>
E	<u>140.50</u>	J	<u>26.00</u>	O	<u>44.75</u>	T	<u>75.50</u>		

Wheel Center Ht Front 14.12 Wheel Well Clearance (FR) 6.12 Frame Ht (FR) 16.62

Wheel Center Ht Rear 14.25 Wheel Well Clearance (RR) 11.25 Frame Ht (RR) 24.25

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

GVWR Ratings:	Mass: lb	Curb	Test Inertial	Gross Static
Front <u>3650</u>	M_{front}	<u>2769</u>	<u>2786</u> Allowable	Allowable
Back <u>3900</u>	M_{rear}	<u>1994</u>	<u>2222</u> Range	Range
Total <u>6650</u>	M_{Total}	<u>4763</u>	<u>5008</u> 5000 ±110 lb	5000 ±110 lb

Mass Distribution:

lb LF: 1420 RF: 1366 LR: 1110 RR: 1112

Figure C3. Vehicle Properties for Test No. 420020-8.

Table C6. Vehicle Parametric Measurements for Vertical CG for Test No. 420020-7.

Date: 2010-07-21 Test No.: 420020-8 VIN: 1D7HA18N235509534

Year: 2003 Make: Dodge Model: Ram 1500

Body Style: Quad Cab Mileage: 153319

Engine: 4.7 liter Transmission: Automatic

Fuel Level: Empty Ballast: 255 + 315 lb at front of bed (440 lb max)

Tire Pressure: Front: _____ psi Rear: _____ psi Size: _____

Measured Vehicle Weights: (lb)

LF: 1408 RF: 1368 Front Axle: 2776

LR: 1132 RR: 1132 Rear Axle: 2264

Left: 2540 Right: 2500 Total: 5040

5000 ±110 lb allowed

Wheel Base: 140.5 inches Track: F: 68.25 inches R: 67.25 inches

148 ±12 inches allowed

Track = (F+R)/2 = 67 ±1.5 inches allowed

Center of Gravity, SAE J874 Suspension Method

X: 63.11 in Rear of Front Axle (63 ±4 inches allowed)

Y: -0.27 in Left - Right + of Vehicle Centerline

Z: 28.25 in Above Ground (minumum 28.0 inches allowed)

Hood Height: 44.75 inches Front Bumper Height: 26.0 inches

43 ±4 inches allowed

Front Overhang: 39.0 inches Rear Bumper Height: 28.75 inches

39 ±3 inches allowed

Overall Length: 227.0 inches

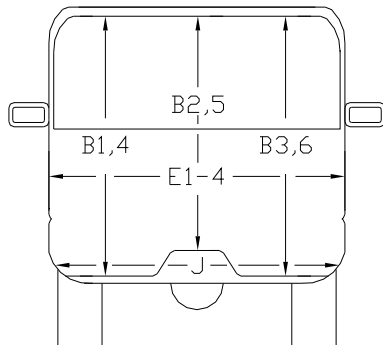
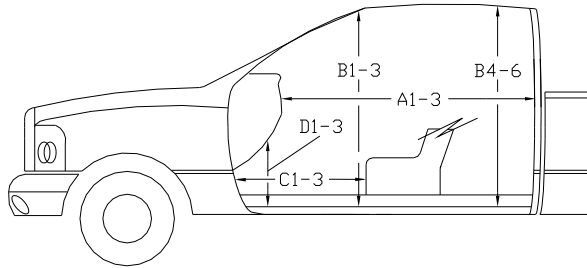
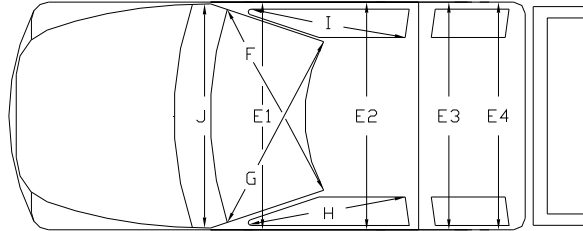
237 ±13 inches allowed

Table C8. Occupant Compartment Measurements for Test No. 420020-8.

Date: 2010-07-19 Test No.: 420020-7 VIN No.: 1D7HA18N43525276

Year: 2003 Make: Dodge Model: Ram 1500 Quad-Cab

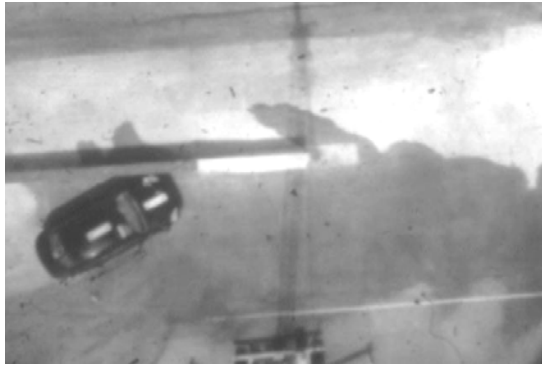
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT



	Before (inches)	After (inches)
A1	64.25	64.50
A2	64.75	64.50
A3	65.25	64.75
B1	45.50	44.50
B2	39.12	38.25
B3	45.50	46.00
B4	42.12	42.12
B5	42.50	42.50
B6	42.12	42.12
C1	29.12	29.12
C2	----	----
C3	26.25	21.00
D1	12.75	12.75
D2	2.50	2.25
D3	11.75	10.75
E1	62.62	63.00
E2	64.25	65.12
E3	64.00	64.12
E4	64.00	64.00
F	39.50	39.50
G	39.50	39.50
H	60.00	59.00
I	60.00	60.25
J*	62.00	60.00

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

APPENDIX D. SEQUENTIAL PHOTOGRAPHS



0.000 s



0.071 s



0.140 s



0.211 s



Figure D1. Sequential Photographs for Test No. 420020-6 (Overhead and Frontal Views).



0.280s



0.351 s



0.420 s



0.491 s



Figure D1. Sequential Photographs for Test No. 420020-6 (Overhead and Frontal Views) (Continued).



0.000 s



0.280 s



0.071 s



0.351 s



0.140 s



0.420 s



0.294 s



2.303 s

Figure D2. Sequential Photographs for Test No. 420020-6 (Rear View).



0.000 s



0.071 s



0.140 s



0.211 s



**Figure D3. Sequential Photographs for Test No. 420020-7
(Overhead and Frontal Views).**



0.280 s



0.351 s



0.419 s



0.490 s



**Figure D3. Sequential Photographs for Test No. 420020-7
(Overhead and Frontal Views) (Continued).**



0.000 s



0.280 s



0.071 s



0.351 s



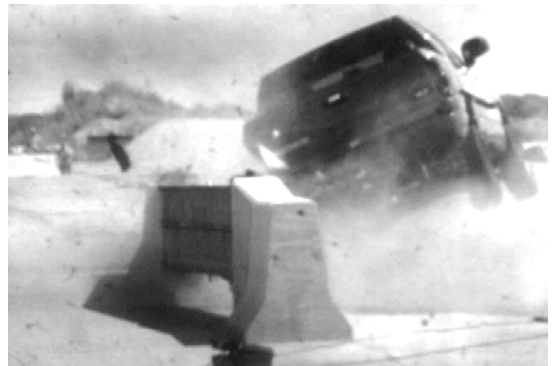
0.140 s



0.419 s



0.211 s

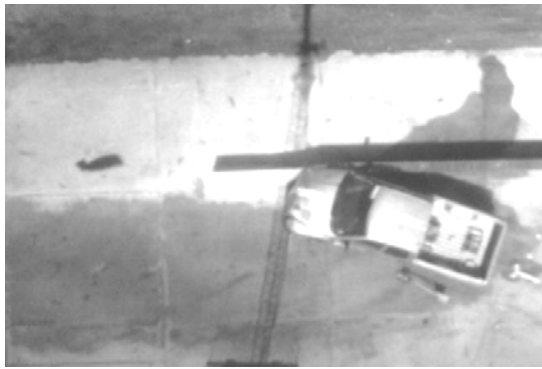


0.490 s

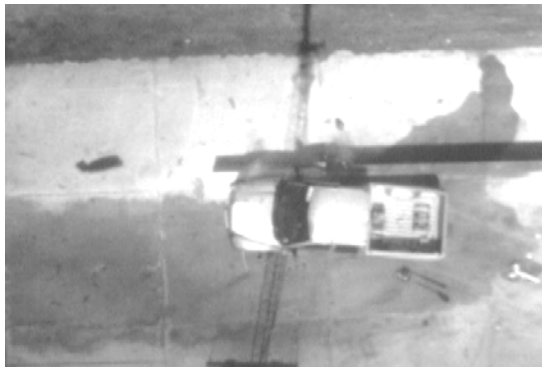
Figure D4. Sequential Photographs for Test No. 420020-7 (Rear View).



0.000 s



0.071 s



0.140 s



0.211 s



Figure D5. Sequential Photographs for Test No. 420020-8 (Overhead and Frontal Views).



0.280 s



0.351 s



0.420 s



0.490 s



**Figure D5. Sequential Photographs for Test No. 420020-8
(Overhead and Frontal Views) (Continued).**



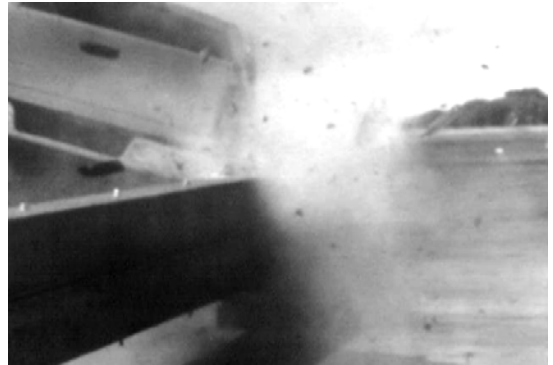
0.000 s



0.280 s



0.071 s



0.351 s



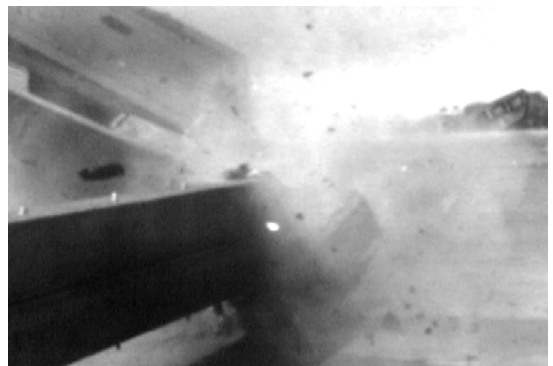
0.140 s



0.420 s



0.211 s



0.490 s

Figure D6. Sequential Photographs for Test No. 420020-8 (Rear View).

Roll, Pitch, and Yaw Angles

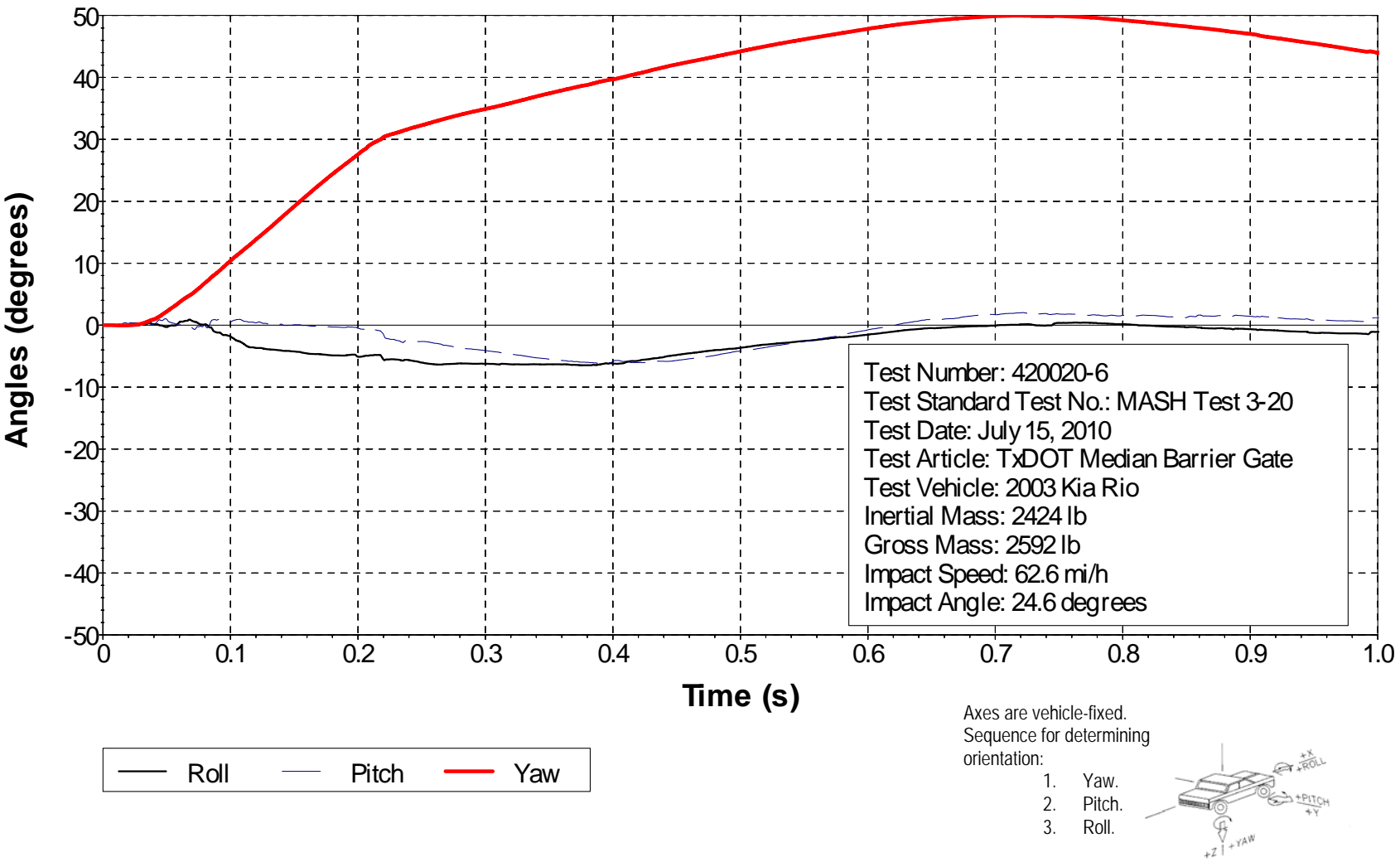


Figure E1. Vehicle Angular Displacements for Test No. 420020-6.

X Acceleration at CG

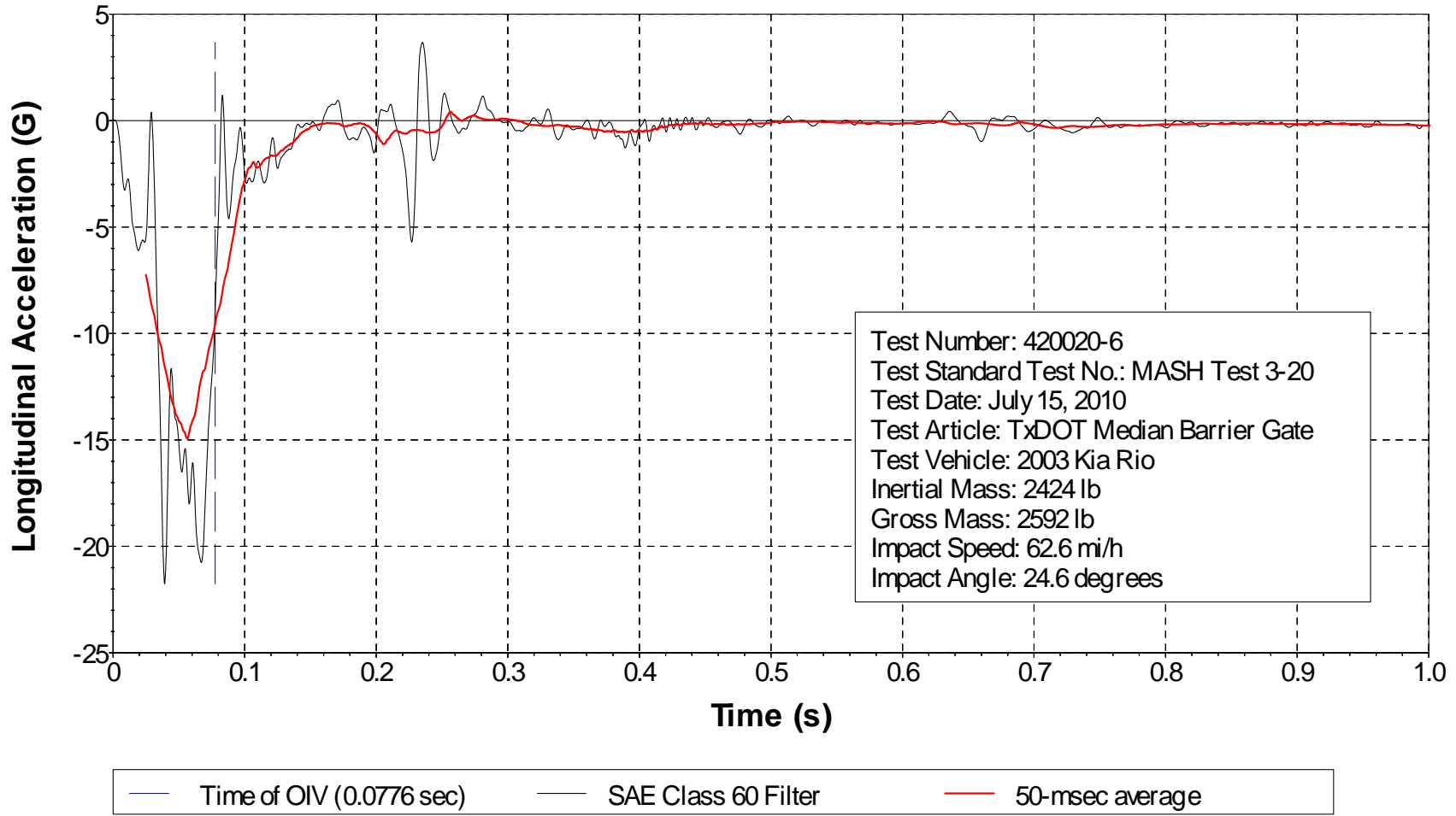


Figure E2. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-6 (Accelerometer Located at Center of Gravity).

Y Acceleration at CG

611

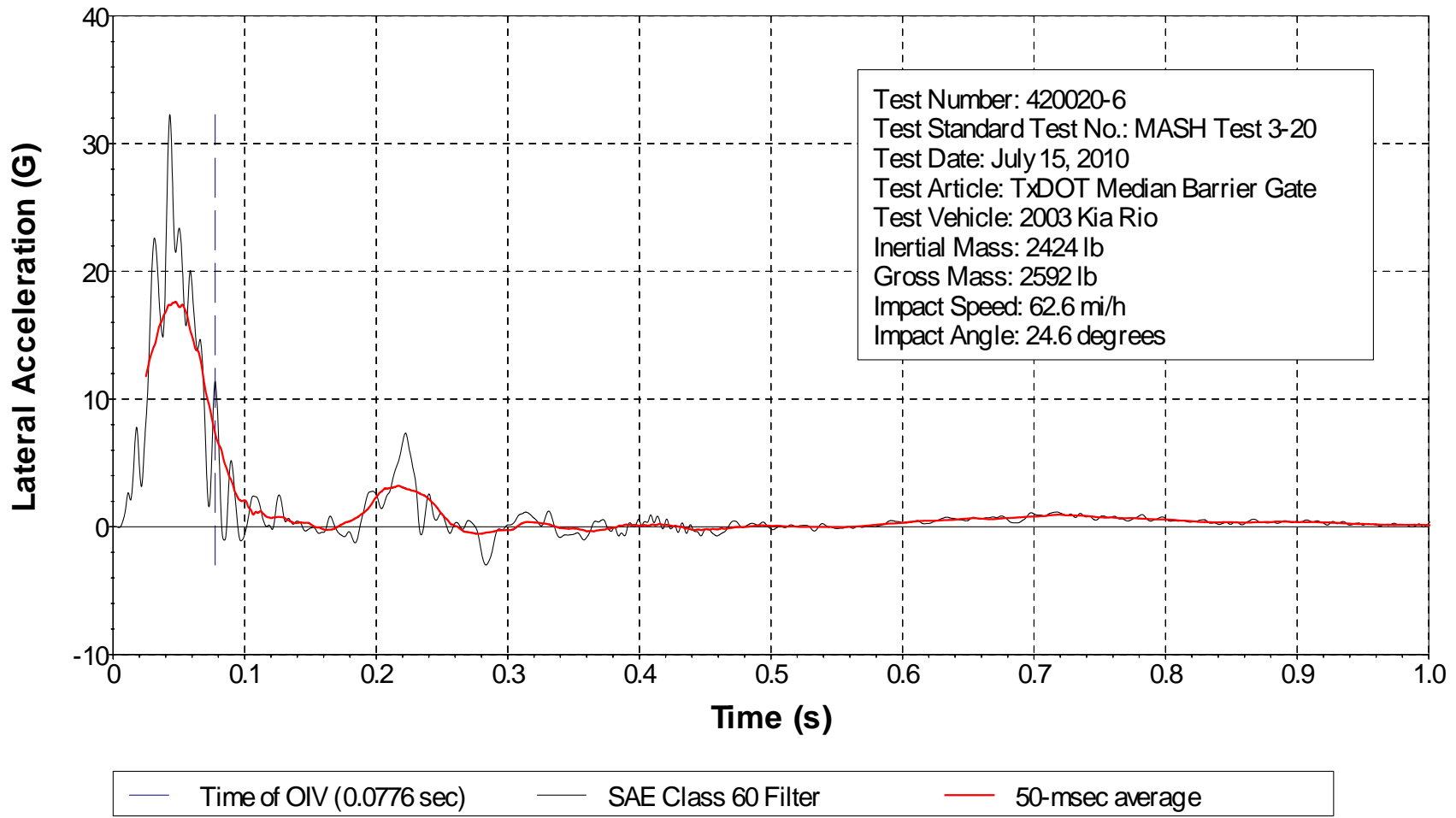
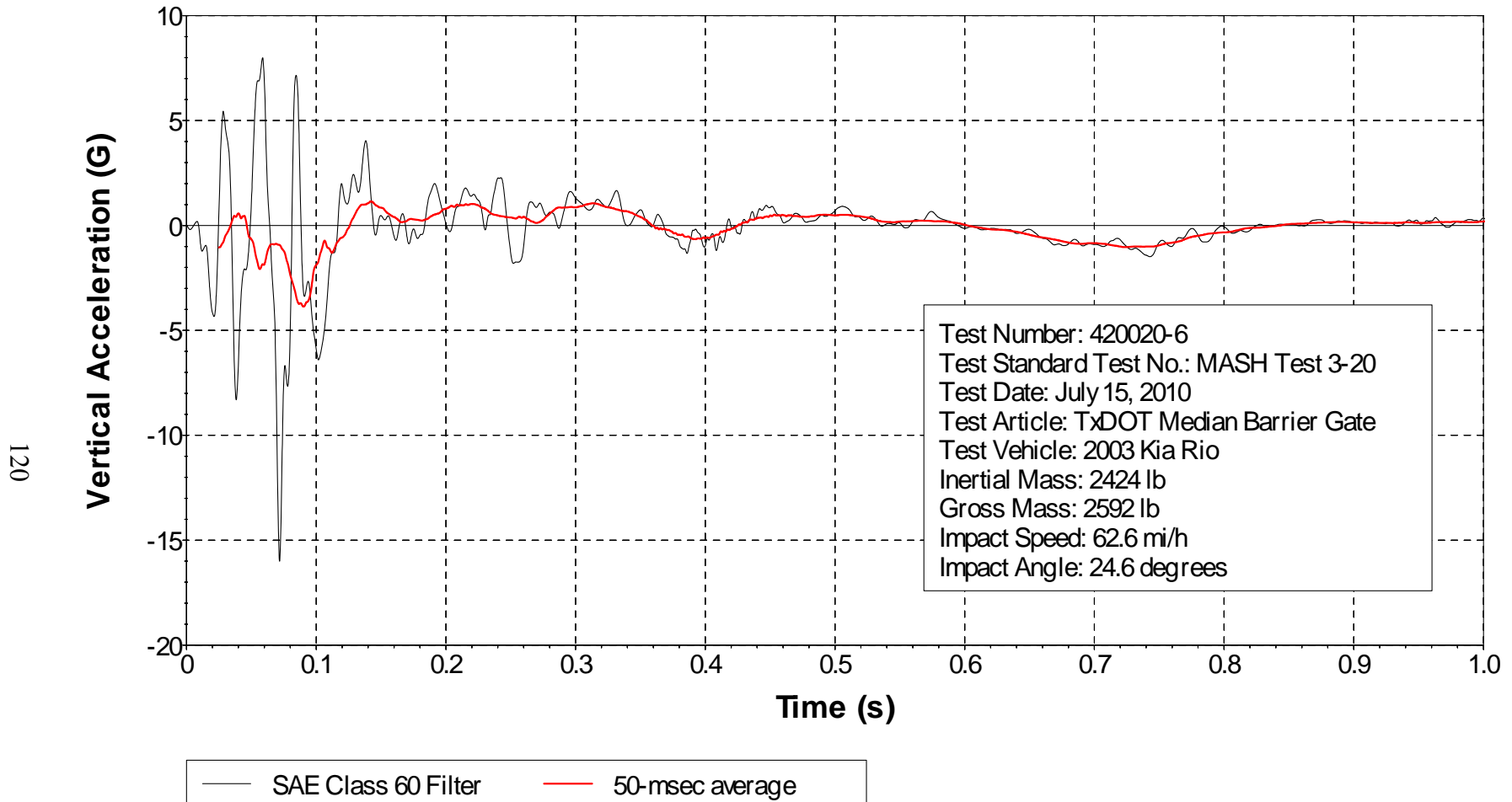


Figure E3. Vehicle Lateral Accelerometer Trace for Test No. 420020-6 (Accelerometer Located at Center of Gravity).

Z Acceleration at CG



**Figure E4. Vehicle Vertical Accelerometer Trace for Test No. 420020-6
(Accelerometer Located at Center of Gravity).**

X Acceleration over Rear Axle

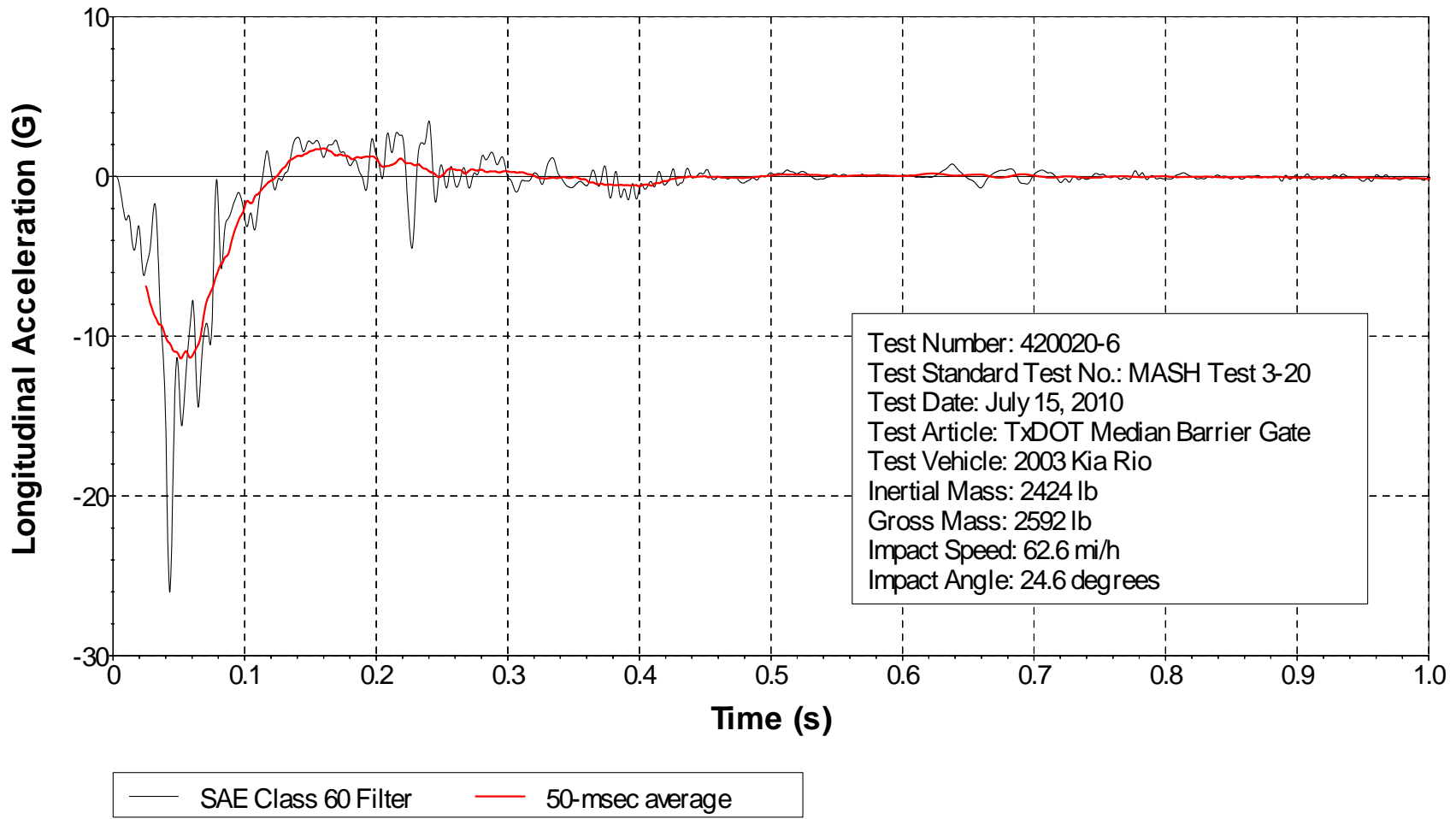
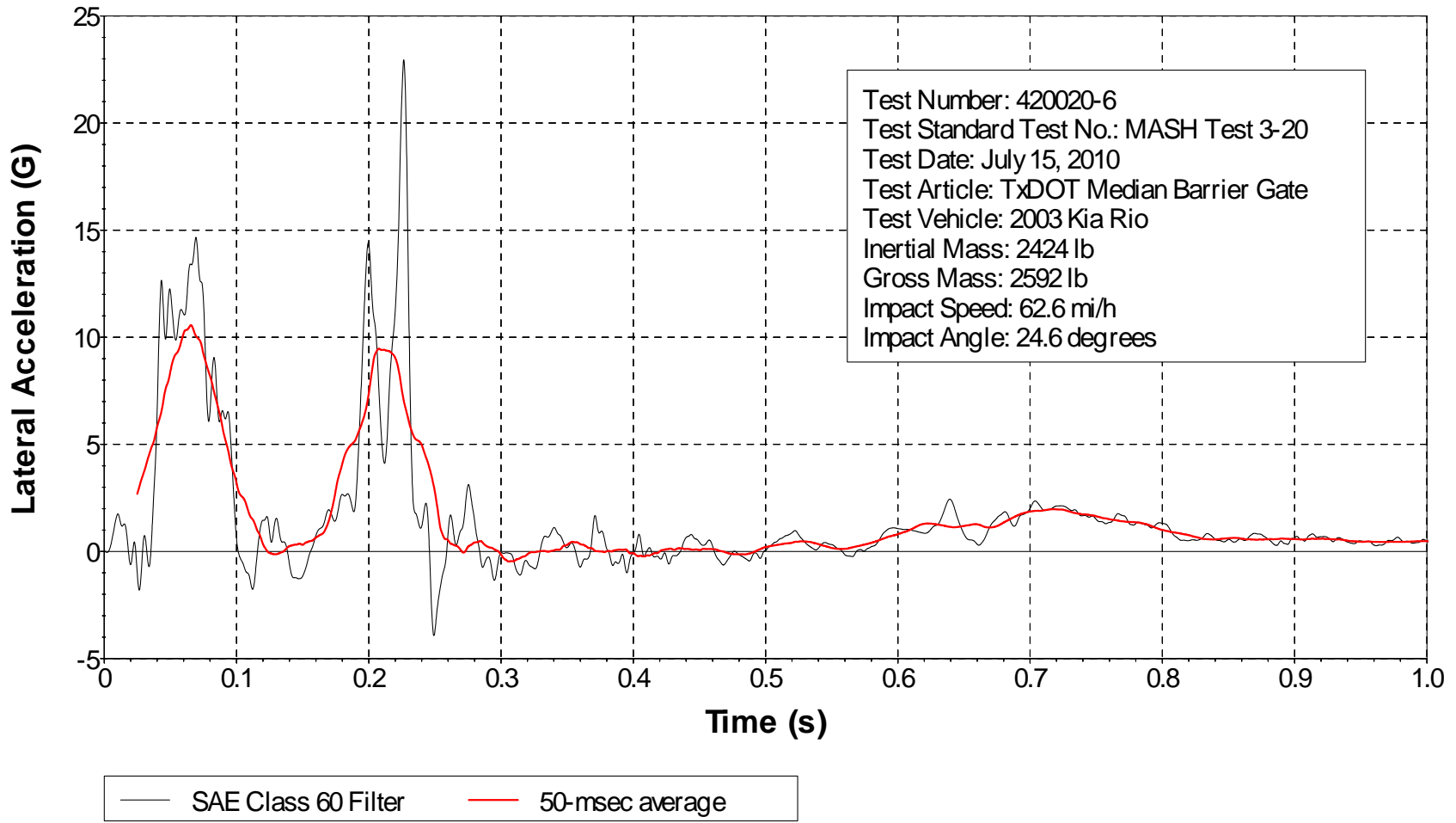


Figure E5. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-6 (Accelerometer Located over Rear Axle).

Y Acceleration over Rear Axle

122



**Figure E6. Vehicle Lateral Accelerometer Trace for Test No. 420020-6
(Accelerometer Located over Rear Axle).**

Z Acceleration over Rear Axle

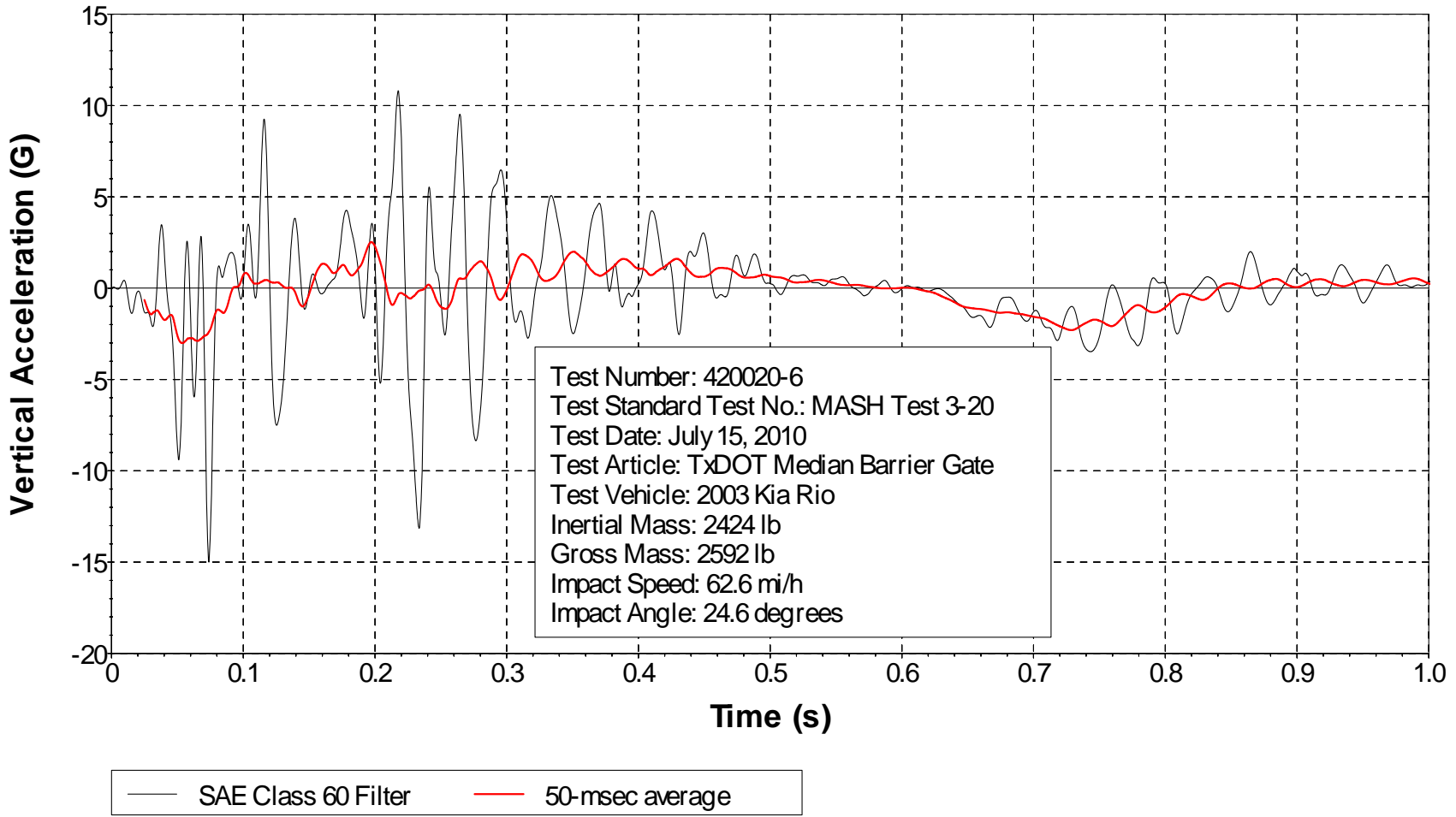


Figure E7. Vehicle Vertical Accelerometer Trace for Test No. 420020-6 (Accelerometer Located over Rear Axle).

Roll, Pitch, and Yaw Angles

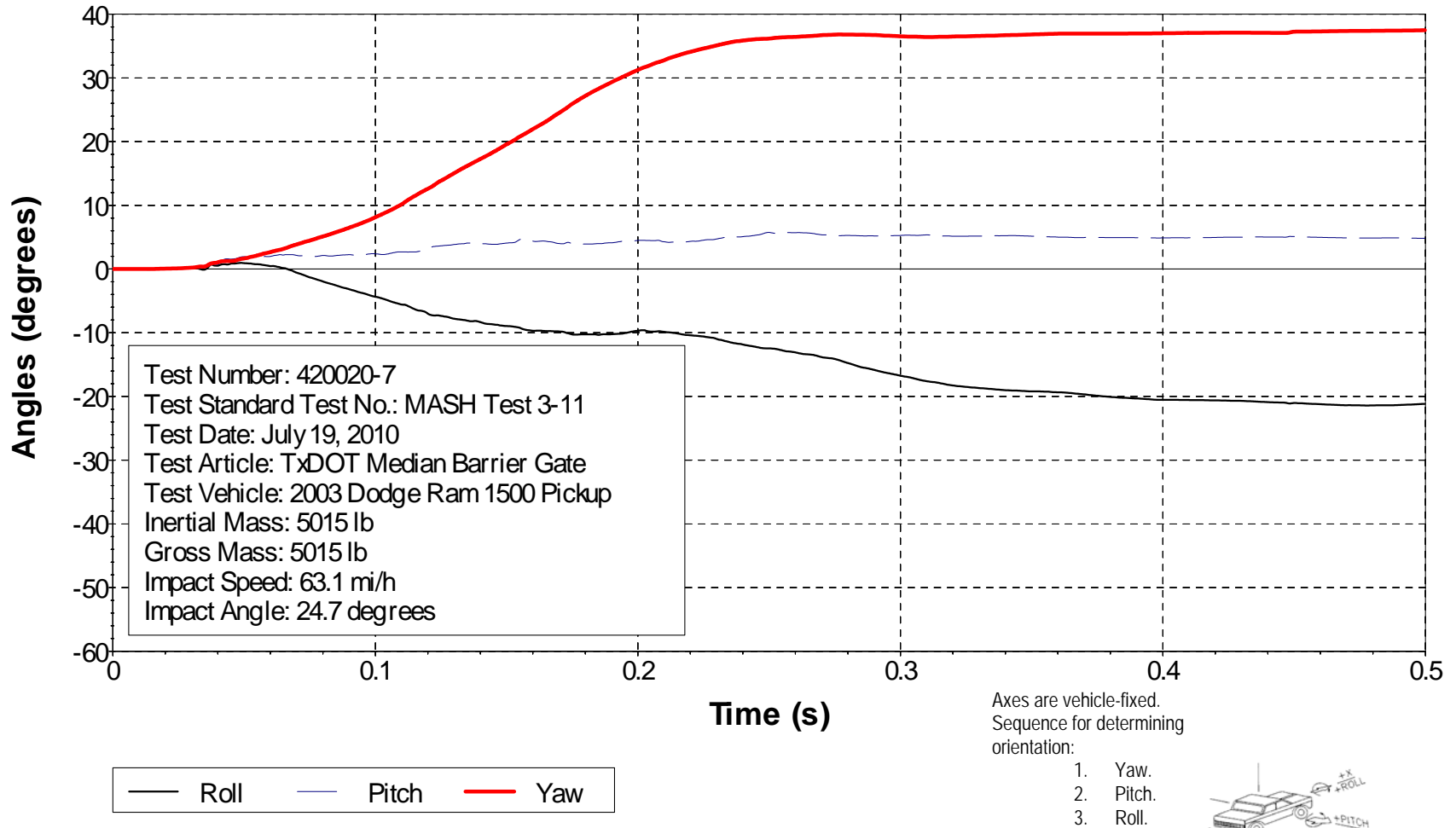


Figure E8. Vehicle Angular Displacements for Test No. 420020-7.

X Acceleration at CG

125

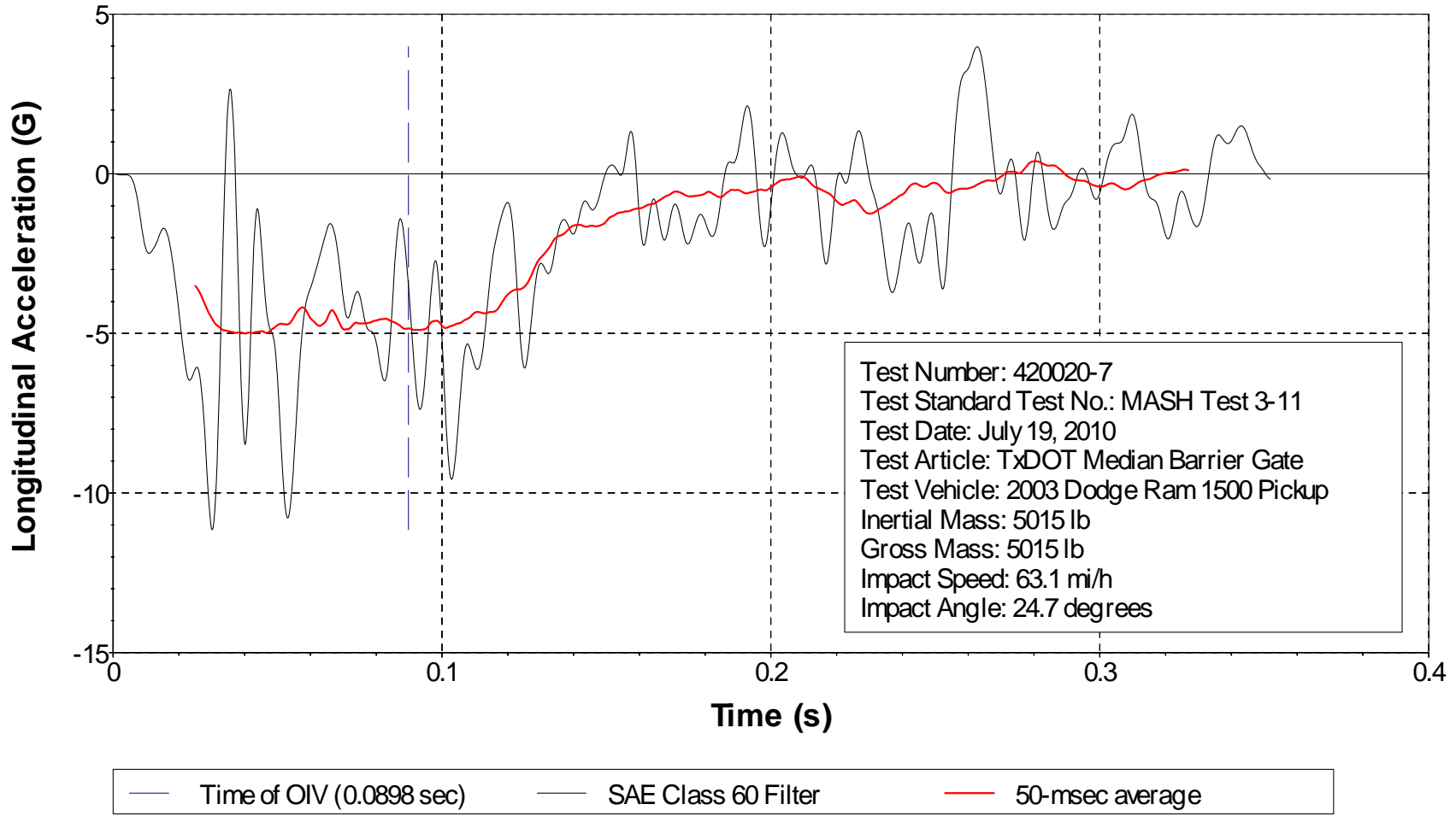
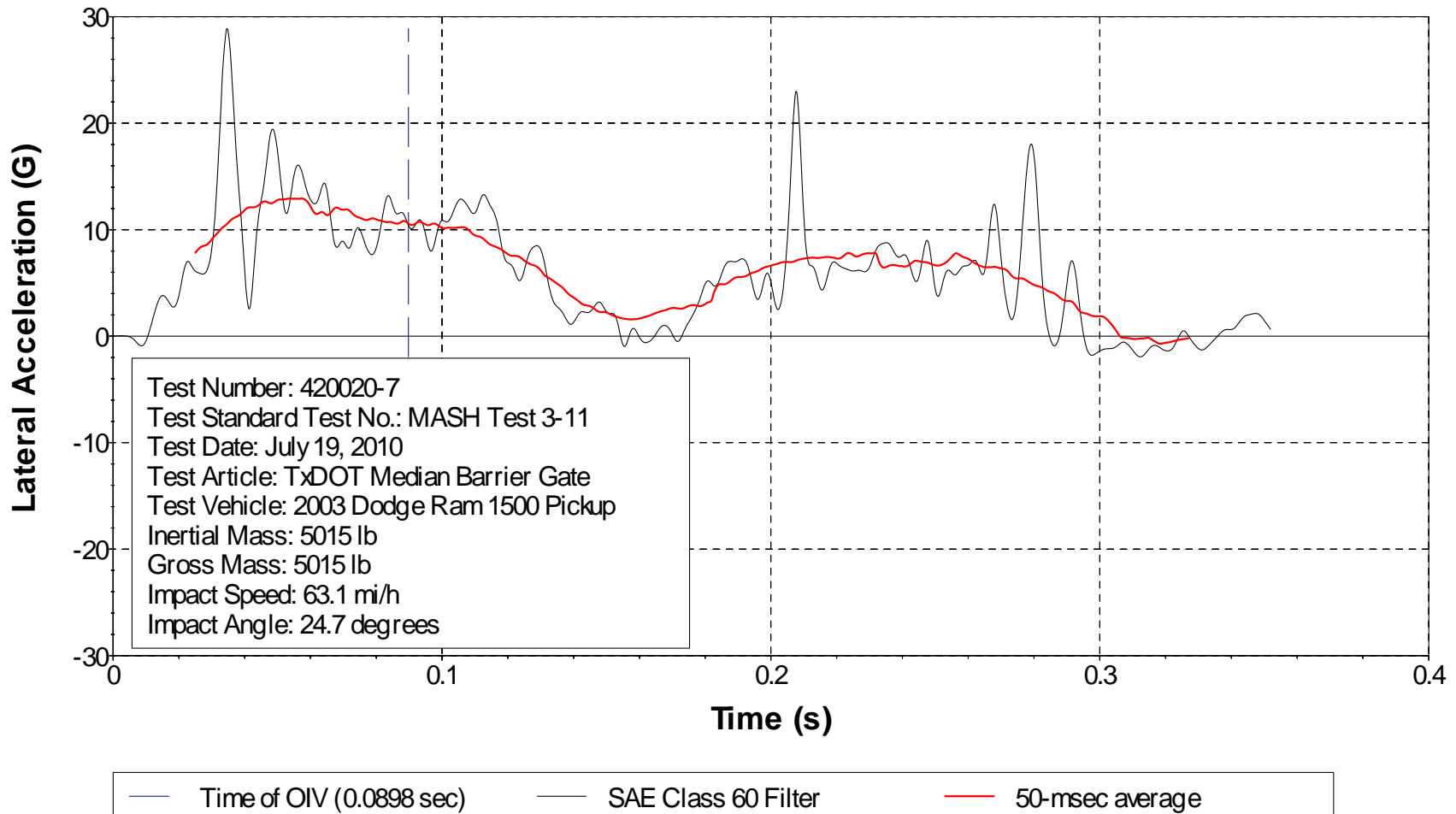


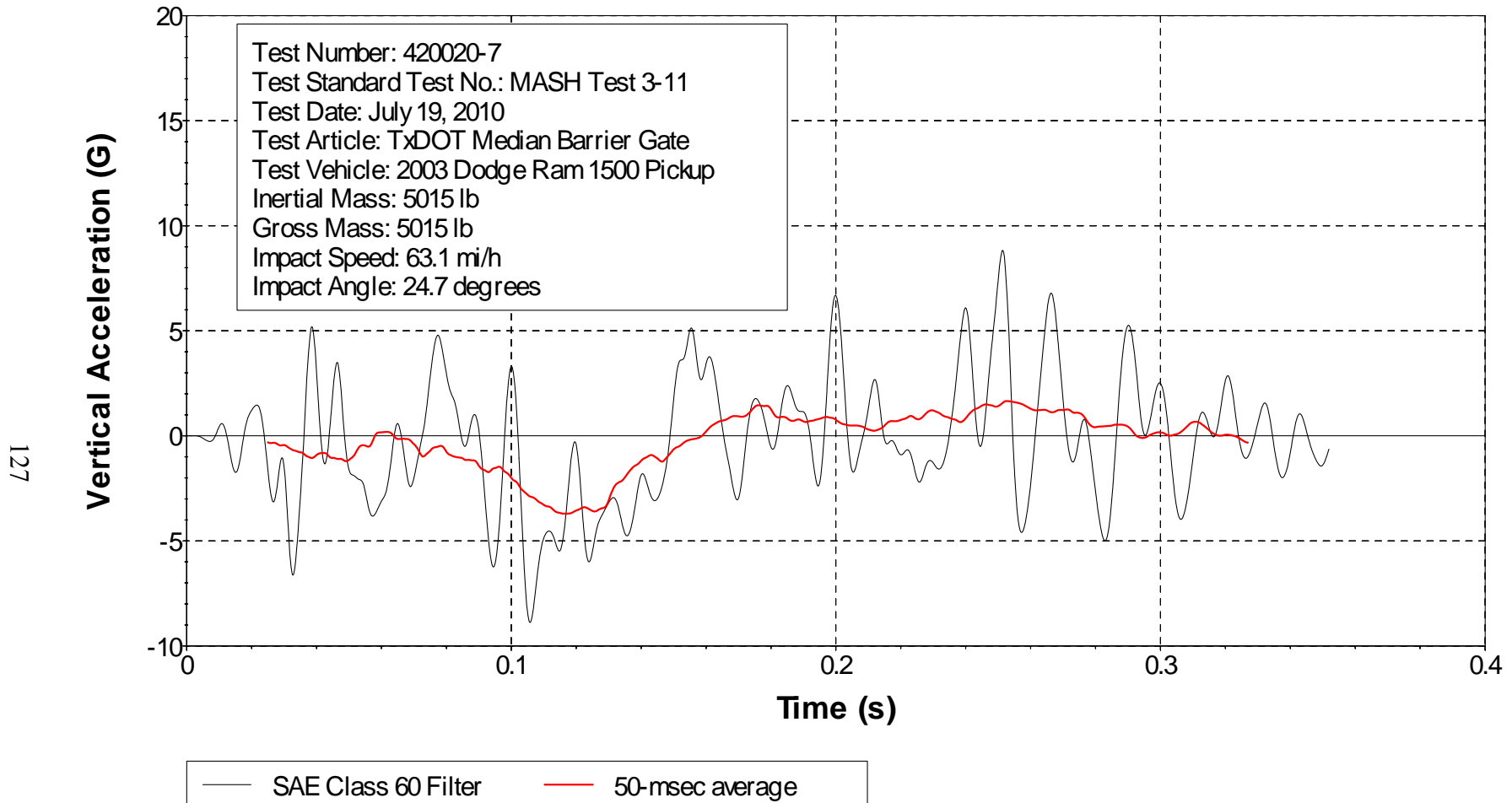
Figure E9. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-7 (Accelerometer Located at Center of Gravity).

Y Acceleration at CG



**Figure E10. Vehicle Lateral Accelerometer Trace for Test No. 420020-7
(Accelerometer Located at Center of Gravity).**

Z Acceleration at CG



**Figure E11. Vehicle Vertical Accelerometer Trace for Test No. 420020-7
(Accelerometer Located at Center of Gravity).**

X Acceleration over Rear Axle

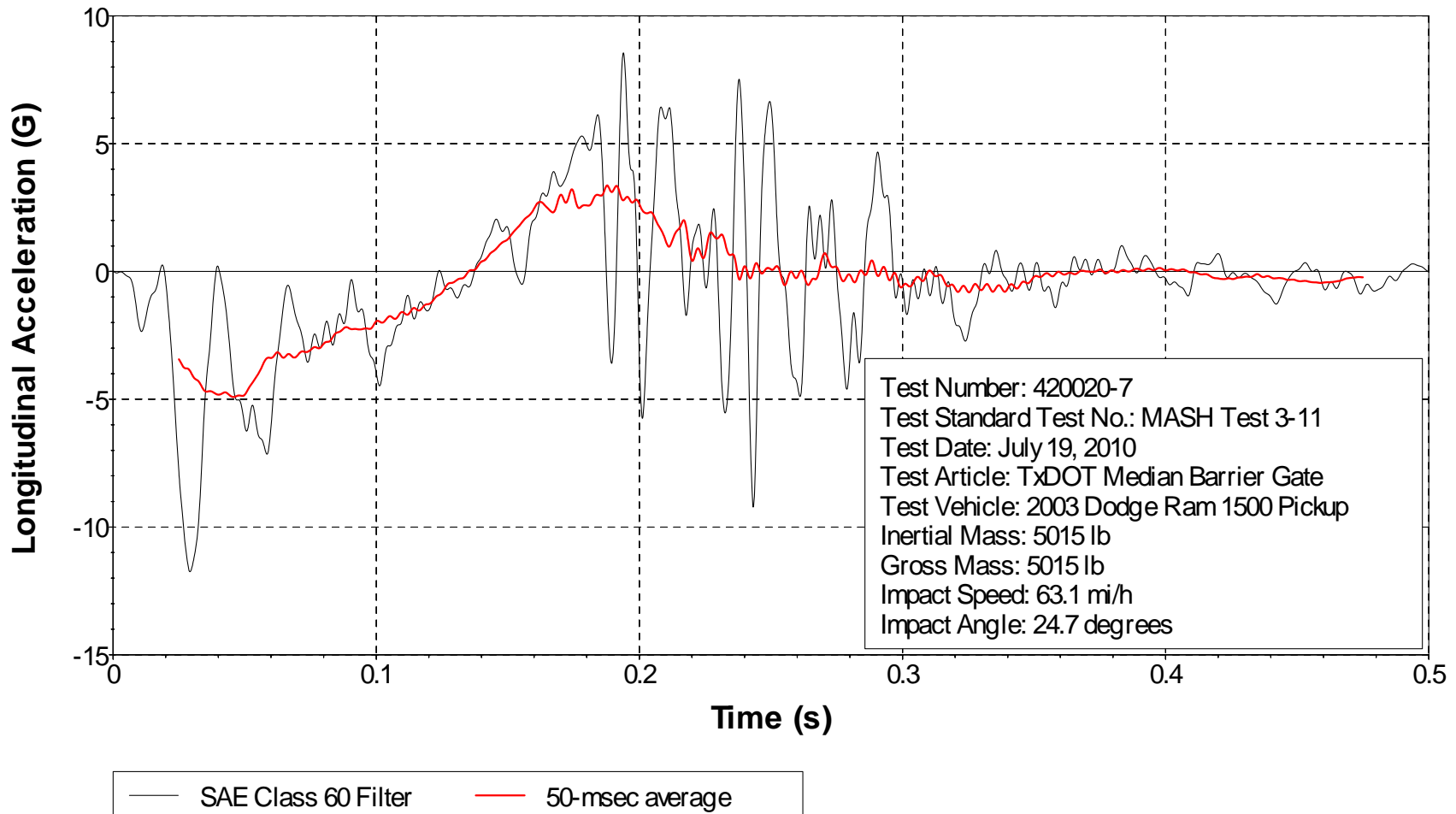
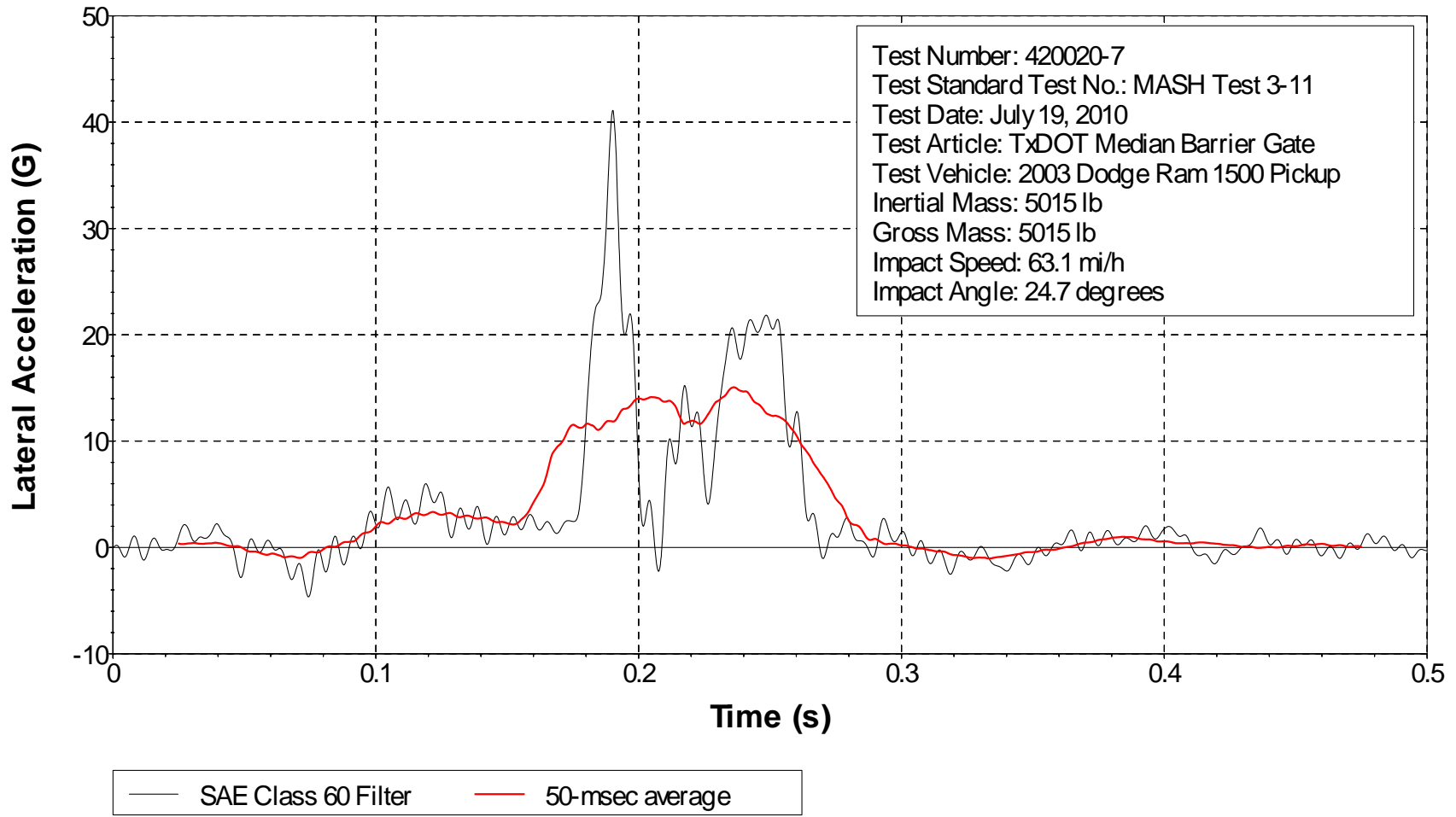


Figure E12. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-7 (Accelerometer Located over Rear Axle).

Y Acceleration over Rear Axle

129



**Figure E13. Vehicle Lateral Accelerometer Trace for Test No. 420020-7
(Accelerometer Located over Rear Axle).**

Z Acceleration over Rear Axle

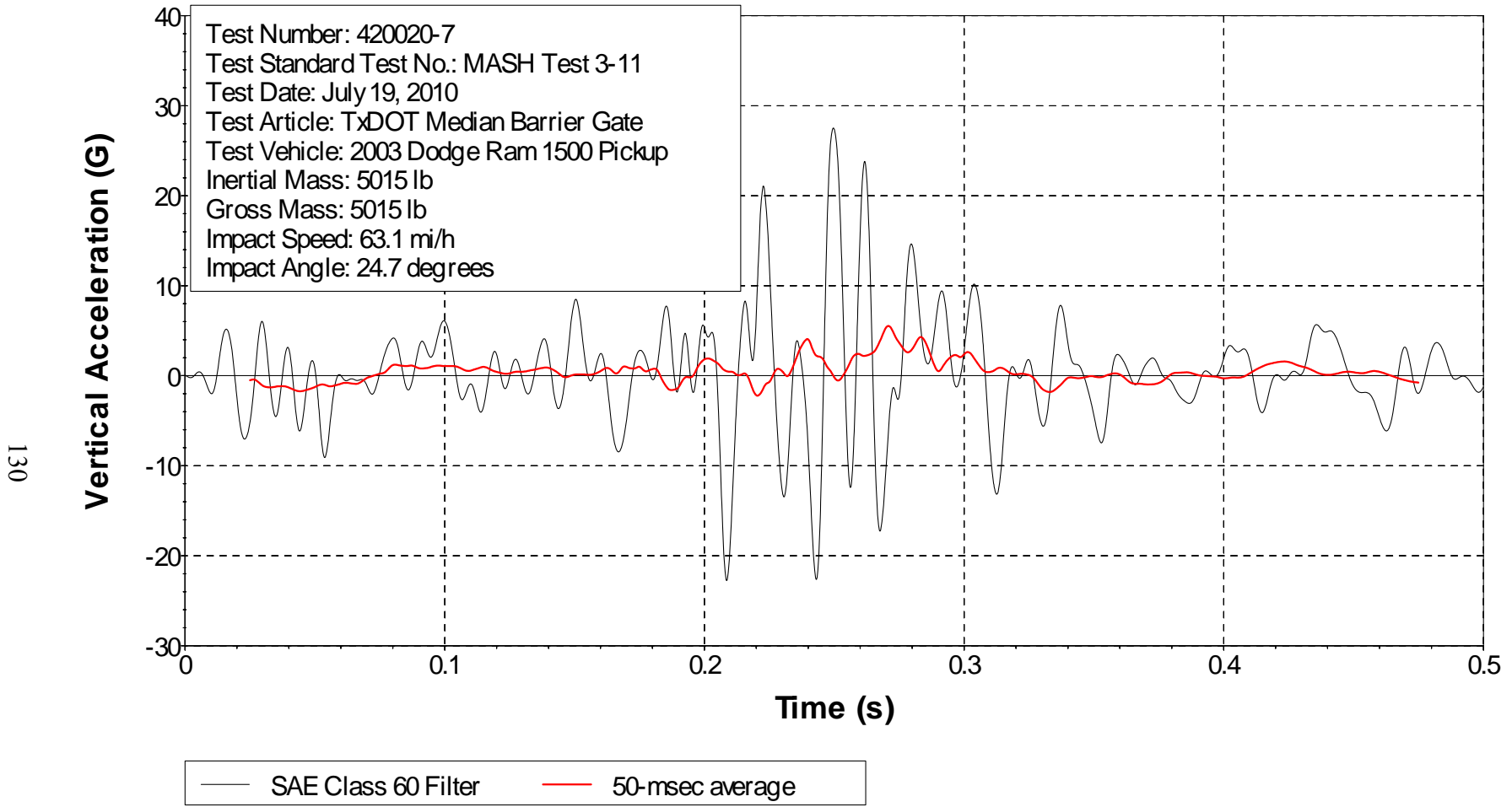


Figure E14. Vehicle Vertical Accelerometer Trace for Test No. 420020-7 (Accelerometer Located over Rear Axle).

Roll, Pitch, and Yaw Angles

131

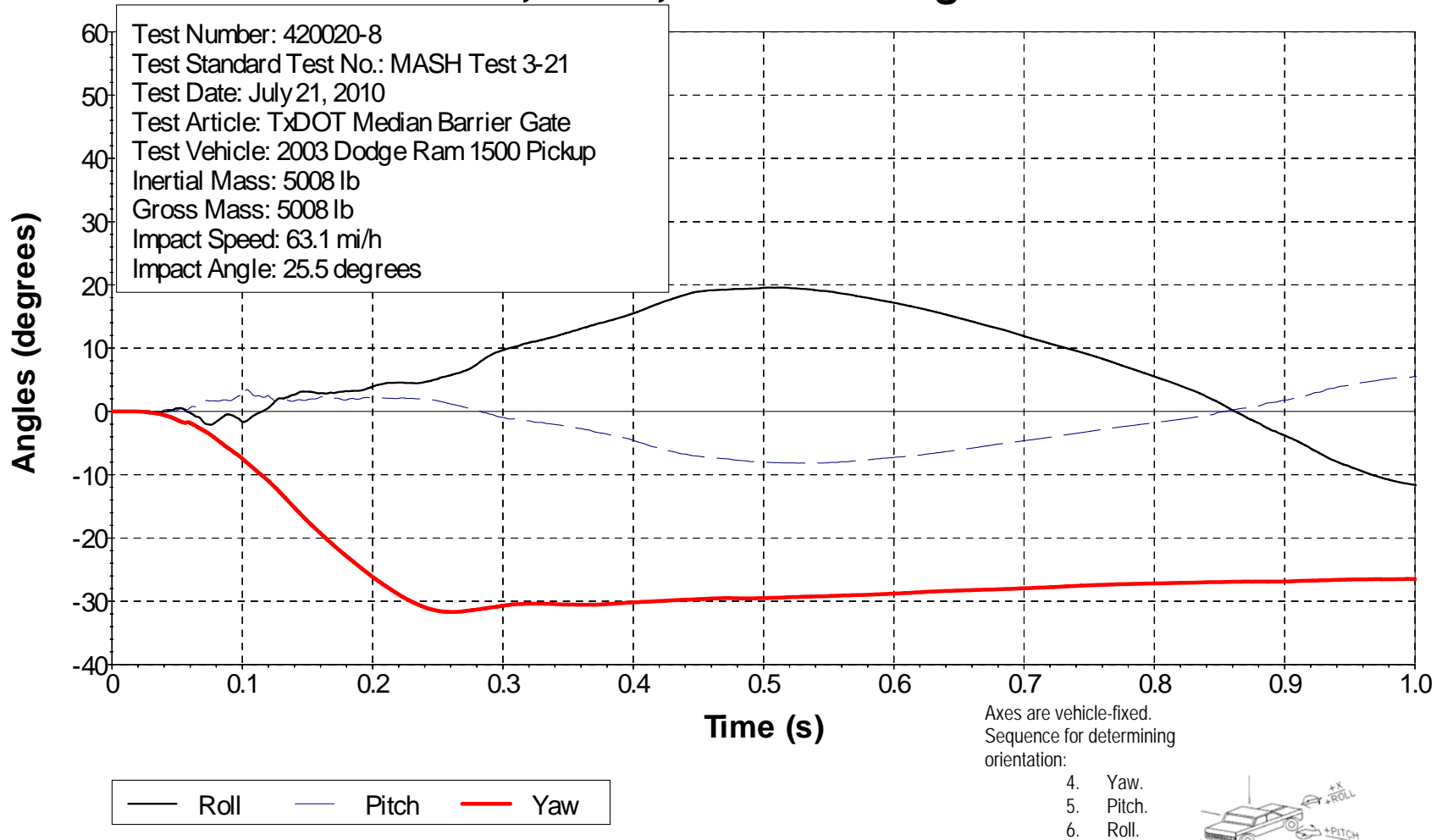
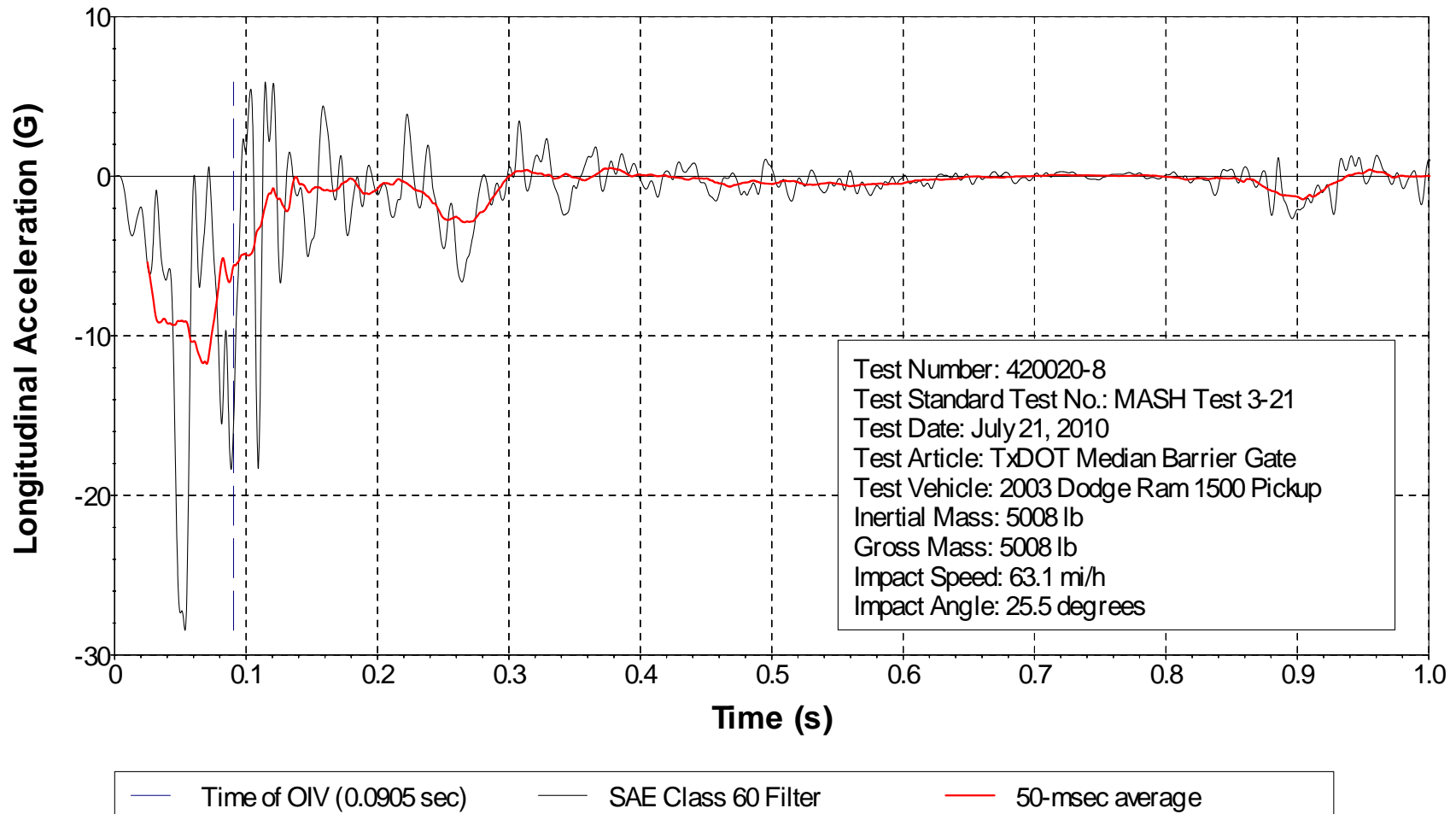


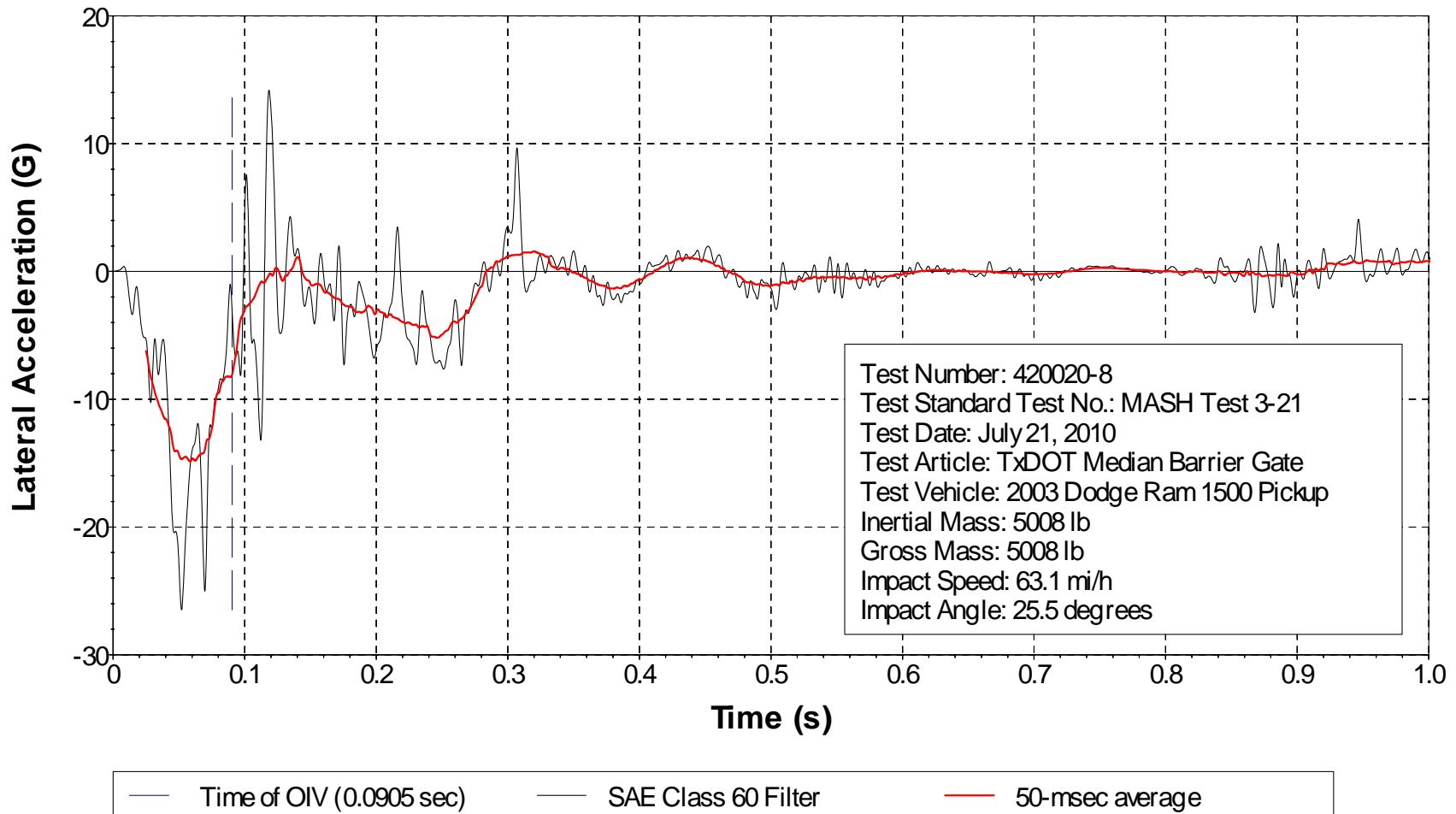
Figure E15. Vehicle Angular Displacements for Test No. 420020-8.

X Acceleration at CG



**Figure E16. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-8
(Accelerometer Located at Center of Gravity).**

Y Acceleration at CG



**Figure E17. Vehicle Lateral Accelerometer Trace for Test No. 420020-8
(Accelerometer Located at Center of Gravity).**

Z Acceleration at CG

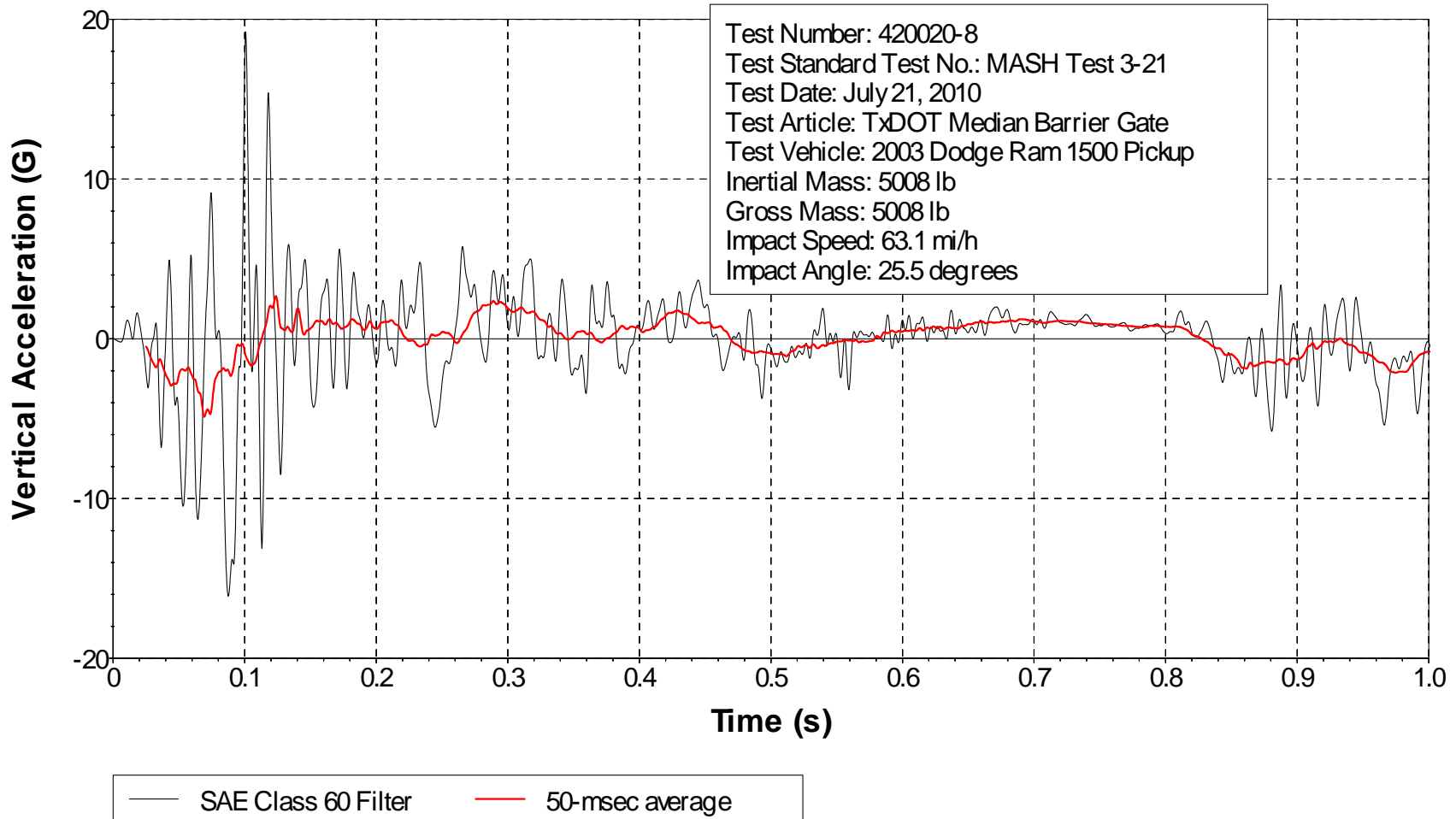


Figure E18. Vehicle Vertical Accelerometer Trace for Test No. 420020-8 (Accelerometer Located at Center of Gravity).

X Acceleration over Rear Axle

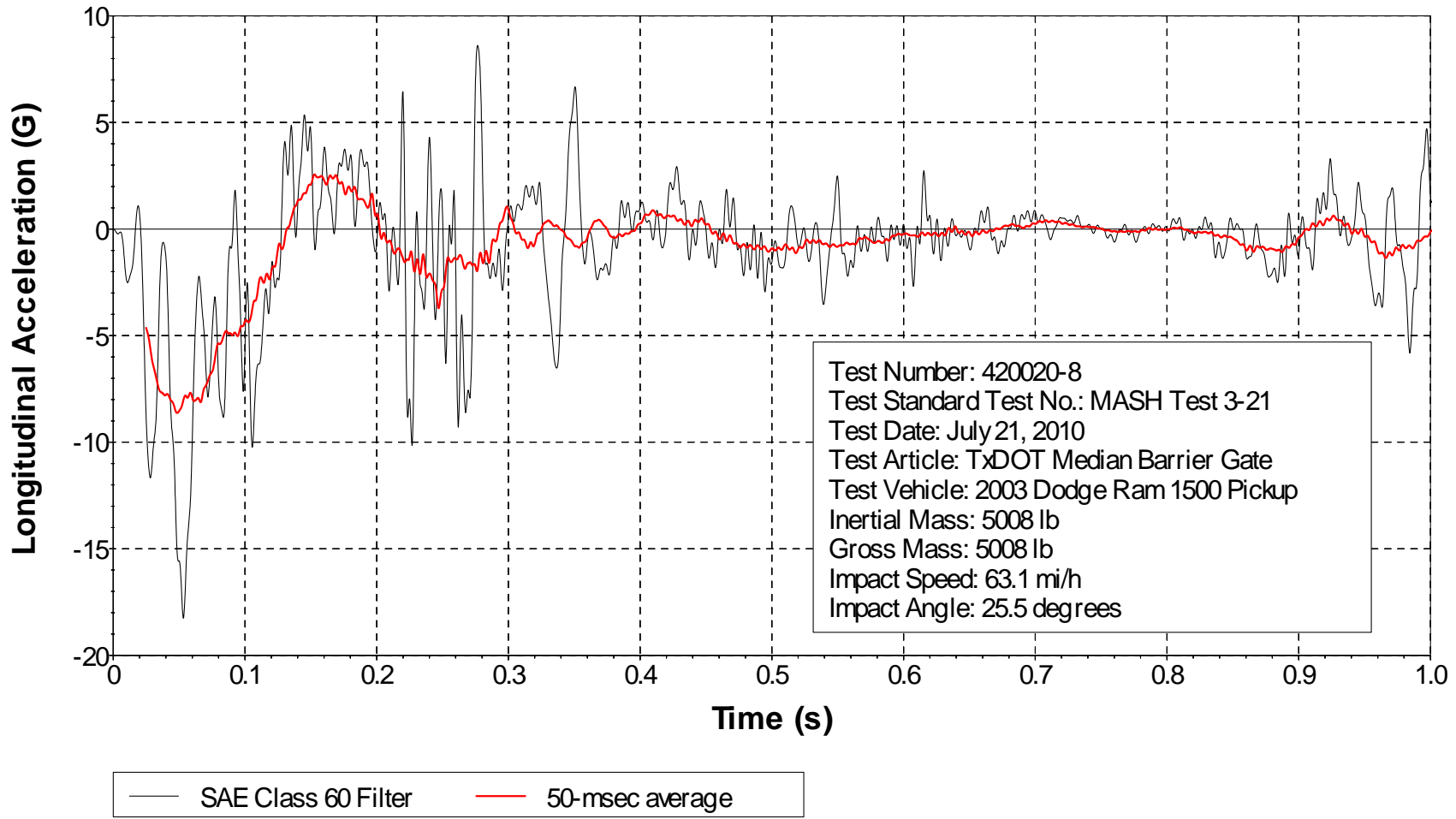
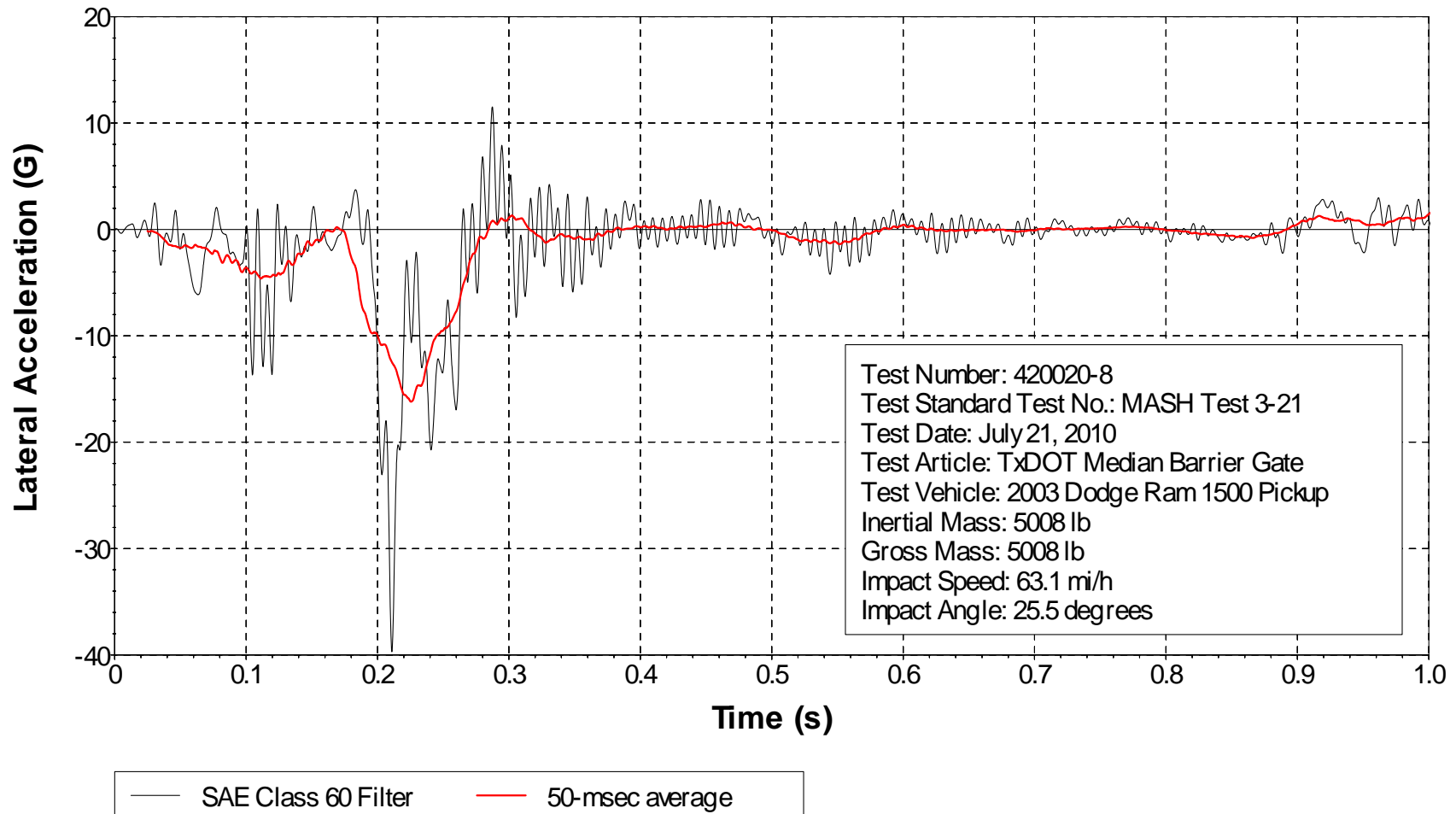


Figure E19. Vehicle Longitudinal Accelerometer Trace for Test No. 420020-8 (Accelerometer Located over Rear Axle).

Y Acceleration over Rear Axle



**Figure E20. Vehicle Lateral Accelerometer Trace for Test No. 420020-8
(Accelerometer Located over Rear Axle).**

Z Acceleration over Rear Axle

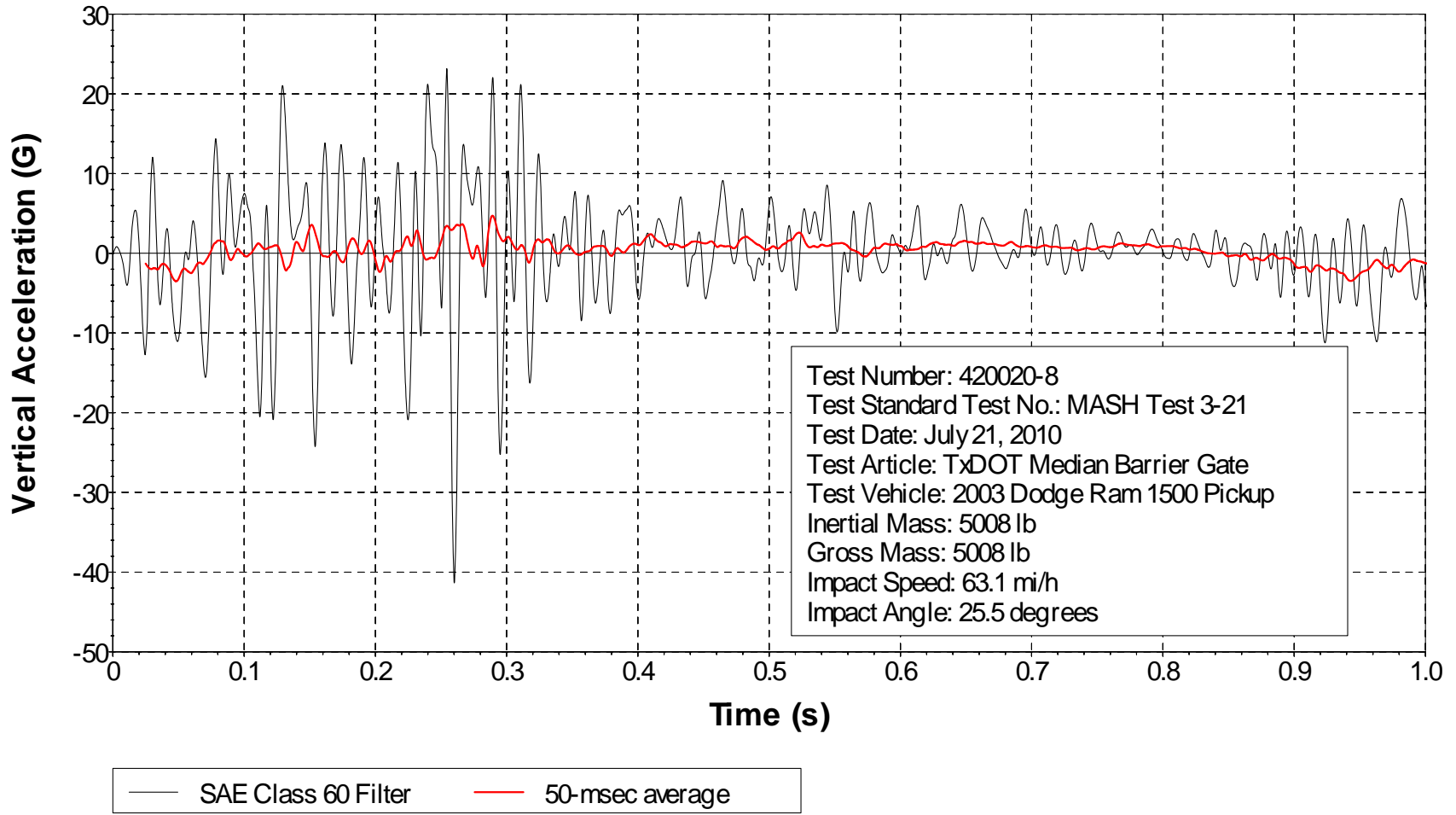
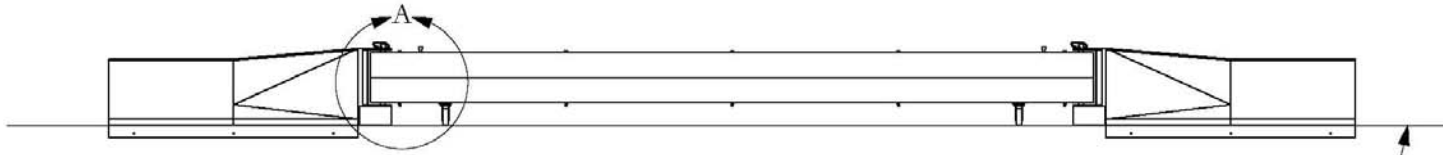
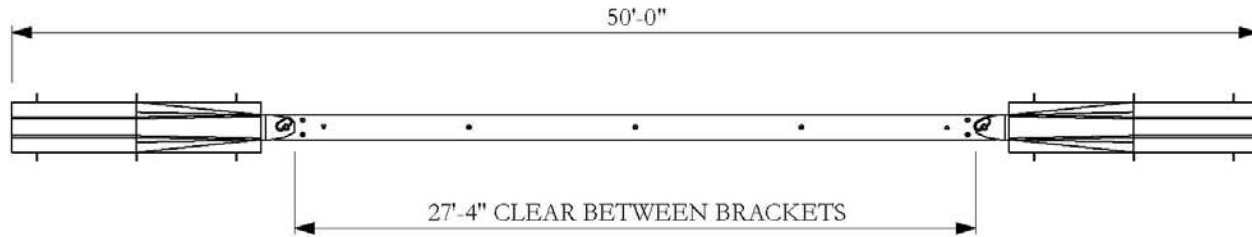


Figure E21. Vehicle Vertical Accelerometer Trace for Test No. 420020-8 (Accelerometer Located over Rear Axle).

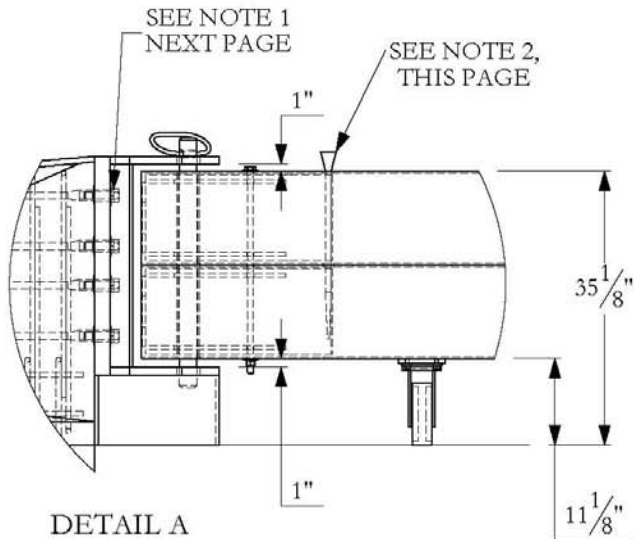


ELEVATION VIEW

GROUND LINE



PLAN VIEW



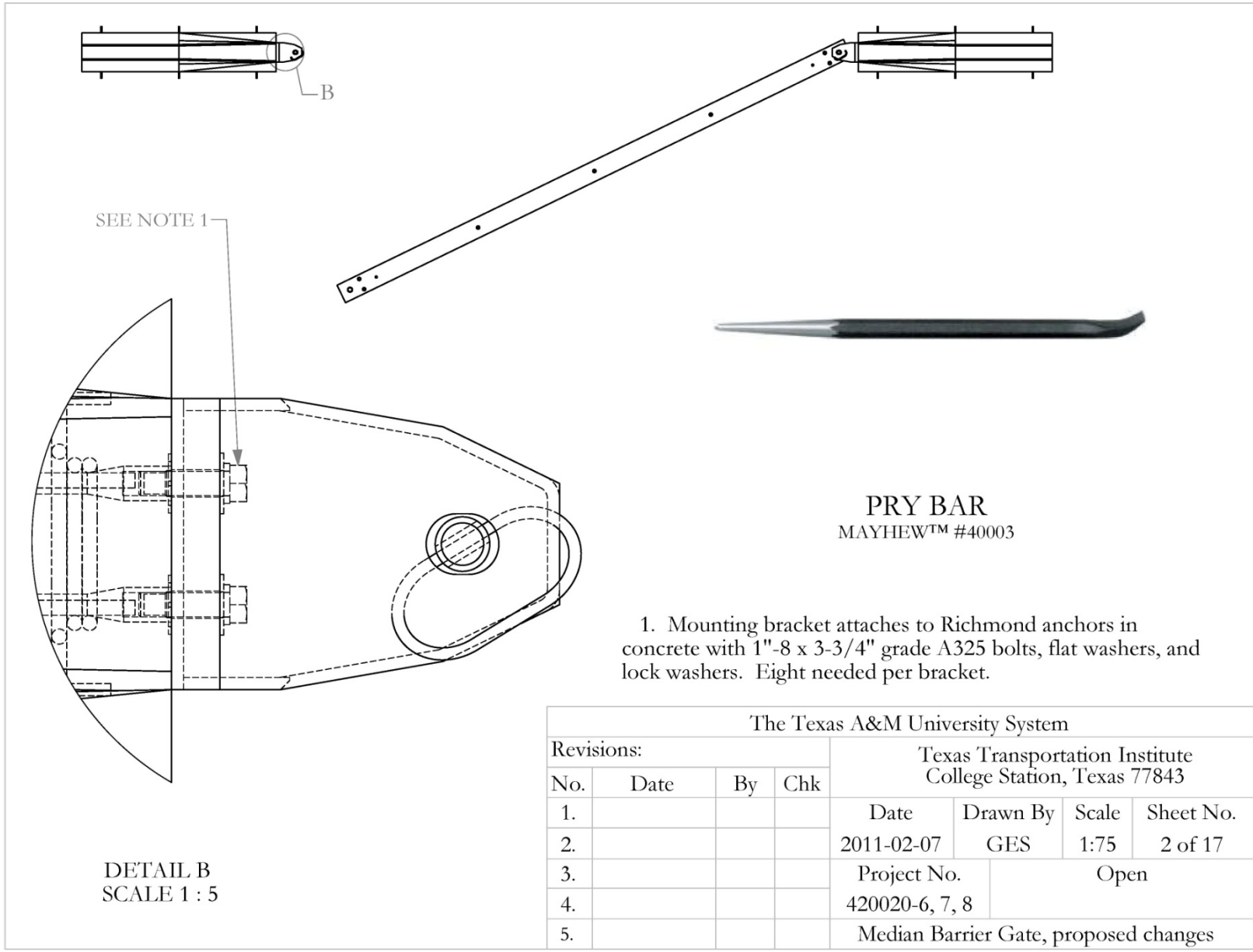
DETAIL A
SCALE 1 : 20

1. Concrete shall be 3600 psi.
2. Prybar may be needed to relieve bearing pressure on pin if gate is shifted to one side. Prybar is Mayhew™ Tools 40003 - Line-Up Pry Bar - 472 (24") or equivalent. See next page for image.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:75	1 of 17
2.				Project No.		Full Installation	
3.				420020-6, 7, 8			
4.				Median Barrier Gate, proposed changes			
5.							
Approved: Roger Bligh: _____				Signature: _____		Date: _____	

T:\2009-2010\420020 TR&DOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed

APPENDIX F. RECOMMENDED MEDIAN BARRIER GATE DETAILS



PRY BAR
MAYHEW™ #40003

1. Mounting bracket attaches to Richmond anchors in concrete with 1"-8 x 3-3/4" grade A325 bolts, flat washers, and lock washers. Eight needed per bracket.

The Texas A&M University System

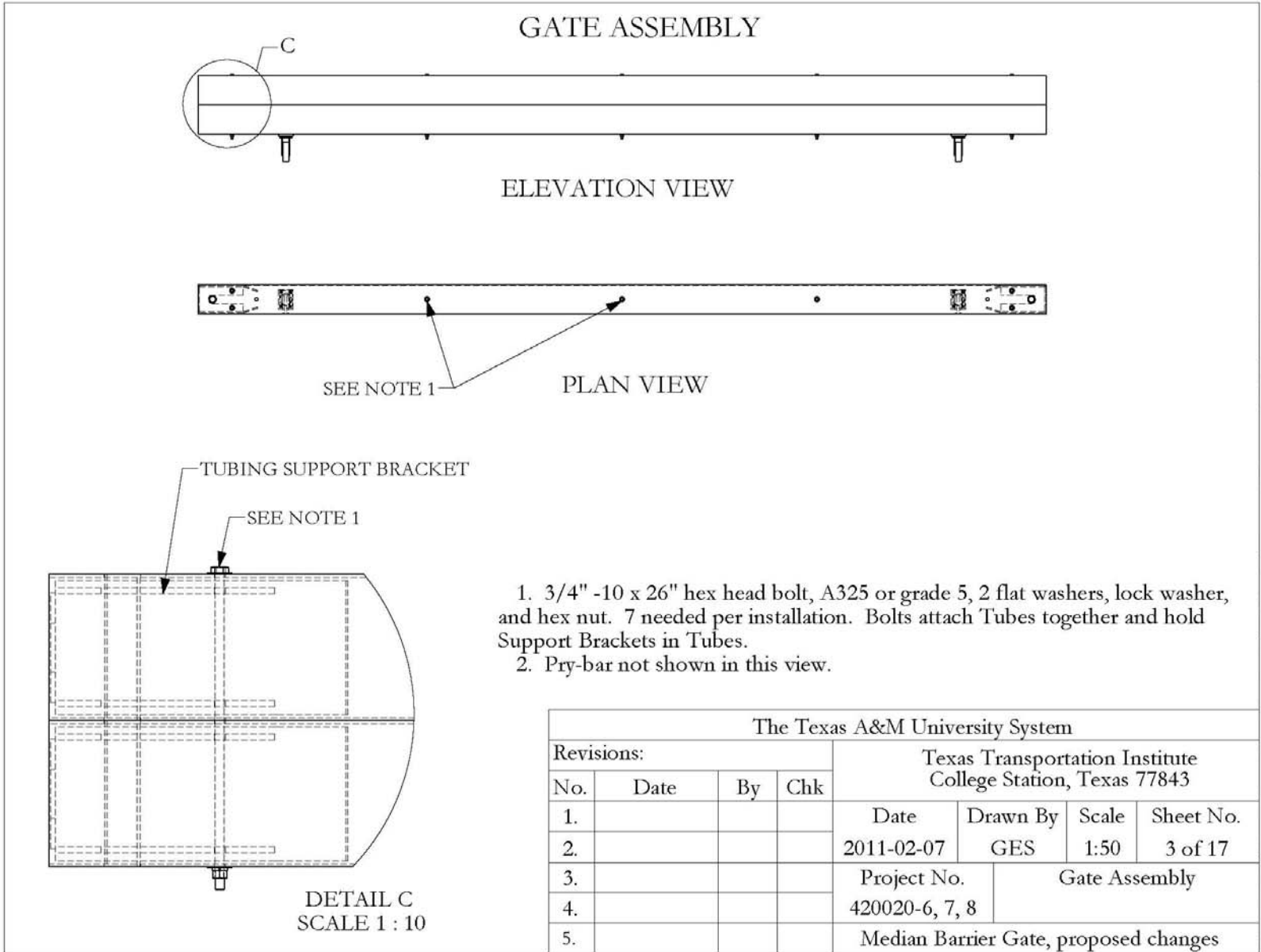
Revisions:

No.	Date	By	Chk
1.			
2.			
3.			
4.			
5.			

Texas Transportation Institute
College Station, Texas 77843

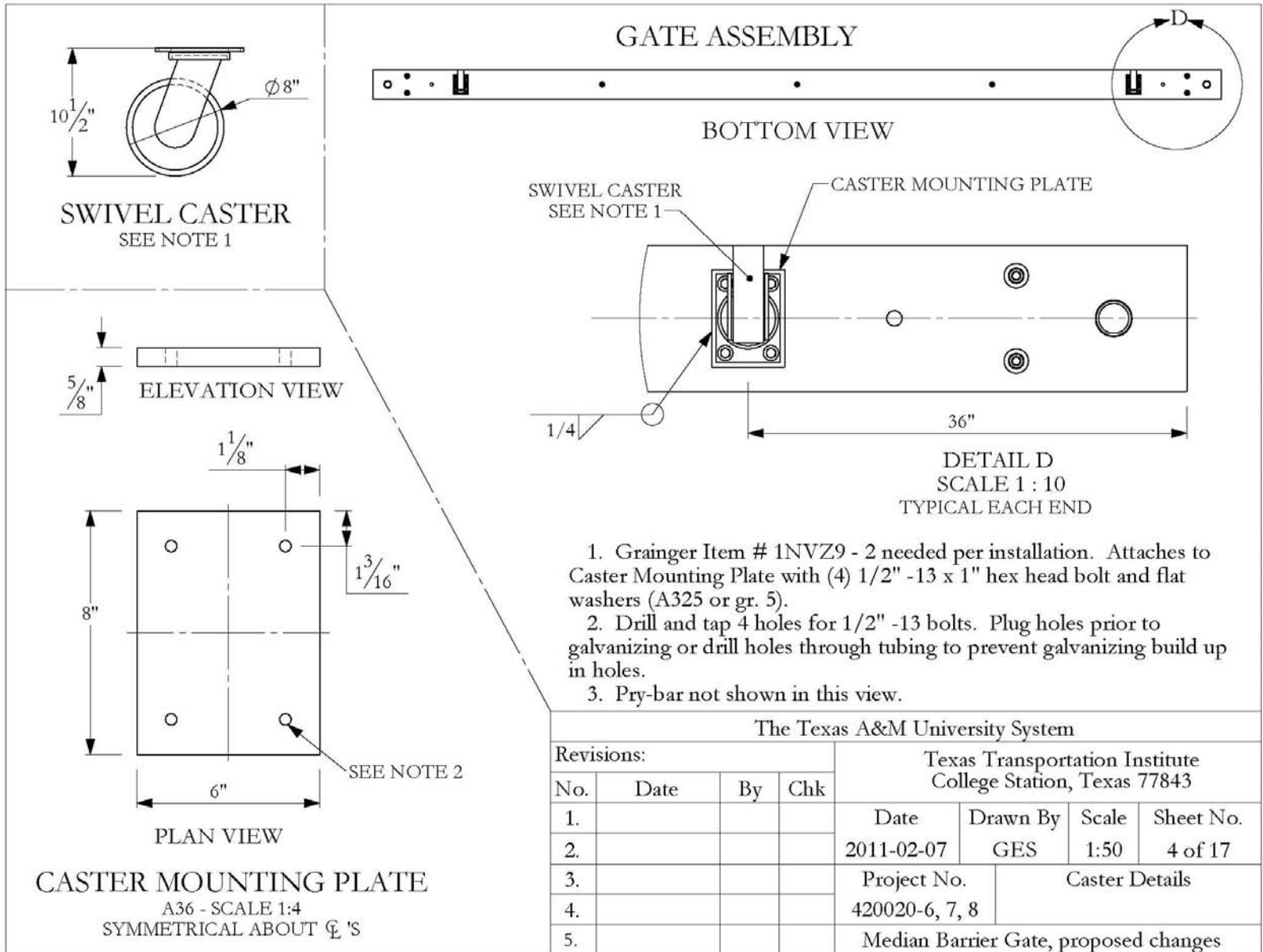
Date	Drawn By	Scale	Sheet No.
2011-02-07	GES	1:75	2 of 17
Project No.		Open	
420020-6, 7, 8			
Median Barrier Gate, proposed changes			

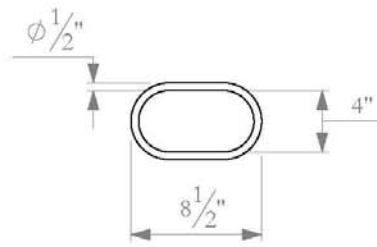
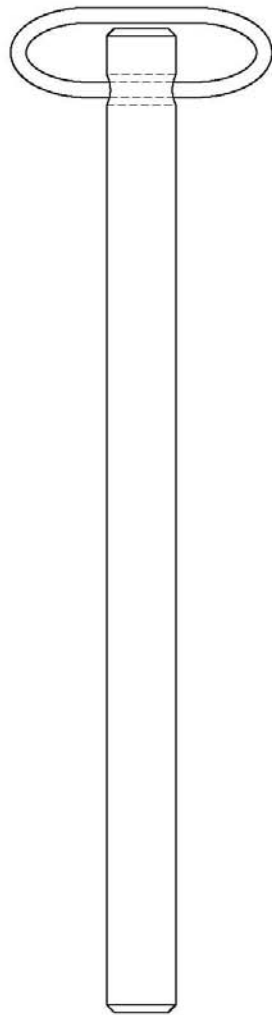
DETAIL B
SCALE 1 : 5



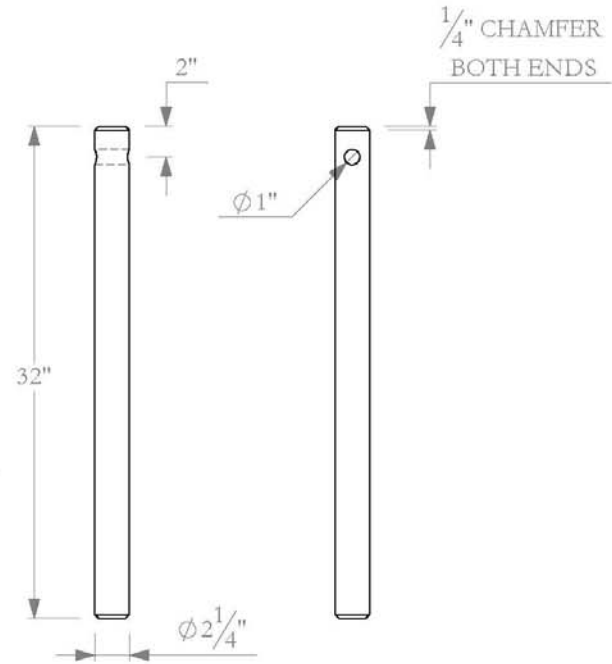
1. 3/4" -10 x 26" hex head bolt, A325 or grade 5, 2 flat washers, lock washer, and hex nut. 7 needed per installation. Bolts attach Tubes together and hold Support Brackets in Tubes.
2. Pry-bar not shown in this view.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:50	3 of 17
3.				Project No.		Gate Assembly	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			





HANDLE
A36

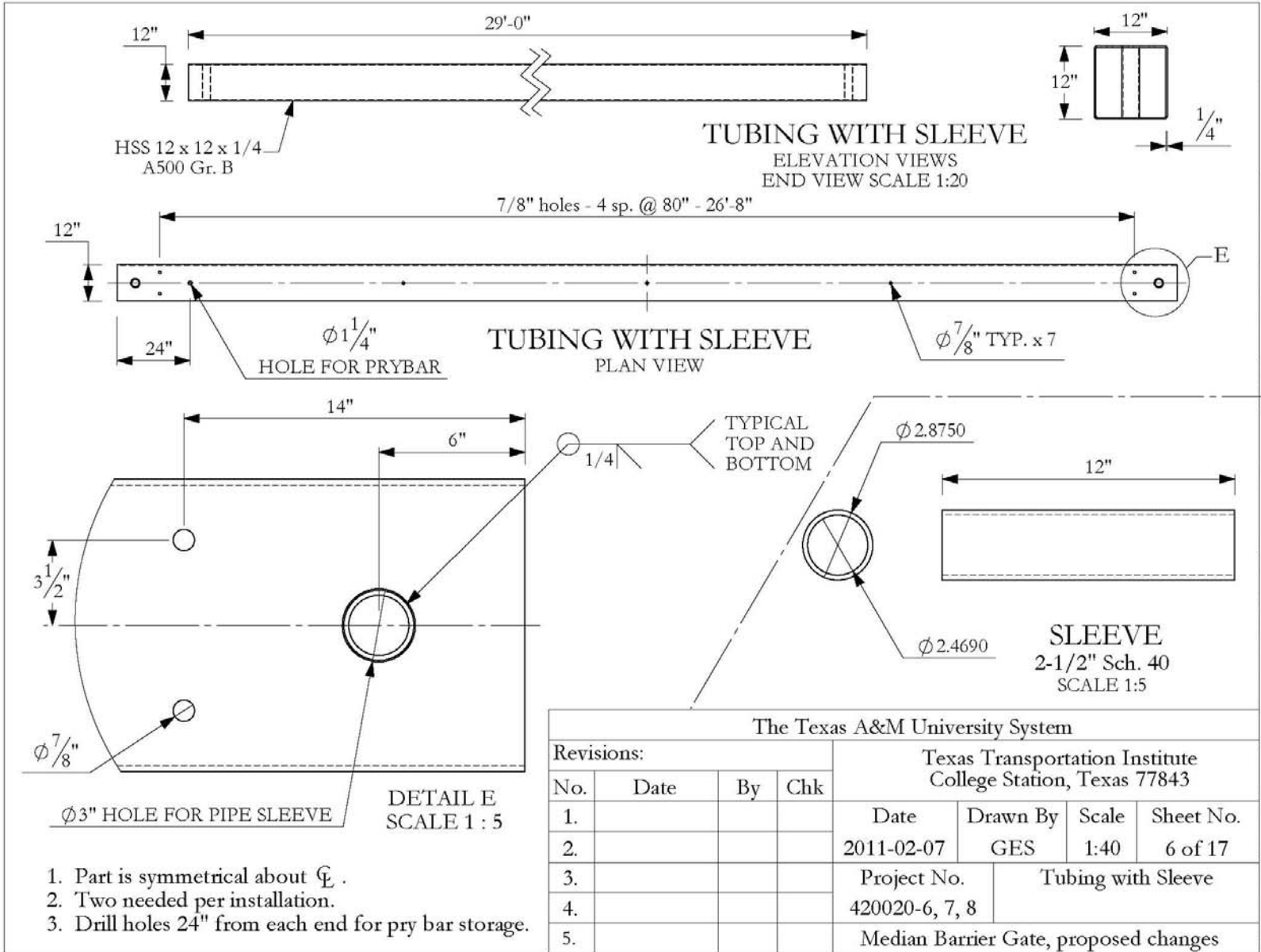


PIN
A36 HOT ROLLED

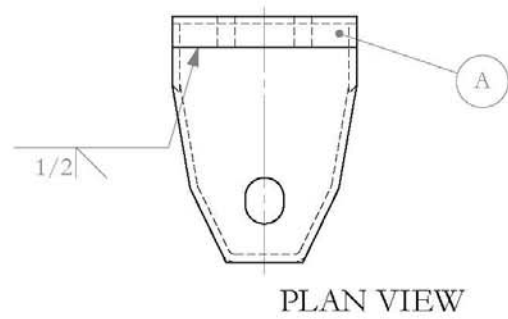
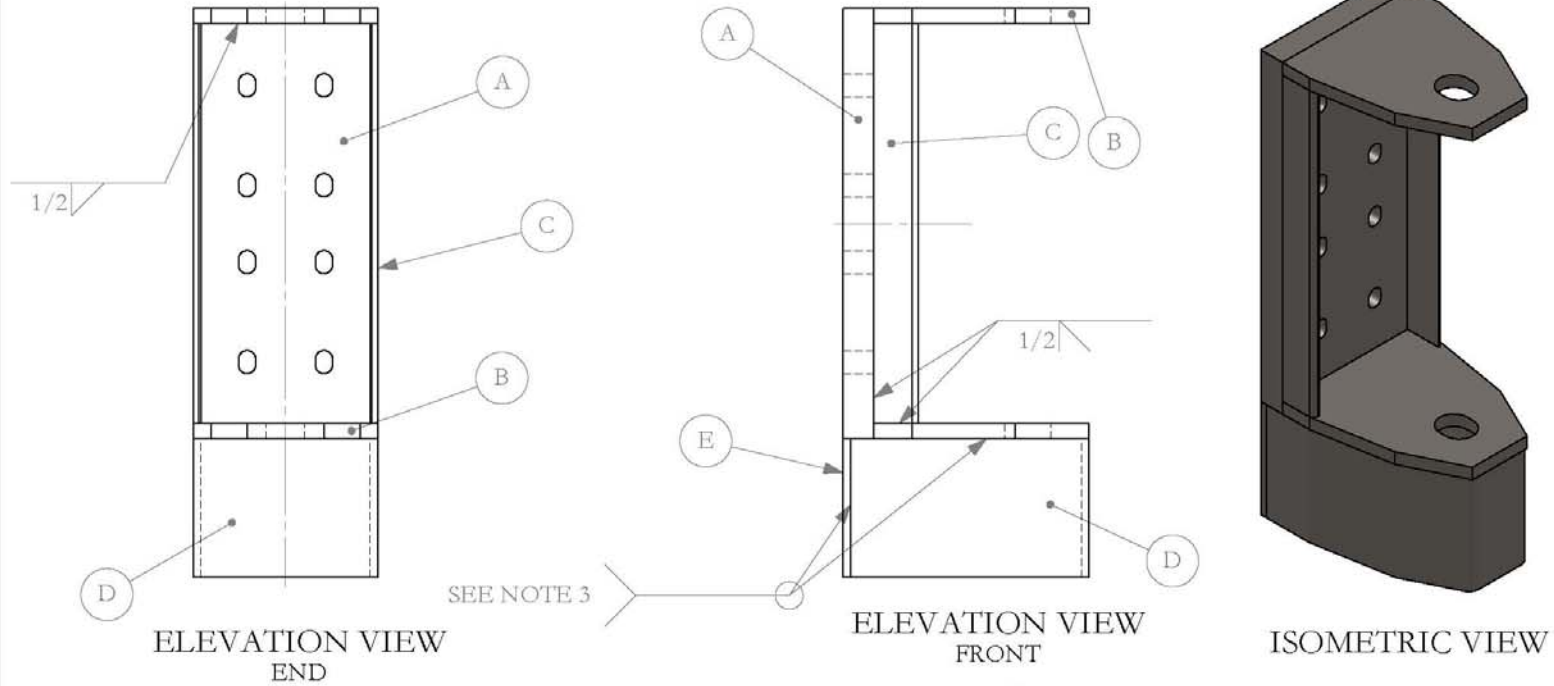
PIN ASSEMBLY
2 NEEDED PER INSTALLATION

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:5	5 of 17
2.							
3.				Project No.		Sheet Name	
4.				420020-6, 7, 8		Pin	
5.				Median Barrier Gate, proposed changes			

T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



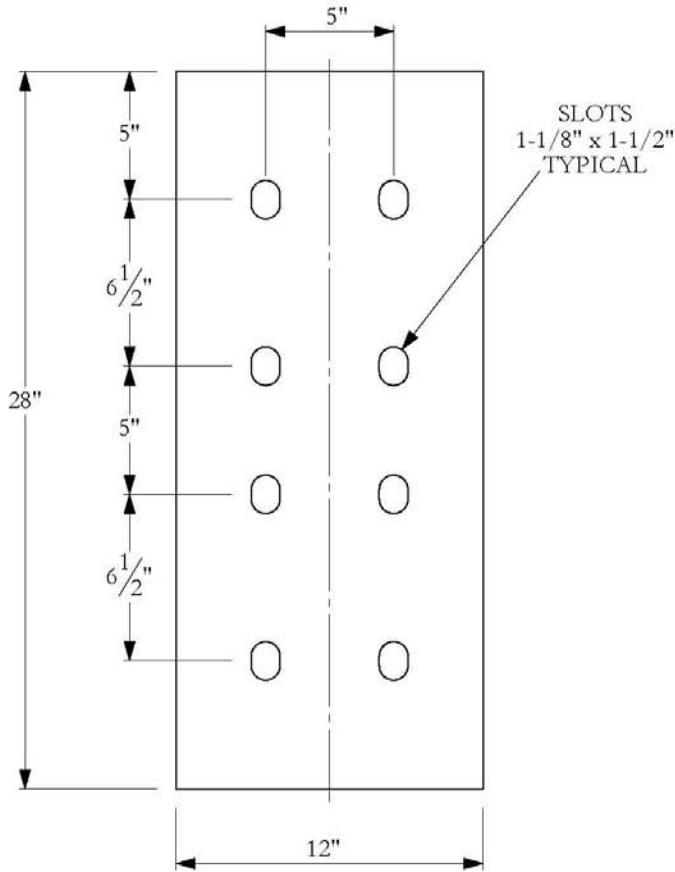
MOUNTING BRACKET



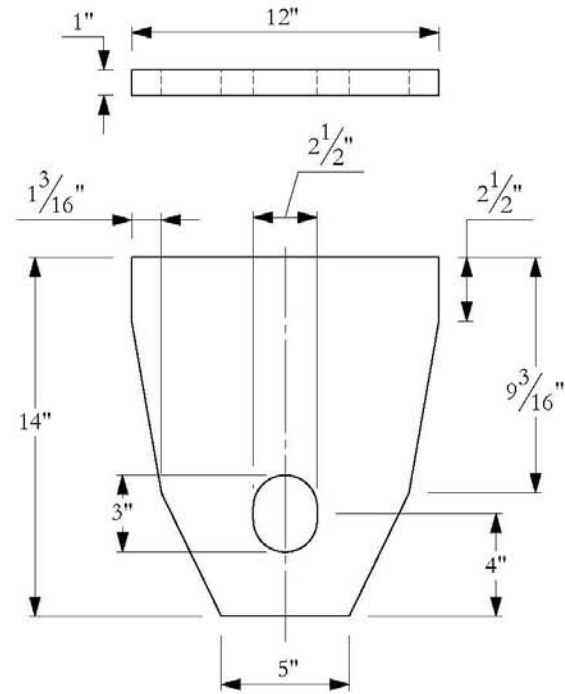
1. Part is symmetrical about Φ 's.
2. Two needed per installation.
3. Toe Plate to Back Plates and Horizontal Plate, and Bottom Back Plate to Top Back Plate - 1/4" bevel weld outside, 1/4" fillet weld inside.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:10	7 of 17
3.				Project No.		Mounting Bracket	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



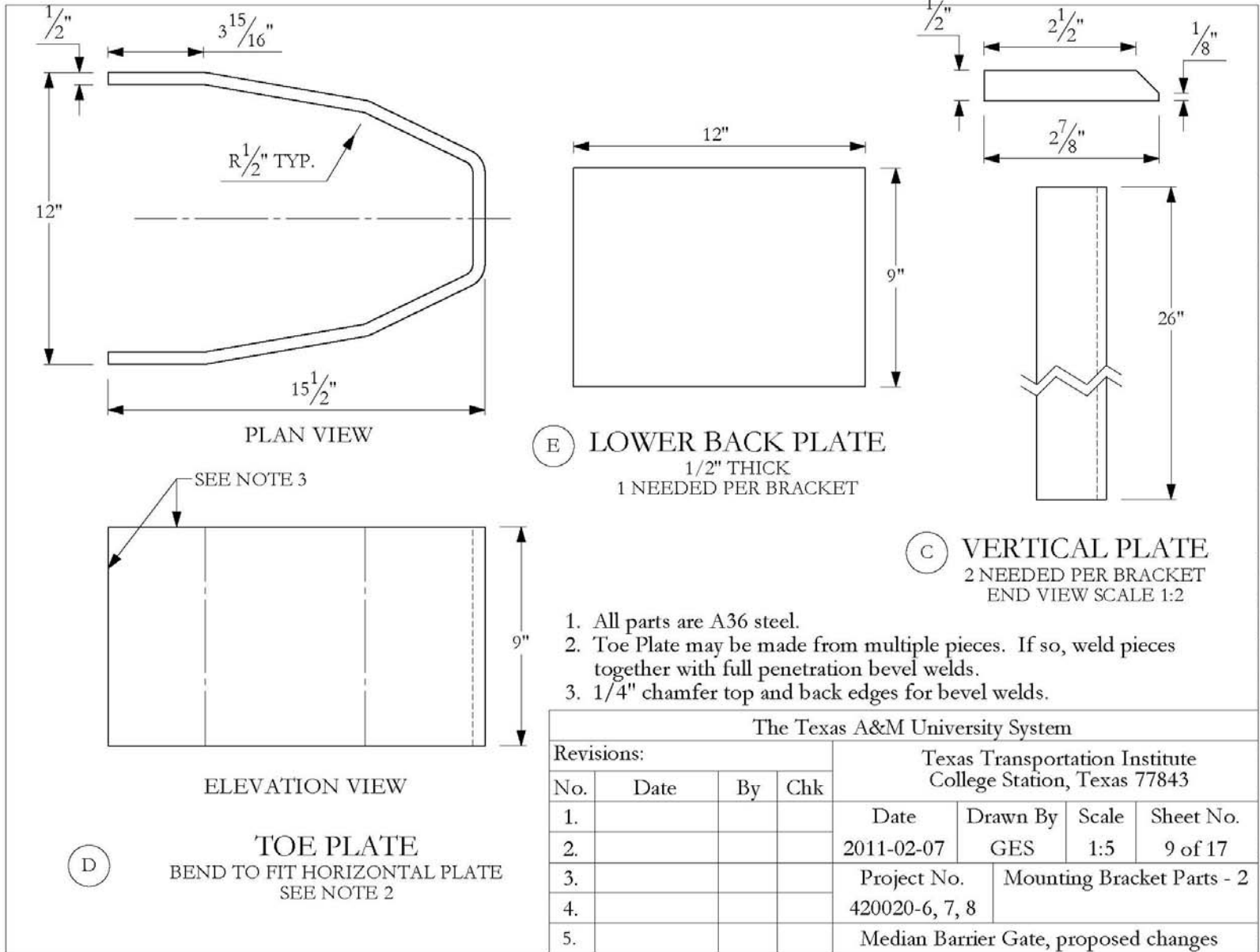
(A) **BACK PLATE**
2" THICK
1 NEEDED PER BRACKET



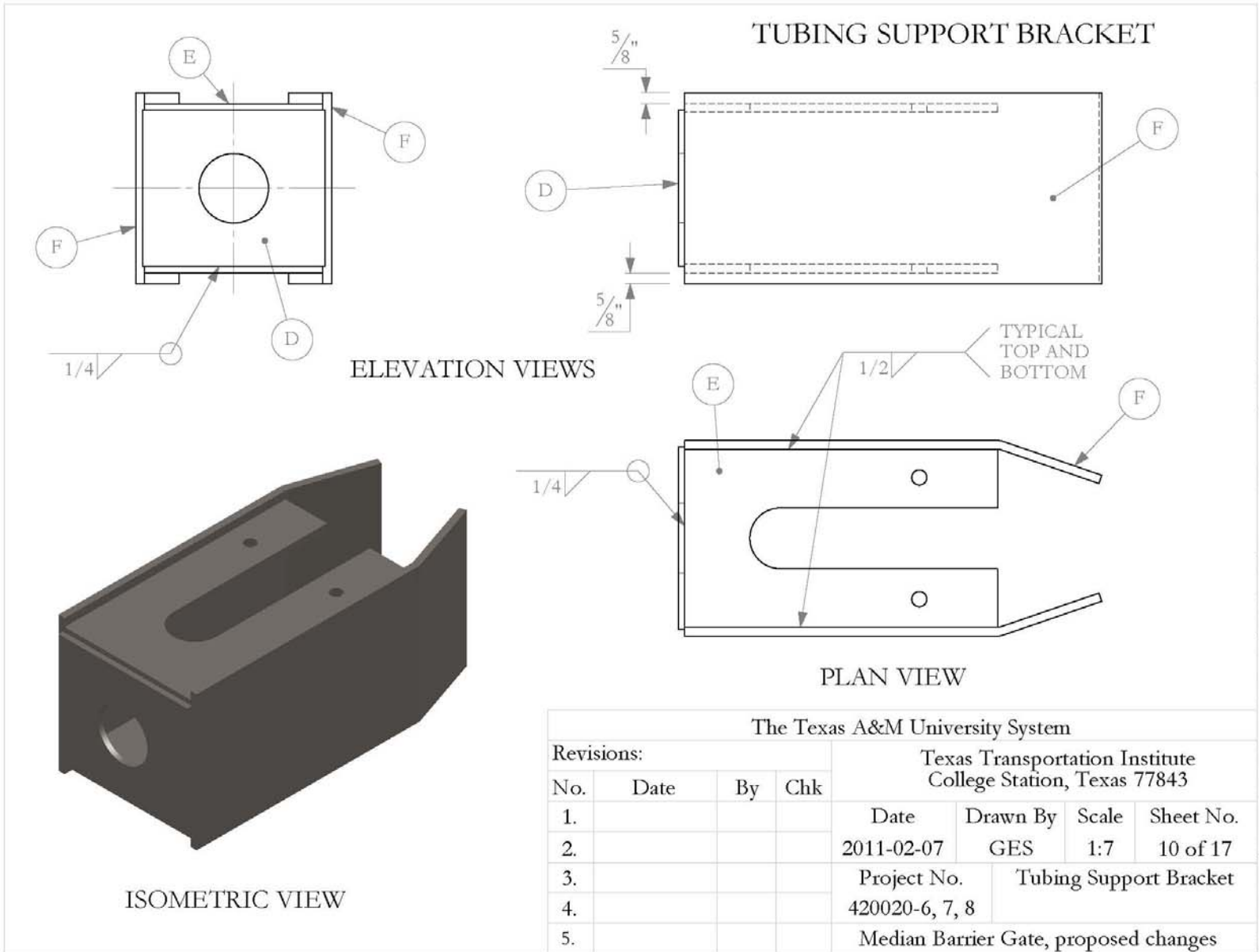
(B) **HORIZONTAL PLATE**
2 NEEDED PER BRACKET

1. All parts are A36 steel.
2. Parts A and B are symmetrical about ϕ 's.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:6	8 of 17
3.				Project No.		Mounting Bracket Parts - 1	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

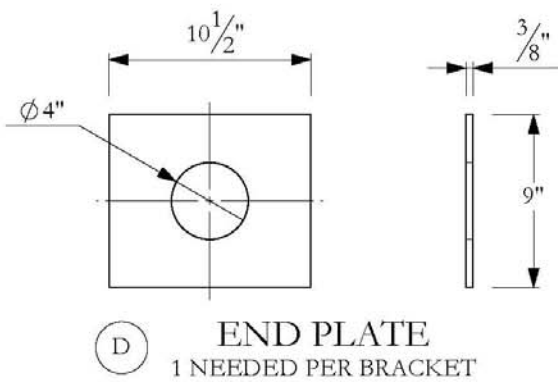
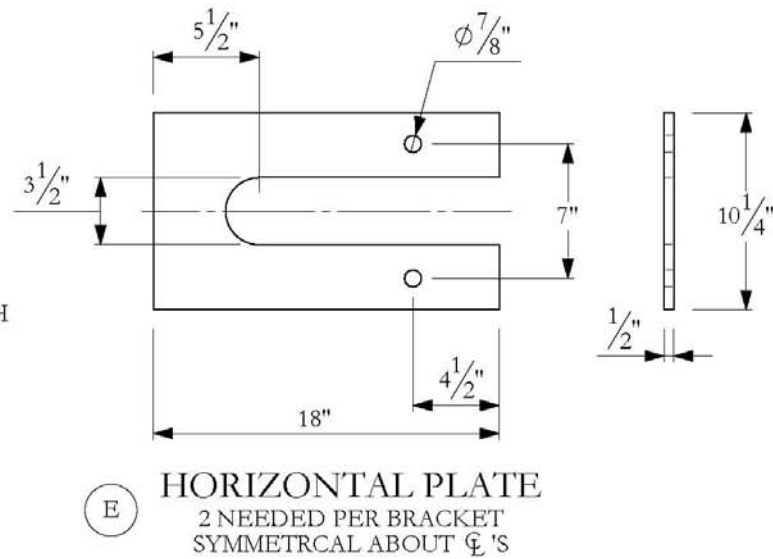
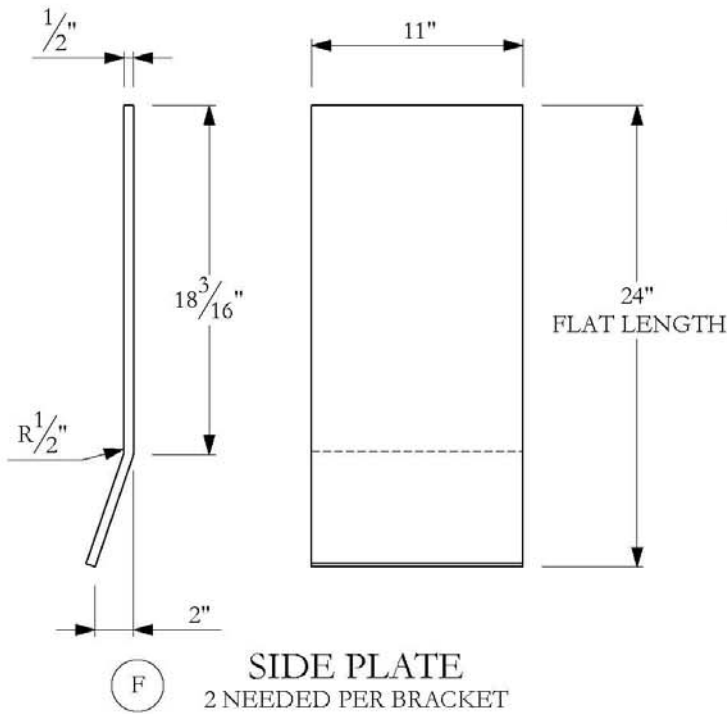


T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



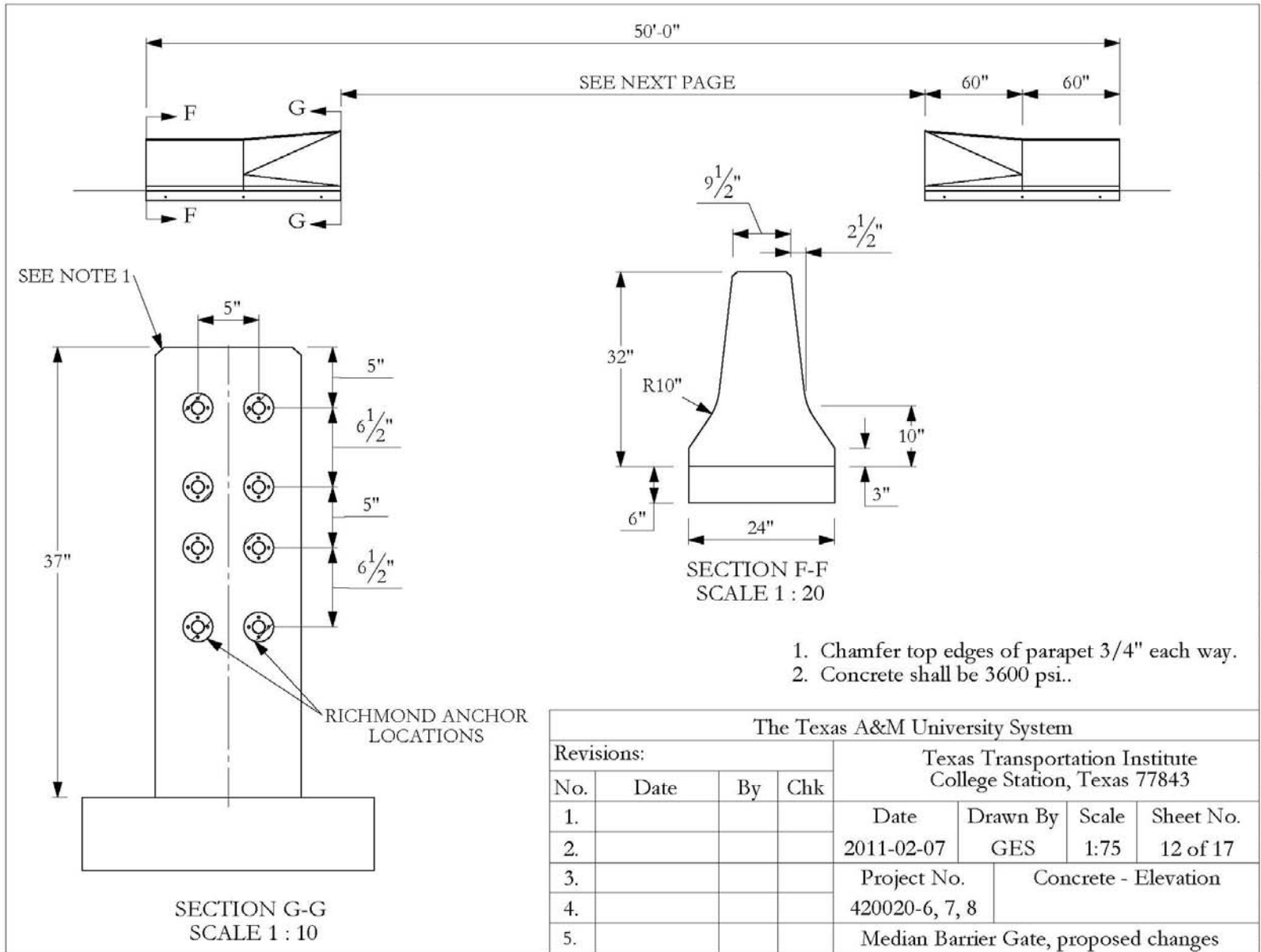
The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:7	10 of 17
3.				Project No.		Tubing Support Bracket	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

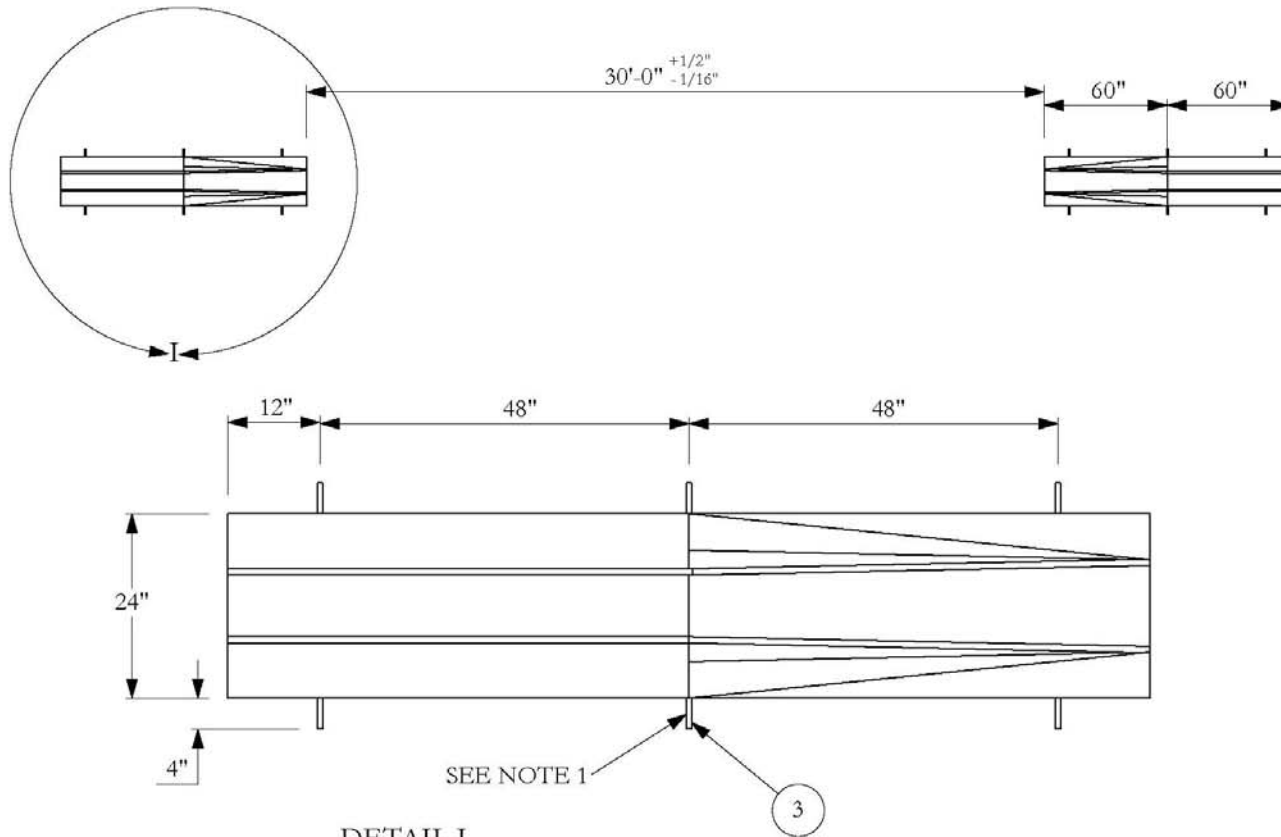
T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



1. All parts are A36 steel.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:8	11 of 17
3.				Project No.		Support Bracket Parts	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

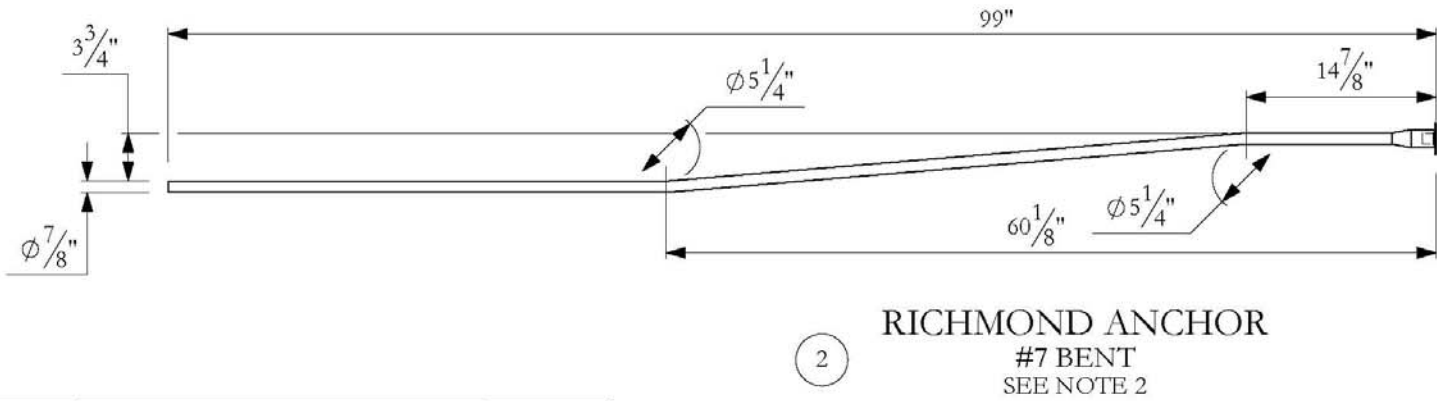
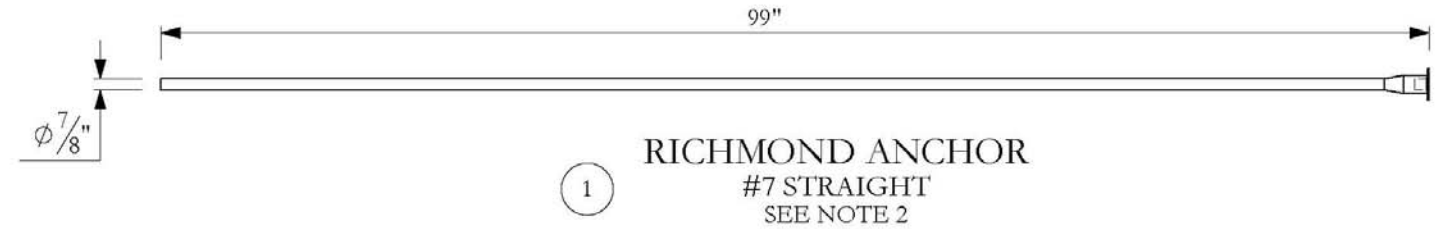




DETAIL I
SCALE 1 : 20

1. Drill into existing concrete and insert #5 x 12" rebars.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:75	13 of 17
3.				Project No.	Concrete - Plan		
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

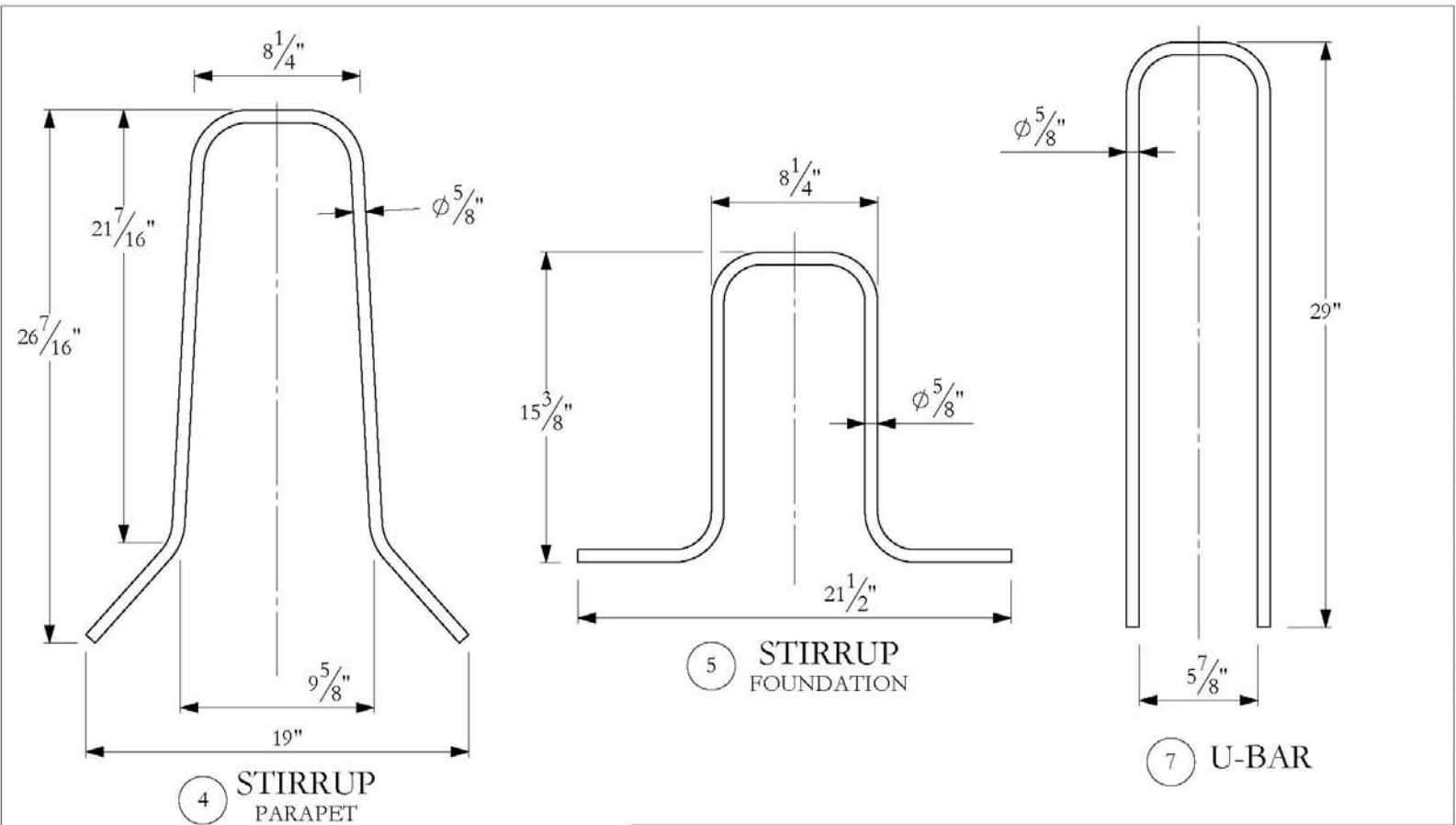


#	PART NUMBER	QTY.
1	Richmond Anchor, #7 straight	12
2	Richmond Anchor, #7 bent	4
3	Rebar, #5 x 12"	18
4	Stirrup, parapet	16
5	Stirrup, foundation	32
6	Rebar, #5 x 57"	16
7	U-bar, parapet	76
8	Rebar, #5 x 93"	8
9	Rebar, #4 x 9' 8"	12

1. All rebar is grade 60.
2. Dayton Superior D-101-A Dowel Bar Splicers, #7 rebar.

The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:12	14 of 17
3.				Project No.		Rebar List	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

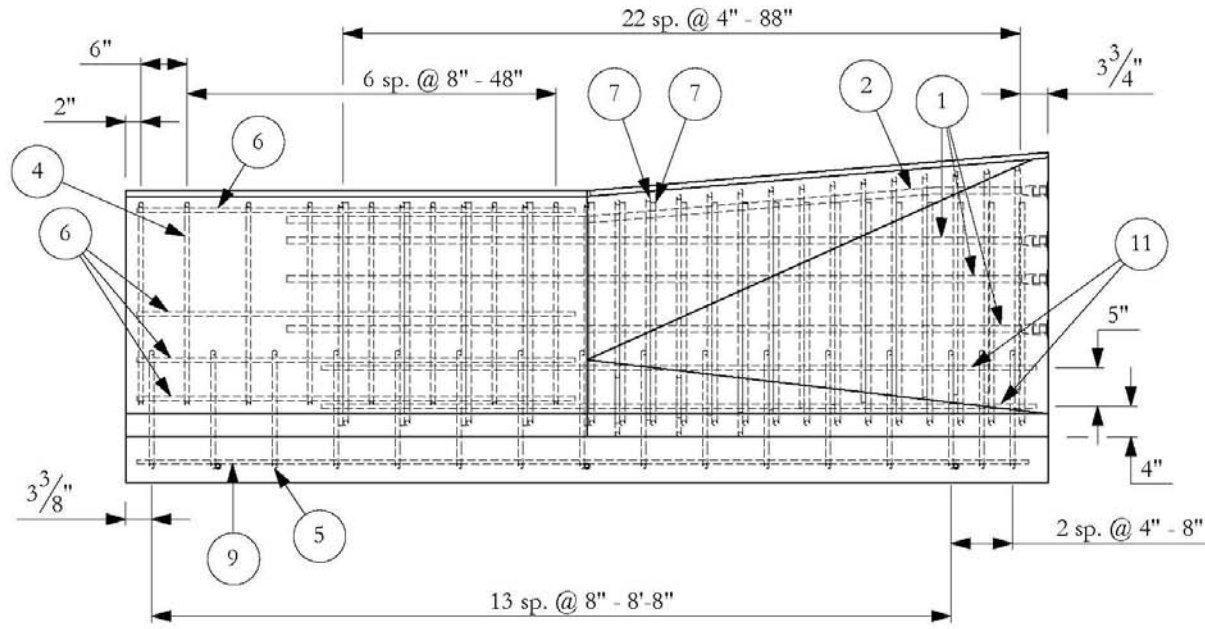
T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



1. All rebar is grade 60.
2. Bends are $\phi 3\text{-}3/4$ " (R $1\text{-}7/8$ "") for all #5 stirrups.
3. Bars 4, 5, and 7 are symmetrical about $\text{\textcircled{C}}$'s.

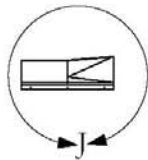
The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:7	15 of 17
3.				Project No.		Rebar Details	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed



DETAIL J
SCALE 1 : 20

1. Rebar typical both ends.
2. Rebar clearance is 1-1/2" unless otherwise indicated.



The Texas A&M University System							
Revisions:				Texas Transportation Institute College Station, Texas 77843			
No.	Date	By	Chk	Date	Drawn By	Scale	Sheet No.
1.				2011-02-07	GES	1:200	16 of 17
3.				Project No.		Rebar - Elevation	
4.				420020-6, 7, 8			
5.				Median Barrier Gate, proposed changes			

T:\2009-2010\420020 TxDOT\Median Barrier\Solidworks\Proposed Changes after Test\Median Barrier Gate Drawing, proposed

