Roadside Safety Pooled Fund

Texas Transportation Institute
Proving Ground

Test Report No. 405160-11-1
Test Report Date: August 2010

Development of Field Applied Fittings for Wire Rope Barrier and Conversion to High Tension

by

Dusty R. Arrington
Engineering Research Associate

Dean C. Alberson, P.E.
Research Engineer

and

Wanda L. Menges
Research Specialist

Contract No. T4541-AK
Report/Test No. 405160-11-1
Date of Test: 2008-07-11

Sponsored by
Roadside Safety Research Program Pooled Fund
Study No. TPF-5(114)

TEXAS TRANSPORTATION INSTITUTE PROVING GROUND

Mailing Address:	Located at:
Roadside Safety & Physical Security	Texas A&M Riverside Campus
Texas A&M University System	Building 7091
3135 TAMU	3100 State Highway 47
College Station, TX 77843-3135	Bryan, TX 77807

DISCLAIMER

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

Development of Field Applied Fittings for Wire Rope Barrier and Conversion to High Tension

5. Report Date

August 2010

6. Performing Organization Code

7. Author(s)

Dusty R. Arrington, Dean C. Alberson,
and Wanda L. Menges

8. Performing Organization Report No.

405160-11-1

9. Performing Organization Name and Address

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

T4541-AK

12. Sponsoring Agency Name and Address

Washington State Department of Transportation
Transportation Building, MS: 47372
Olympia, Washington, 98504-7372

13. Type of Report and Period Covered

Final Report:
January – April 2010

14. Sponsoring Agency Code

15. Supplementary Notes

Research Study Title: Development of Field Applied Fittings for Wire Rope Barrier and Conversion to High Tension

Name of Contacting Representative: Dave Olson

16. Abstract

The objective of this project is to identify and test a new field application method for wire rope terminations. The project also provides a procedure converting low-tension wire rope system to a higher tension system. Performance of the terminations and the higher tension system was verified through a full-scale crash test.

The Field Swage termination and the Epoxy Socket performed the best under dynamic and static loading conditions. Both terminations will provide the full strength of the connected wire rope if installed properly. Mechanical terminations may have sufficient capacity, however, further testing needs to be done to verify that they will not release wire rope due to vibrations of wire ropes seen in high-speed videos of redirection impacts.

The process of converting to high tension will require the low-tension terminals to be replaced with FHWA accepted high-tension terminals. The spring compensators will need to be removed and the terminations should be replaced.

The retrofitted system met the criteria for an *NCHRP Report 350* TL-3 crash test rating. However, the large size of the Epoxy Socket termination has raised questions about the system when impacted by a smaller vehicle. Therefore, it is recommended that a small car test be run on this system. The Field Swage termination should meet all criteria for TL-3 and a number of similar factory applied swage fittings have performed acceptably with both cars and pickups.

Low-tension systems could benefit from the addition of a fourth wire rope to further reduce potential for vehicle underride. Data from NCAC and MwRSF indicates the lower additional wire rope should not be placed higher than 13.5 inches above grade.

At the request of sponsoring states two detailed retrofit manuals were developed for retrofitting existing low-tension three wire rope systems. The first manual located in Appendix H details the conversion process to a three wire rope high tension system. The second manual located in Appendix I details the conversion process to a four wire rope high tension system. Each manual describes the retrofit process step by step in a way that it can be easily understood and followed by maintenance personnel.

17. Key Words Cable rail, wire rope barrier, median barrier, guardrail, longitudinal barrier, roadside safety, crash testing.	18. Distribution Statement Not to be reprinted without consent from Washington State DOT.

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	160	

Form DOT F 1700.7 **(8-72)** **Reproduction of completed page authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

ACKNOWLEDGMENTS

This research project was performed under a pooled fund program between the State of Alaska Department of Transportation and Public Facilities, California Department of Transportation (Caltrans), Louisiana Department of Transportation and Development, Minnesota Department of Transportation, Pennsylvania Department of Transportation, Tennessee Department of Transportation, Washington State Department of Transportation, and the Federal Highway Administration. The authors acknowledge and appreciate their guidance and assistance.

Roadside Safety Research
Pooled Fund Committee
PARTNERS

Revised February 2009

ALASKA

Jeff C. Jeffers, P.E.
Assistant State Traffic & Safety Engineering
Alaska Department of Transportation and
Public Facilities
3132 Channel Drive
P.O. Box 112500
Juneau, AK 99801-7898
(907) 465-8962
jeff.jeffers@alaska.gov

Kurt Smith, P.E.
Statewide Traffic & Safety Engineer
(907) 465-6963
kurt.smith@alaska.gov

CALIFORNIA

John Jewell, P.E.
Caltrans
Office of Materials and Infrastructure
Division of Research and Innovation
5900 Folsom Blvd
Sacramento, CA 95819
(916) 227-5824
(916) 227-5856
john_jewell@dot.ca.gov

LOUISIANA

Paul Fossier
Assistant Bridge Design Administrator
Bridge and Structural Design Section
Louisiana Transportation Center
1201 Capitol Road
P.O. Box 94245
Baton Rouge, LA 79084-9245
(225)379-1323
PaulFossier@la.gov

Kurt M. Brauner, P.E.
Bridge Engineer Manager
(225) 379-1933
(225) 379-1786 (fax)
Kurt.Brauner@la.gov

MINNESOTA

Michael Elle, P.E.
Design Standards Engineer
Minnesota Department of Transportation
395 John Ireland Blvd, MS 696
St. Paul, MN 55155-1899
(651) 366-4622
michael.elle@state.mn.us

PENNSYLVANIA

Mark R. Burkhead, P.E.
Standards &Criteria Engineer
Pennsylvania Department of Transportation
400 North Street
Harrisburg, PA 17105
(717) 783-5110
(717) 705-2379 (fax)
mburkhead@state.pa.us

TENNESSEE

Jeff Jones, Director
Design Division
Tennessee Department of Transportation
Suite 1300
James K. Polk State Office Building
Nashville, TN 37243-0348
(615) 741-2221
Jeff.C.Jones@state.tn.us

Ali Hangul, P.E.
Design Division
(615) 741-0840
(615) 532-7745 (fax)
Ali.Hangul@state.tn.us

WASHINGTON

Dave Olson, Chair
Design Policy, Standards,
& Research Manager
Washington State
Department of Transportation
P.O. Box 47329
Olympia, WA 98504-7329
(360) 705-7952
Olsonda@wsdot.wa.gov

Rhonda Brooks
Research Manager
(360) 705-7945
Brookrh@wsdot.wa.gov

FEDERAL HIGHWAY ADMINISTRATION

Richard B. (Dick) Albin, P.E.
Safety Engineer
FHWA Resource Center Safety & Design
Technical Services Team
12300 West Dakota Avenue, Suite 340
Lakewood, CO 80228
(303)550-8804
Dick.Albin@fdot.gov

William Longstreet
Highway Engineer
FHWA Office of Safety Design
Room E71-107
1200 New Jersey Avenue, S.E.
Washington, DC
(202)366-0087
Will.Longstreet@dot.gov

TEXAS TRANSPORTATION INSTITUTE

D. Lance Bullard, Jr., P.E.
Research Engineer
Roadside Safety & Physical Security Div.
Texas Transportation Institute
Texas A&M University System
College Station, TX 77843-3135
(979) 845-6153
L-Bullard@tamu.edu

C. Eugene Buth, Ph.D., P.E.
Senior Research Fellow
(979) 845-6159
G-Buth@tamu.edu

Roger P. Bligh, Ph.D., P.E.
Research Engineer
(979) 845-4377
RBligh@tamu.edu

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 PROBLEM

Expanded use of wire rope barrier systems has increased the knowledge of how these systems perform. Experience has shown that there have been a few crashes where the wire rope unexpectedly released from the connection hardware and the system did not contain the vehicle. It appears these instances are limited to low tension (generic) wire rope barrier systems using a tapered socket and wedge connection to connect the wire ropes with the hardware. It is not clear whether expansion/contraction cycles are loosening the connections, or whether the initial installation was inadequate. Regardless of the reason, there is a desire to identify or develop a connection with improved reliability.

To resolve this concern a field applied connection was identified for replacement during routine maintenance of the system. The chosen solution is accompanied by a detailed installation manual for maintenance personnel.

1.2 BACKGROUND

In 1996, the Washington State DOT 3-strand wire rope median barrier was subjected to National Cooperative Highway Research Program (NCHRP) *Report 350* test designation 3-10.(1,2) The test involved an 1808 lb passenger car impacting the median barrier at a speed of 62.0 mi/h and an angle of 20.4 degrees. The median barrier performed acceptably by redirecting and containing the vehicle. The two rear mounted wire ropes went under the vehicle and the vehicle became entrapped between the front and rear wire ropes. The wire rope median barrier met all evaluation criteria set forth in *NCHRP Report 350* for test designation 3-10.

In October of 1998, *NCHRP Report 350* test designation 3-34 was performed on the New York wire rope terminal.(3) This test involved an 1808 lb passenger vehicle impacting the terminal at the critical impact point (CIP) at a speed and angle of 61.7 mi/h and 14.7 degrees, respectively. Federal Highway Administration (FHWA) and Texas Transportation Institute (TTI) determined the CIP involved the right front corner of the bumper of the vehicle impacting the wire ropes in the region where they sloped downward to attach to the concrete anchor block. The New York wire rope terminal allowed the vehicle to gate through the end of the installation with minimal damage to the vehicle. The New York wire rope terminal performed acceptably according to criteria specified in *NCHRP Report 350* for test designation 3-34. On the basis of this test and other tests previously conducted by New York State DOT(4), the New York wire rope anchorage terminal was approved by FHWA for use on the NHS.

In February 2000, a 475 ft long test installation of Washington 3-strand wire rope guardrail was constructed in accordance with Washington State Department of Transportation standard drawings modified to include a New York wire rope terminal on each end. (3) Posts were installed in drilled holes and backfilled with *NCHRP Report 350* standard soil. The Washington

3-strand wire rope guardrail with New York wire rope terminal performed acceptably for *NCHRP Report 350* test 3-11.

A number of high tension wire rope median barriers have been successfully tested at both Test Level 3 (TL-3) and Test Level 4 (TL-4) under *NCHRP Report 350*. TL-3 involves a 3/4 ton, 4409 lb, pickup impacting the system at 62 mi/h and 25 degrees. TL-4 involves an 18,000 lb single unit truck impacting the system at 50 mi/h and 15 degrees. The systems have a variety of post configurations and spacings. While there is some variation on the wire rope strength and installed modulus of elasticity, all the systems utilize 0.75 inch, 3x7 wire ropes.

Collision experience in Washington State includes some occurrences of wire ropes releasing from the connecting hardware in collisions with low tension cable barrier systems. Additionally, when low tension systems are compared to high tension systems, maintenance appears to be a larger issue with lower tension systems.

1.3 OBJECTIVES/SCOPE OF RESEARCH

The objective of this project is to identify and test a new field application method for wire rope terminations. The project will also provide a procedure for converting the low tension wire rope systems to a higher tension system. Performance of the terminations and the higher tension system were verified through a full scale crash test.

CHAPTER 2: IDENTIFICATION OF ALTERNATIVE WIRE ROPE TERMINATION METHODS

2.1 EXAMPLE OF PRODUCTS TO BE REPLACED

Existing field applied fittings consist of a tapered cast iron housing (socket), a three-sided fluted wedge, and threaded rod, as shown in Figures 2.1 and 2.2. The end fittings are connected to the wire ropes by splaying the three strands of the wire rope after the wire rope is inserted into the cast iron housing. The fluted wedge is then driven into the center of the wire strands seating them in the cast iron housing. These products have a proven static capacity equal to that of the wire rope. If the wedge is placed properly between the wire rope strands, the wedge will seat the wire rope deeper into the socket when the system is under tension. Under cyclic or dynamic loading the wedges can become unseated, thus releasing the wire rope from the termination.

Figure 2.1. Assembled termination with wedge (Bennett Bolt Works, Inc.).

Figure 2.2. Exploded view of assembly (Assembly Specialty Products, Inc.).

2.2 ALTERNATIVE TERMINATION METHODS

Six samples of termination methods were obtained. Two of the samples are prototypes of a similar existing product modified to fit the 3x7 wire rope. Below is a list of all six products obtained, with photographs shown in Figures 2.3 through 2.8.

1. Epoxy Socket

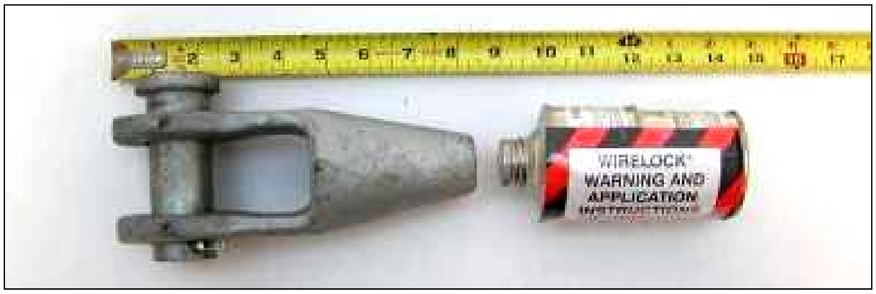


Figure 2.3. Required products for assembly of Wirelock Epoxy Socket.

2. Field Swage

Figure 2.4. Field swaged termination that has been previously tested.

3. Precision Sure-Lock Prototype 1

Figure 2.5. Precision Sure-Lock Prototype 1 with tensioning linear jack.

4. Precision Sure-Lock Prototype 2

Figure 2.6. Assembled view of the Precision Sure-Lock Prototype 2 termination with required wrenches.

5. Electroline by ESMET, Inc.

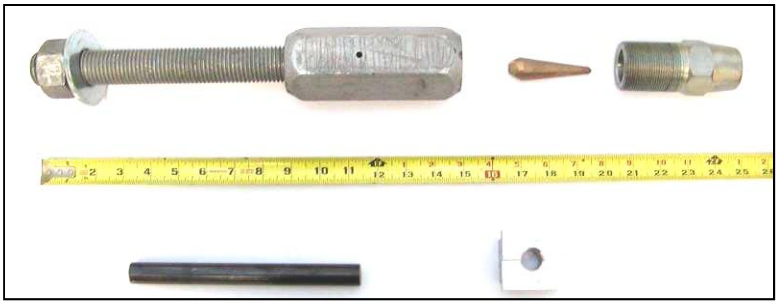


Figure 2.7. Exploded view of Electroline (by ESMET, Inc.) assembly.

6. Nucor Steel Marion, Inc.

Figure 2.8. Exploded view of Nucor Steel Marion assembly.

2.3 PRODUCTS CHOSEN FOR FURTHER TESTING

The six products listed above were reviewed by the project technical representative. The technical representative then selected three sample products for further testing. The products selected show the highest probability of maintaining a permanent connection to the 3x7 wire rope under dynamic and loading conditions. Nucor Steel Marion, Inc. provided funding for the testing of their product.

2.3.1 Field Swage

The first product selected was the Field Swage Termination. This type of termination has been used extensively in the wire rope industry. Previously, dies in large presses were used to permanently mold a termination to a wire rope end, also known as swaging. These presses are too large to be considered portable. Due to this, wire ropes were created in shop by pre-measuring/estimating the wire rope lengths. Standard construction tolerances made this technique an inefficient method for attaching wire rope terminations. Figure 2.4 shows an image of this termination.

In recent years, new die swaging machines have become available. These machines, an example of which is shown in Figure 2.9, use a hydraulic cylinder to pull the steel termination through two identical opposing dies. This process compresses the termination around the wire rope end. This technique produces a termination that is exemplar to shop applied swage fittings. One major advantage to this new technique is: the machine is relatively light weight and portable making it possible to produce swage terminations in the field. The field swaging process solves the previous construction tolerance problems associated with shop swaging while still providing the static and dynamic capacity of the wire rope.

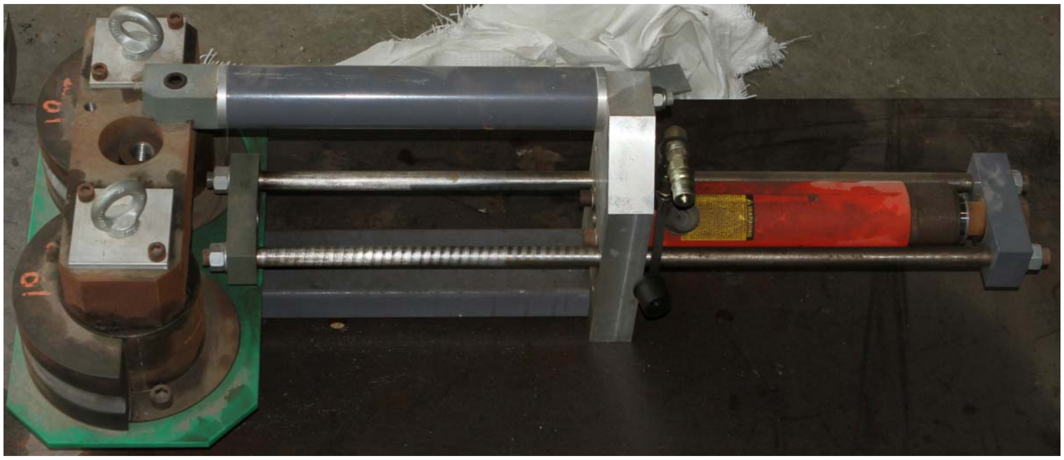


Figure 2.9. Field swaging machine.

Obviously a contractor must have a swaging machine onsite when constructing a wire rope installation. These machines cost approximately $15,000 each. These machines also require an external power supply and mounting platform for field use. Even with the added initial tooling cost associated with this product, it shows the most promise for reliably developing both the static and dynamic capacity of the wire rope.

2.3.2 Epoxy Socket

This product is considered to be the second most reliable termination technique of the presented options. This method has been used extensively in the wire rope industry as a field applied termination technique for high strand count wire ropes. Figure 2.3 shows an image of this termination.

This product consists of three main features. The first feature is a socket that is in the shape of an inverted cone. The second feature includes splaying the individual wires of the end of the wire rope to be terminated. This process of splaying the wire rope allows for a better bond between the strands and the epoxy. The third feature of the termination includes the epoxy itself.

When assembling the termination the wire rope is inserted through the bottom of the socket and then splayed before a silicone sealer is used to close holes between the wire rope and the bottom of the socket. The sockets are then supported in a vertical position to allow the epoxy to be poured into the socket around the splayed wire rope. The epoxy then forms a wedge within the socket after the epoxy has hardened. Unlike mechanical wedges, the epoxy forms a chemical bond to the strands preventing them from slipping without failing the epoxy itself. This product is rated for the full strength of the wire rope being terminated if installed properly.

There are some concerns with this type of termination. First, this product has not been rated for the standard 3x7 wire rope used exclusively in the highway safety industry. Second, the curing time of the epoxy is extremely temperature sensitive. According to Crosby, the manufacture of the “WireLock” epoxy used in our testing, temperature does not affect the strength of the connection; however, it does affect the hardening time of the epoxy. Crosby sells an accelerant for use in low temperature conditions.

Third, this type of termination does not have a threaded rod option. This makes terminating to current standard terminals impossible without the use of eyebolts; also larger, more expensive turnbuckles will be required for splicing wire ropes. The fourth and final problem is the size of the termination. The large diameter of the socket compared to the diameter of the wire rope can lead to snagging problems while the barrier is interacting with the vehicle.

2.3.3 Precision Sure-Lock Prototype 2

The third and final product selected by the technical advisor was a prototype of a company’s existing termination modified to fit the 3x7 wire rope. This product also had modifications to allow the termination to be installed without a hydraulic tensioning jack.

This product is a mechanical termination that relies on three mechanical wedges that fit in a conical socket, to pinch and hold a wire rope end. Theoretically, mechanical wedges are drawn into the socket with increased tension in the rope. Therefore, the more load on the termination, the stronger the interface connection between the wedges and the wire rope.

If the wedges are not properly seated, the wire rope will slip out of the connection. Additionally, if the wedges are not set deep enough, the wedges could be loosened by dynamic loading or by repetitive expansion/contraction cycles in the wire rope caused by normal temperature fluctuation. This problem has been previously avoided in the post tensioning industry by preloading the wedges. Terminations are preloaded to near the ultimate capacity of the wire rope. Preloading the wedges will cause them to be set deep within the socket. The friction between the wedges and the socket help to hold them in place under cyclic loading. The original prototype preloaded the connection using a hydraulic tensioning jack. This prototype uses a threaded rod at the back of the termination to force the wedges deep into the socket. This prototype will accomplish the same effect as preloading; however this method only requires two standard mechanics wrenches. Figures 2.10 and 2.11 show the internal components of the product.

Figure 2.10. Exploded view of the components of Precision Sure-Lock Prototype 2.

Figure 2.11. Exploded view Precision Sure-Lock Prototype 2 with wire rope.

This product is a mechanical system and must be installed correctly. Because the final assembled product is sealed; it leaves no method for inspection. Finally, mechanical wedges have been known to cause stress concentrations on wire ropes that can significantly reduce the tensile capacity of the termination.

2.3.4 Nucor Steel Marion, Inc.

This product was not chosen by the technical representative. However, the supplier of this product provided funding for the testing of their product in parallel to the other products that were chosen. This product is the simplest of the presented samples to install.

This product is a mechanical termination. This product uses wedges in a socket that are similar to those used in the Precision Sure-Lock products; however, the major difference is in how the wire rope is installed in the termination. This product uses an internal spring to position the wedges. To install this product, the installer simply inserts the free end of a wire rope into the open end of the terminations. The installer should be careful to verify that the wire rope bottoms out on the back of the termination. This ensures the wedges are seated properly. As the wire rope is inserted the spring forces the wedges around the wire rope. When the wire rope is tensioned the wire rope will then seat the wedges in the socket. The spring helps to ensure that the wedges will not slip on the wire rope when initially seating the wedges. Figure 2.8 shows an exploded view of the termination.

This product is the simplest (requires no tools) and the fastest to install of the presented products. However this product, when compared to the other products listed, has an increased likelihood of releasing the wire rope under dynamic or cyclic loading conditions. This product is again a hollow closed termination. Therefore, inspecting its installation is impossible without disassembling the termination.

CHAPTER 3: STATIC AND DYNAMIC TESTING OF CHOSEN METHODS

3.1 STATIC TESTING

Each of the four considered wire rope termination products were subjected to static load tests under the same conditions shown in Figure 3.1. The load was applied using a hydraulic cylinder at one end of the load frame and loads were recorded at 5 samples per second. The load was recorded using an automated data acquisition system (DAQ). Photographs of the test samples were taken before and after each test. Load curves for each sample were also created for each test. A summary of all results is shown in Figure 3.2. In this report, the termination closest to the hydraulic cylinder will be referred to as termination A. The termination farthest away from the hydraulic cylinder will be referred to as termination B. All terminations were installed using manufacturer provided installation instructions presented in Appendix A.

The wire rope used in the tests was standard 3x7 stranded wire rope. There are three 0.375 inch strands with seven wires in each. The wire rope was pre-stretched and was received from Guardian Cable Systems LLC. The wire rope had a breaking strength of 43 kips. A copy of the standard specification and certification sheet for this product can be found in Appendix B.

Figure 3.1. Static load frame with test sample installed and ready for testing.

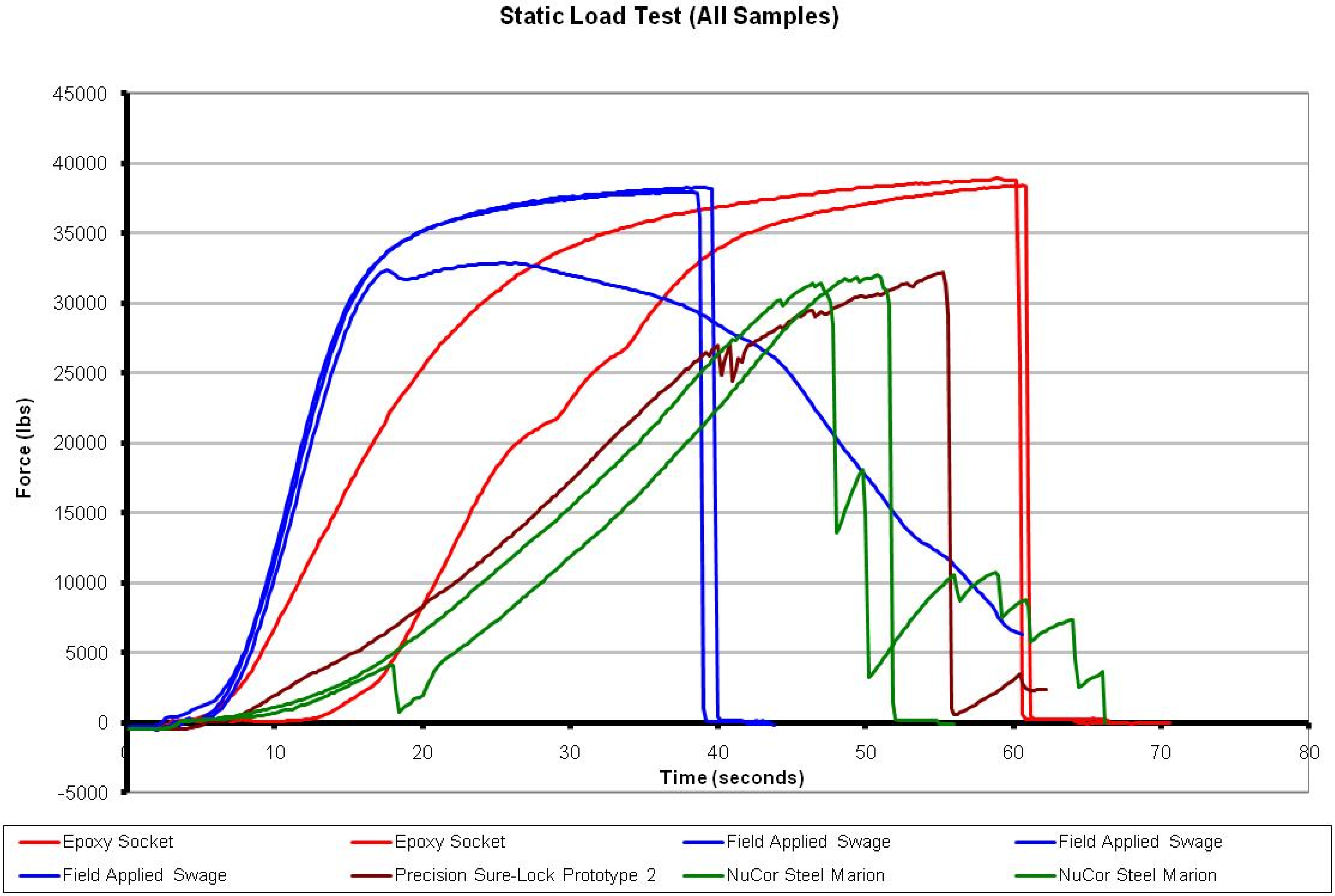


Figure 3.2. Static load curves for all terminations.

3.1.1 Epoxy Socket (S1 and S2)

Test S1 samples had a pull out distance of 0.1 inch at termination A and 0.2 inch at termination B. The wire rope failed 5½ inches from termination B as shown in Figure 3.3. The wire rope failed at 38.92 kips of load. Test S2 samples had a pull out distance of 0.2 inch at termination A. The wire rope failed at the end of termination B as shown in Figure 3.4. The wire rope failed at 38.43 kips of load. The load curves for these tests is shown in Figure 3.5.

Figure 3.3. Epoxy Socket wire rope termination B after test S1.

Figure 3.4. Epoxy Socket wire rope termination B after test S2.

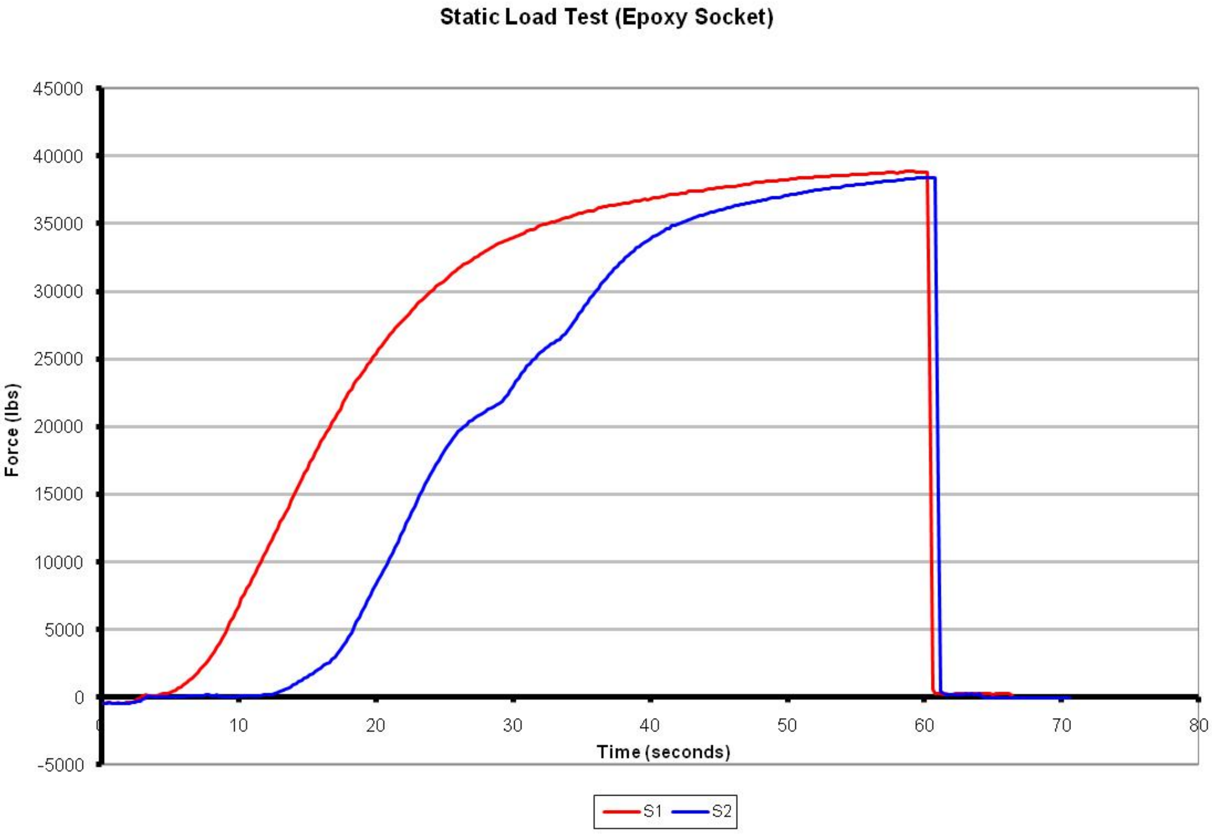


Figure 3.5. Static load curves for Epoxy Socket terminations.

3.1.2 Field Swage (S3, S4, and S7)

In test S3, the wire rope pulled out 0.1 inch at termination B. The wire rope ruptured 1.1 inches inside termination A, as shown in Figure 3.6, at 37.94 kips of load. In test S4, the wire rope pulled out 2.3 inches at termination B, as shown in Figure 3.7, and 0 inch at termination B before the test was halted. The failure strength was 32.89 kips. Test S7 was a duplicate of test S3. The wire rope ruptured at 38.28 kips. The wire rope pulled out 0.6 inch and then ruptured 0.4 inch inside the end of termination B as shown in Figure 3.8. The wire rope at termination A pulled out 0.2 inch.

In test S4, the wire rope would have pulled out of the swage termination during the test if testing was not halted. This was an unexpected failure mode. Upon further inspection of the swage termination, a 2 inch long zinc plug was found in the base of the swage termination that prevented the wire rope from being fully engaged by the swaging process. When additional supplied swage terminations were inspected, a number of defective terminations were found to have zinc plugs. The wire rope should be embedded 5½ inches, as shown in Figure 3.9, to assure that the pullout failure mode will not occur. Photographs of improperly constructed terminations are shown in Figures 3.10 through 3.12. Wire ropes should be marked before insertion into the swage termination for proper embedment verification. It is interesting to note that the improperly installed swage termination failure strength was still equal to or greater than the two mechanical terminations.

The load curves for these tests are shown in Figure 3.13.

Figure 3.6. Field Swage wire rope termination A after test S3.

Figure 3.7. Field Swage wire rope termination B after test S4.

Figure 3.8. Field Swage wire rope terminations after test S7.

Figure 3.9. Correct embedment depth of a Field Swage termination.

Figure 3.10. Example of an incorrect embedment depth of a Field Swage termination due to zinc plug in termination.

Figure 3.11. Field Swage termination cross-section with and without galvanization plug.

Figure 3.12. Field Swage termination cross-section with galvanization plug.

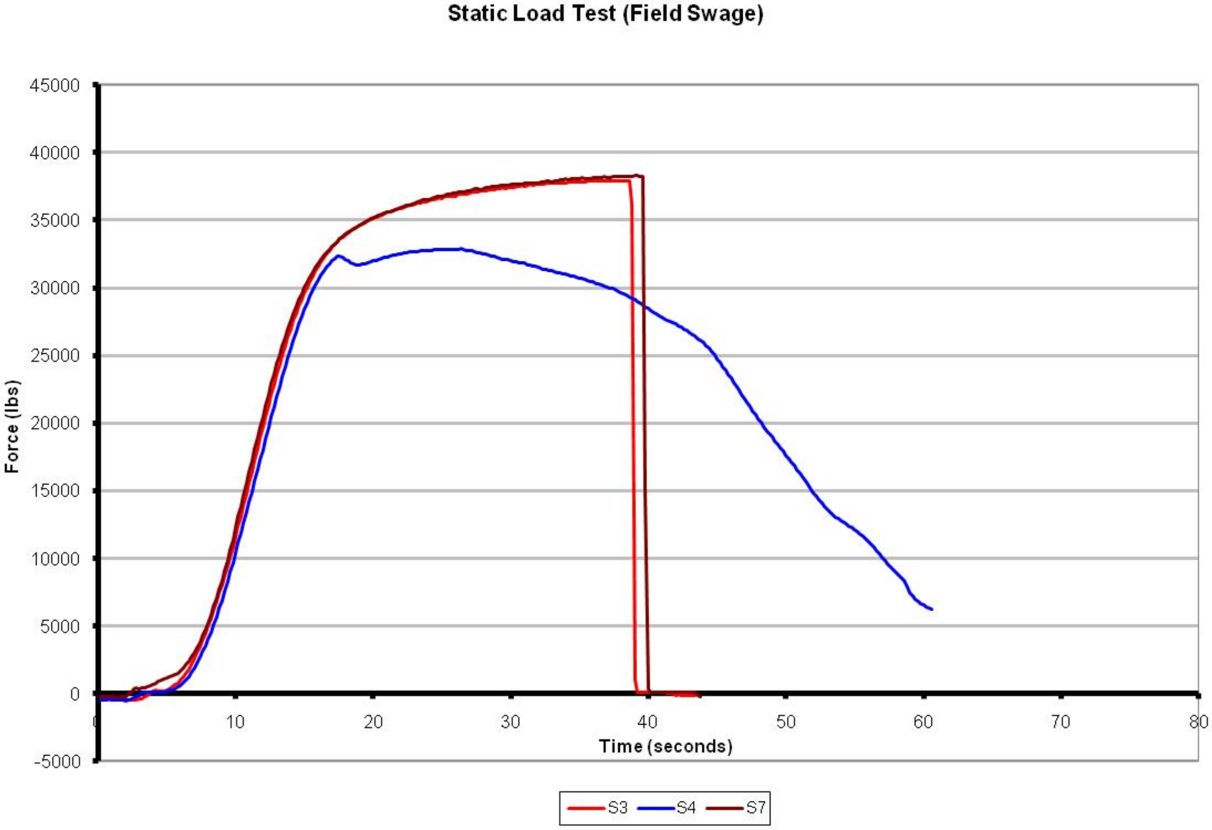


Figure 3.13. Static load curves for Field Swage terminations.

3.1.3 Precision Sure-Lock Prototype 2 (S5 and S6)

During test number S5, a termination provided by Precision Sure-Lock, the DAQ (computer digital I/O card) failed to record the test data. The only record of the breaking load for this test was an approximate breaking strength of 30 kips indictated by an observer from a digital readout. The wire rope pulled out 0.6 inch at termination A and 1-1.5 inches at termination B before breaking flush with ends of interior wedges as shown in Figure 3.14.

Test S6 is a test of a duplicate fitting. However, the fitting was purposely installed with likely field installation errors. The wire rope was oriented in the wedges different than stated in the installation instructions (Termination A) and the wire rope was installed with the end protruding out of the wedges more than required in the installation instructions (Termination B). In Test S6, data was successfully recorded, and the observed maximum value in test S5 was close to the maximum value recorded in test S6. The wire rope failed at 32.20 kips when 2 of the 3 strands ruptured flush with the end of the wedges before the test was halted (see Figure 3.15). The wire rope pulled out 0.75 inch at termination A and 0.2 inch at termination B.

The load curve for this test is shown in Figure 3.16.

Figure 3.14. Precision Sure-Lock Prototype 2 wire rope termination B (end view) after test S5.

Figure 3.15. Precision Sure-Lock Prototype 2 wire rope terminations after test S6.

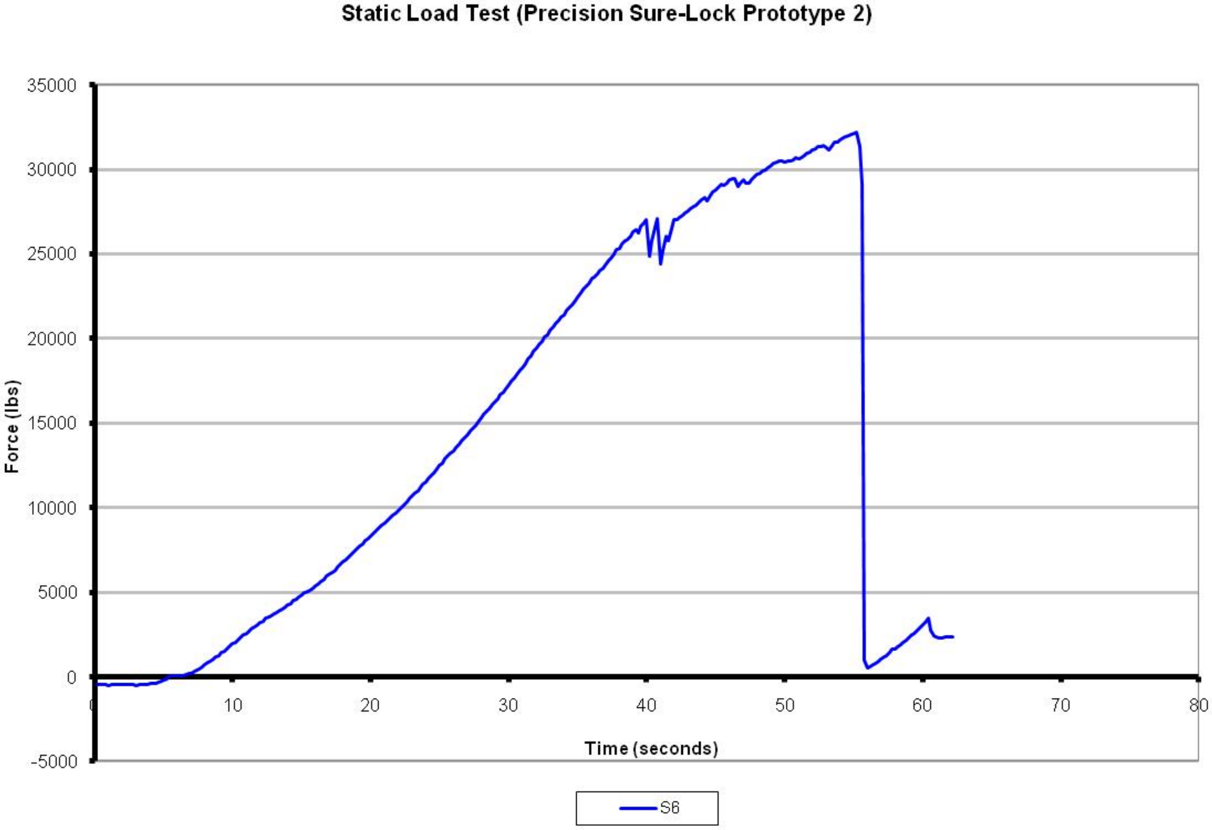


Figure 3.16. Static load curve for test S6 on the Precision Sure-Lock Prototype 2 terminations.

3.1.4 Nucor Steel Marion (NSM-S30 and NSM-S31)

Test NSM-S30 resulted in a rupture strength of 31.47 kips. As the load was being applied, individual wires were observed to rupture while the load continued to increase. This observed progressive failure indicated the wire rope was not uniformly loaded throughout the cross-section by the fitting. This same behavior was witnessed during the testing of Precisions Sure-Lock's Prototype 2 mechanical fitting. The Nucor termination, as with other mechanical terminations, ruptured near the end of the interior wedges. The wire rope pulled out 0.7 inch at the terminal B, and the wire rope failed inside of termination A, as shown in Figure 3.17. Test NSM-S31 resulted in a rupture strength of 32.03 kips. Once again individual strands were ruptured prior to complete failure of the wire rope at termination B (see Figure 3.18). The wire rope strands again failed just inside the end of the wedges. The wire rope pulled out 0.4 inch at termination A. The load curves for these tests are shown in Figure 3.19.

Figure 3.17. Nucor Steel Marion wire rope termination A after test NSM-S30.

Figure 3.18. Nucor Steel Marion wire rope termination B (end view) after test NSM-S31.

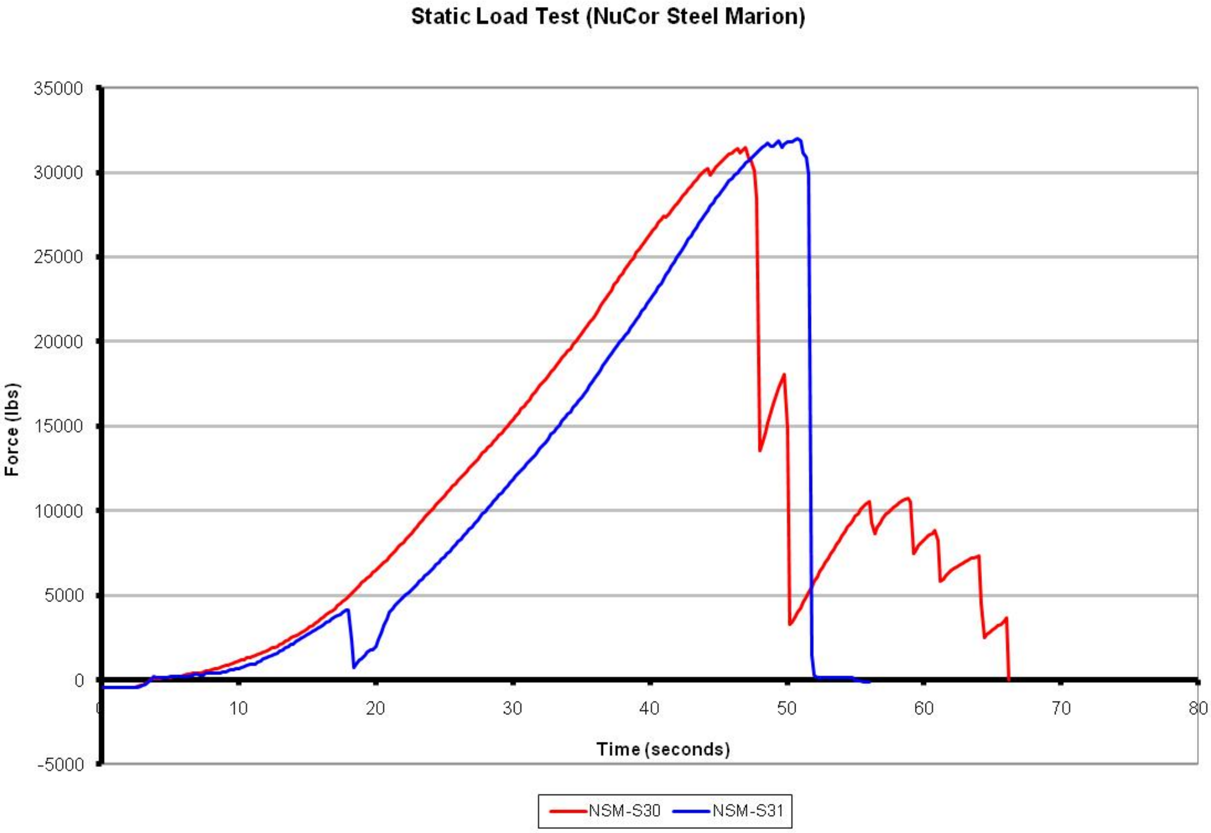


Figure 3.19. Static load curves for Nucor Steel Marion Inc. terminations.

3.2 DYNAMIC TESTING (PENDULUM)

Dynamic testing was conducted to investigate possible failures due to vibration and the strength of the connections under impulse loads. The test setup consists of a falling (swinging) mass (2085 lb pendulum) traveling approximately 22 mph, a rigid fixed post, and a test specimen attached between the pendulum and rigid post. The acceleration of the pendulum was recorded and force was computed. The test configuration is shown in Figure 3.20. The termination attached to the pendulum will be referred to as termination A. The termination attached to the rigid post will be referred to as termination B. All wire rope failures were located at termination A.

3.2.1 Epoxy Socket (P1, P2, and P3)

Test P1 resulted in a rupture force of 37.04 kips. The wire rope ruptured at the end of termination A, as shown in Figure 3.21. The wire rope did not have a measurable pull out distance, as shown in Figure 3.22. In test P2, the nut was stripped off the threaded eyebolt, shown in Figure 3.23. The eyebolt and nut had been used previously in test P1. The socket terminations A and B showed no sign of pull out and sustained a maximum load of 38.37 kips. Test P2 was repeated with new nuts and eyebolts and recorded as test P3. Test P3 exhibited the same failure mechanism seen in P1. The maximum force was recorded as 43.49 kips. The acceleration traces for these tests are shown in Figure 3.24.

Figure 3.20. Dynamic load test setup.

Figure 3.21. Epoxy Socket wire rope termination A after test P1.

Figure 3.22. Epoxy Socket wire rope termination B after test P1.

Figure 3.23. Epoxy Socket eyebolt and nut with stripped treads.

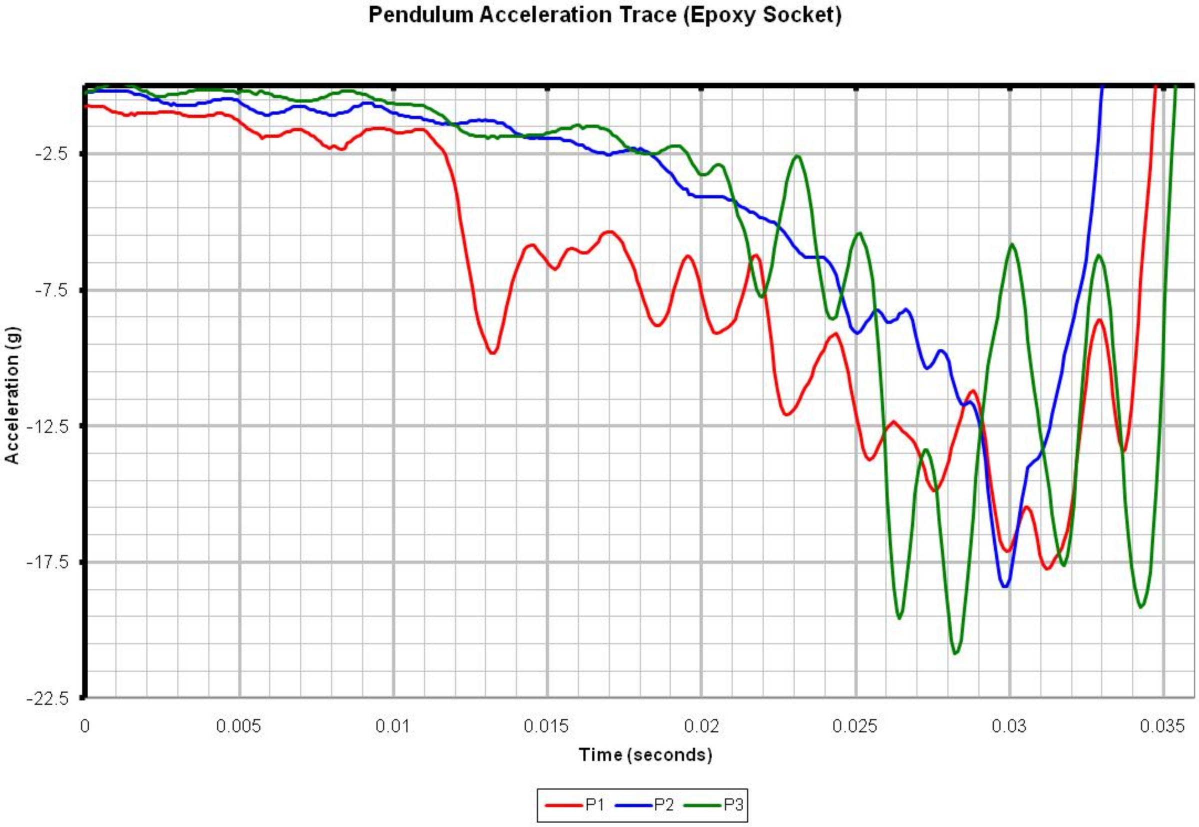


Figure 3.24. Dynamic acceleration traces Epoxy Socket terminations.

3.2.2 Field Swage (P4 and P5)

Test P4 ruptured the wire rope at the end of termination A at a load of 46.83 kips with less than 0.1 inch of pull out at either termination shown in Figures 3.25 and 3.26. Test P5 exhibited the same behavior as test P4 with a maximum load of 40.77 kips. The acceleration traces for these tests are shown in Figure 3.27.

Figure 3.25. Field Swage wire rope termination A after test P4.

Figure 3.26. Field Swage wire rope termination B after test P4.

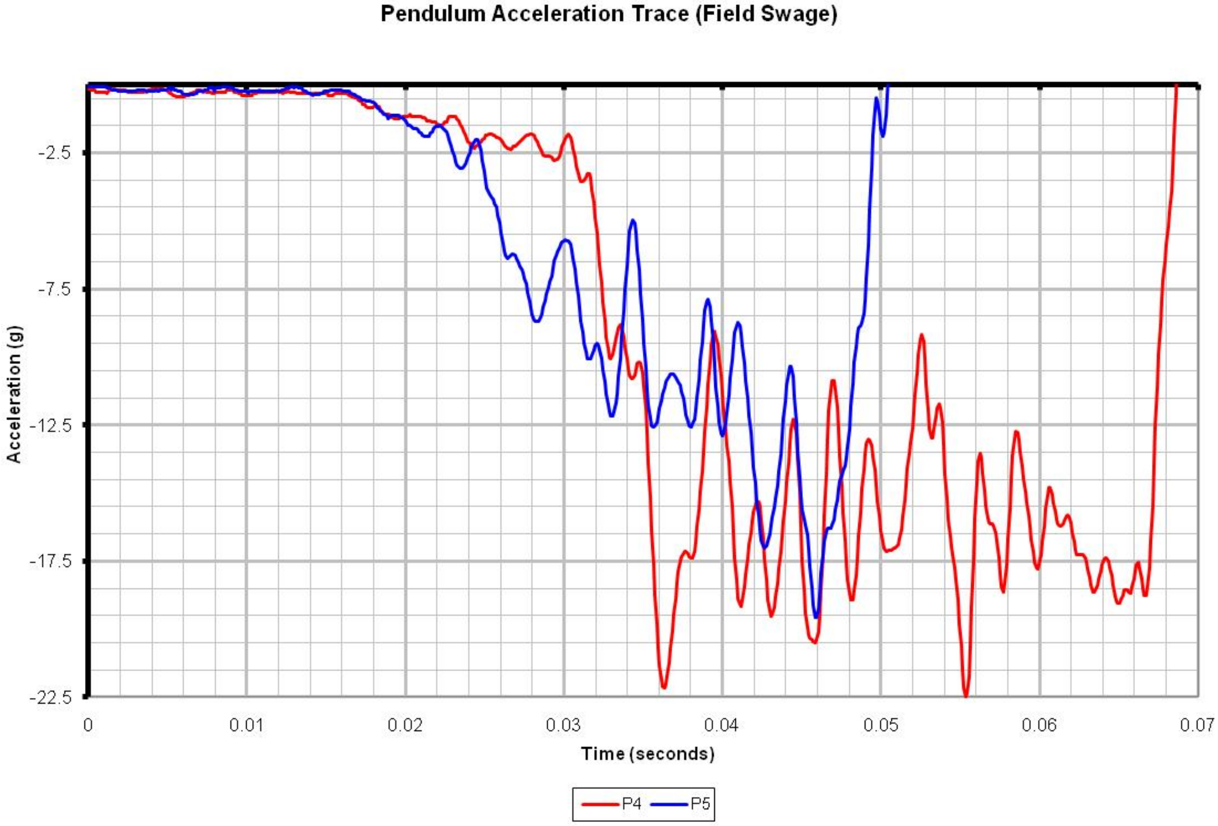


Figure 3.27. Dynamic acceleration traces for Field Swage terminations.

3.2.3 Precision Sure-Lock Prototype 2 (P6 and P7)

Test P6 ruptured the wire rope at end of the wedges at a load of 34.80 kips shown in Figure 3.28. The wire rope pulled out 1.5 inches before rupturing at the end of the wedges of termination A and 1 inch at termination B shown in Figure 3.29. At least 1 of the 21 wires ruptured at termination B. Test P7 failed with the same failure mechanism observed in test P6, at termination A. The maximum load was 33.58 kips. Again, at least 1 of 27 wires ruptured at termination B, as shown in Figure 3.30. In test P6, the wedge setting threaded collar unscrewed 6 mm during loading. This effect is thought to be caused by the unwinding of the strands in the wire rope. This could be solved by simply reversing thread direction. This behavior was not observed in test P7. The acceleration traces for these tests are shown in Figure 3.31.

Figure 3.28. Precision Sure-Lock Prototype 2 wire rope termination A after test P6.

Figure 3.29. Precision Sure-Lock Prototype 2 wire rope termination B after test P6.

Figure 3.30. Precision Sure-Lock Prototype 2 wire rope termination B after test P7.

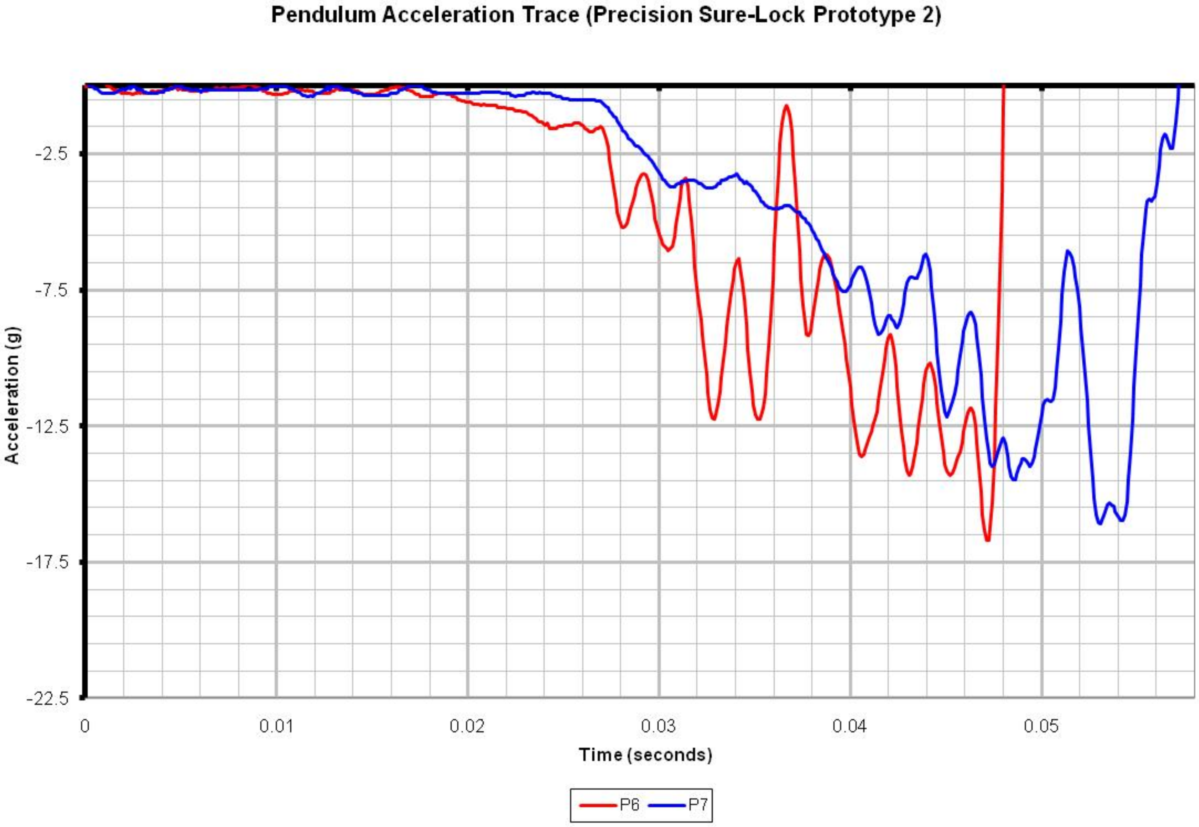


Figure 3.31. Dynamic acceleration traces for Precision Sure-Lock Prototype 2 terminations.

3.2.4 Nucor Steel Marion (NSM-P16 and NSM-P17)

Test NSM-P16 resulted in a maximum load of 35.88 kips with a pull out distance of 0.7 inch at termination B and 1.3 inches at termination A before rupturing at end of wedges, as shown in Figure 3.32 and 3.33. Test NSM-P17 exhibited the same failure mechanism as NSM-P16 except that termination B only pulled out 0.4 inch. The maximum rupture strength was 34.73 kips. The acceleration traces for these tests are shown in Figure 3.34.

Figure 3.32. Nucor Steel Marion wire rope termination A after test NSM-P16.

Figure 3.33. Nucor Steel Marion wire rope termination B after test NSM-P16.

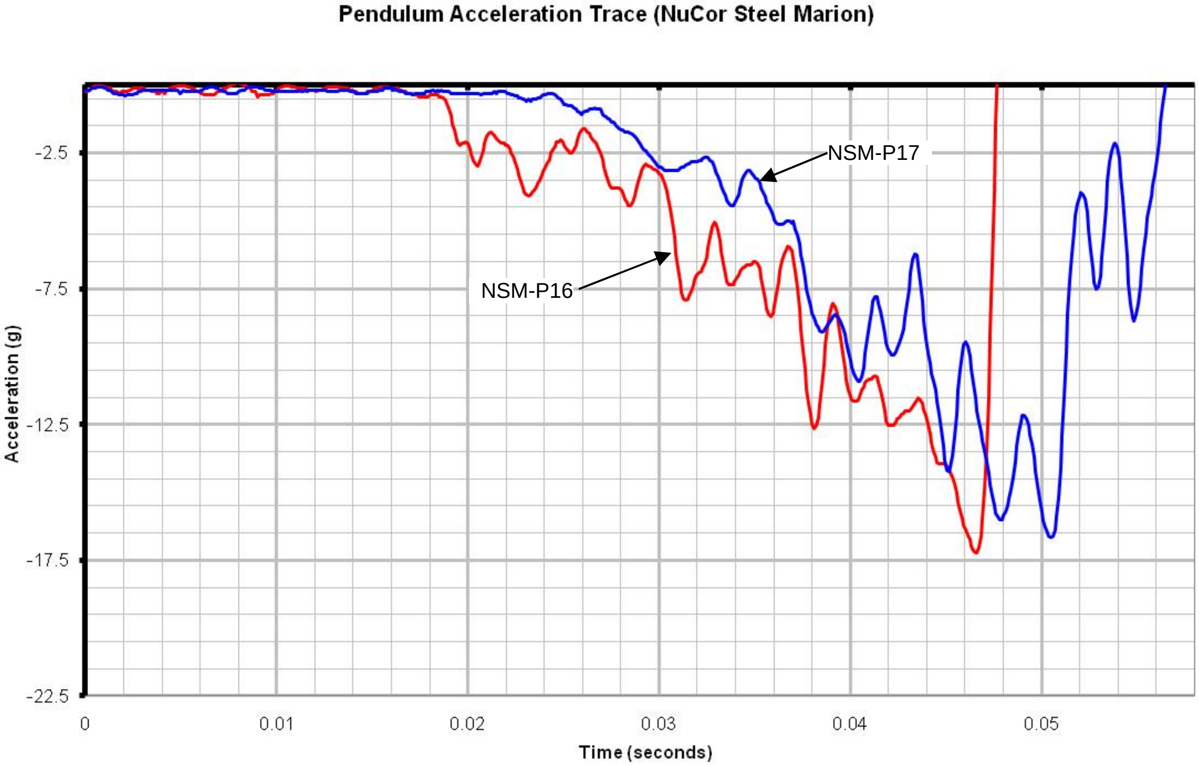


Figure 3.34. Dynamic acceleration traces for Nucor Steel Marion Inc. terminations.

3.3 SUMMARY AND CONCLUSIONS

Tables 3.1 and 3.2 contain a summary of the ultimate loads recorded for each sample under both static and dynamics load conditions. The Epoxy Socket termination resulted in the highest static load recorded (38.92 kips). The lowest recorded failure under static load is Nucor Steel Marion Inc. (31.47 kips).

The maximum load resisted under dynamic loading was the Field Swage termination (46.83 kips). The minimum load resisted under dynamic loading resulted from the Precision Sure-Lock Prototype 2 termination (33.58 kips). None of the dynamic loading tests resulted in the wire rope pulling out of the terminations. The Epoxy Socket termination will require a reevaluation of the nut and eyebolt to prevent the thread stripping that was witnessed in test number P2.

The mechanical terminations did not release the wire ropes; however, the wedges in the mechanism caused lower rupture strengths in the wire rope. It is believed the mechanical terminations do not load the entire cross-section of wire rope uniformly. Rather, only surface wires in contact with the wedge or housing develop tension and thus cause a progressive failure under ultimate load conditions. Another observation from field installations of mechanical terminations is the apparent release of the terminations under certain conditions. It is surmised the pendulum tests may have not generated sufficient transverse vibrations required to release wire rope terminations. If the mechanical terminations are to be considered, a third test should be considered before installing in the field. This test would subject the terminations to cyclic vibration under moderate tensile loads to verify retention of the wire rope. This vibration would simulate the vibration seen in crash test footage of wire rope barrier systems that have released mechanical connections. This test was beyond the scope of the budget for this project.

The researchers recommend the Field Swage termination be used as the retrofit for low tension applications. This product is easier to attach than the Epoxy Socket and performs better than the mechanical terminations.

Table 3.1. Summary of static test results.

Static Test Results

Termination Description	Test Number	Max Force (kips)	
Epoxy Socket	S1	38.92	Max
	S2	38.43	
Field Swage	S3	37.94	
	S4	32.89	
	S7	38.28	
Precision Sure-Lock Prototype 2	S5	▨ 30.00	Min*
	S6	32.20	
Nucor Steel Marion	NSM-S30	31.47	Min
	NSM-S31	32.03	

▨ Data Recording System Failed (Termination failed at approximately 30 kips)

Table 3.2. Summary of dynamic test results.

Mass of Pendulum (lbs)	2085

Dynamic Test Results

Termination Description	Test Number	Max Acceleration (g)	Max Force (kips)	
Epoxy Socket	P1	-17.77	37.04	
	P2	-18.40	38.37	
	P3	-20.86	43.49	
Field Swage	P4	-22.46	46.83	Max
	P5	-19.55	40.77	
Precision Sure-Lock Prototype 2	P6	-16.69	34.80	
	P7	-16.10	33.58	Min
Nucor Steel Marion	NSM-P16	-17.21	35.88	
	NSM-P17	-16.66	34.73	

CHAPTER 4: BENEFITS AND CONSEQUENCES OF CONVERTING LOW TENSION SYSTEMS TO HIGHER TENSION SYSTEMS

4.1 BENEFITS

Certain aspects of low tension wire rope systems could potentially be improved by converting the system to a high tension system. Both the low tension of the system and the travel in the spring compensators contribute to larger deflections. High tension systems without spring compensators have reduced dynamic deflections.

Additionally, the added tension in high tension systems can often sustain the wire ropes at or near their installation heights after an impact. After impacts into low tension wire rope system, the wire rope often drops to the ground providing no protection against secondary impacts prior to repairs. Figures 4.1 and 4.2 show images of high and low tension wire rope system after being impacted.

The maximum lengths of high tension systems are significantly greater than low tension systems. The maximum length of a low tension system is 2000 ft.(7) Therefore, high tension systems require fewer terminals for long continuous runs. This reduces cost of wire rope system installations by reducing the number of required end terminals.

Figure 4.1. Image showing a low tension system after being impacted. (5)

Figure 4.2. Image showing a high tension system after being impacted. (6)

4.2 CONSEQUENCES

The new York low tension terminal is not capable of developing the required anchorage needed to convert the low tension system to a high tension system. Considerable forces are generated by the high tension wire ropes and there will likely be movement of the low tension concrete terminal block and failure of slip base terminal post. Therefore, all low tension terminals will need to be replaced with an FHWA accepted high tension terminal.

CHAPTER 5: *NCHRP REPORT 350* TL-3 COMPLIANCE TEST OF EPOXY SOCKET TERMINATIONS

5.1 TEST PARAMETERS

5.1.1 Test Facility

The test facilities at the Texas Transportation Institute's Proving Ground consist of a 2000 acre complex of research and training facilities situated 10 miles northwest of the main campus of Texas A&M University. The site, formerly an Air Force Base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for the placement of the low-tension wire rope barrier system was along the edge of a wide out-of-service apron. The apron consists of an unreinforced jointed concrete pavement in 12.5 ft by 15 ft blocks nominally 8-12 inches deep. The apron is over 50 years old and the joints have some displacement, but are otherwise flat and level.

5.1.2 Test Article – Design and Construction

The test installation was 476 ft long. It consisted of a 336 ft length modified "Weak-Steel Post Wire Rope Guardrail System SGR01a-b"(7) with high-tension terminal on each end. Details are shown in Figures 5.1 through 5.8 and Appendix C. Wire rope heights are the same as detailed in the SGR01a-b specification. The system was terminated with Trinity terminals that utilize wire rope Controlled Release Posts (CRP) as shown in Figures 5.2 and 5.4. Standard 3x7 non-prestretched wire ropes were used to match field applications of the system. A splice connection was placed in the second clear span downstream of first contact with the test vehicle, as shown in Figure 5.3.

A Crosby 3/4-inch G-416 epoxy socket was used for termination of each wire rope. The epoxy socket termination preformed as well as the field swage termination; however, this termination presented a higher risk of an unsuccessful full-scale test due to snagging at the termination site. It is expected that if the epoxy socket termination is successful the field swage would also be successful. Each epoxy socket requires 86 cc of Crosby Wirelock W416-7 socket compound. A standard Crosby HG-226 1-inch x 12-inch eye and eye turnbuckle were used to connect the two epoxy sockets at each splice. A 1-inch x 6-inch Crosby G-291 eye bolt with double nuts was used to terminate the wire ropes at the CRP. A detail of each of these components can be found in Figure 5.6.

Tension of the wire ropes prior to the full-scale crash test was 5620-5640 lb. Photographs of the completed installation are shown in Figure 5.9.

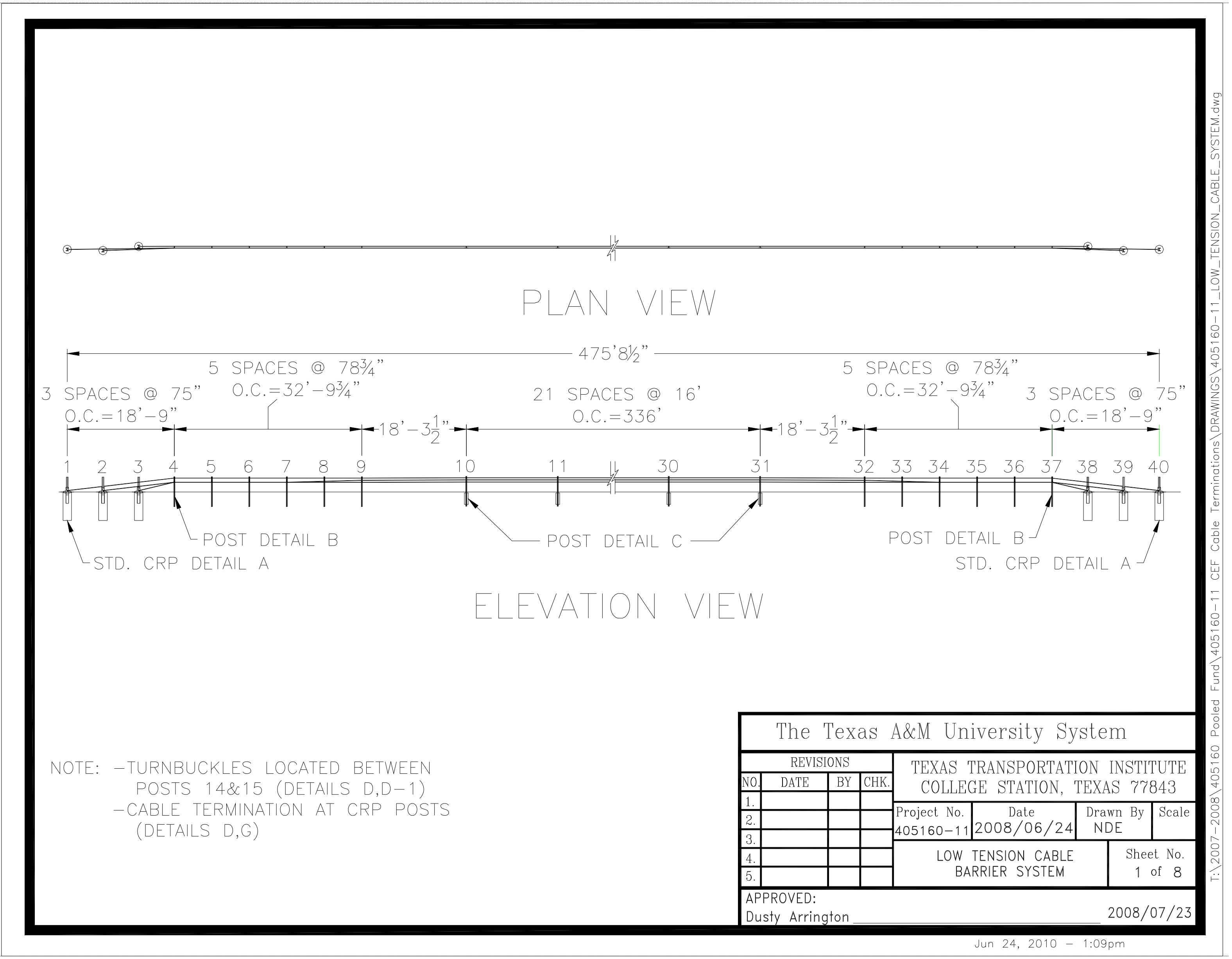
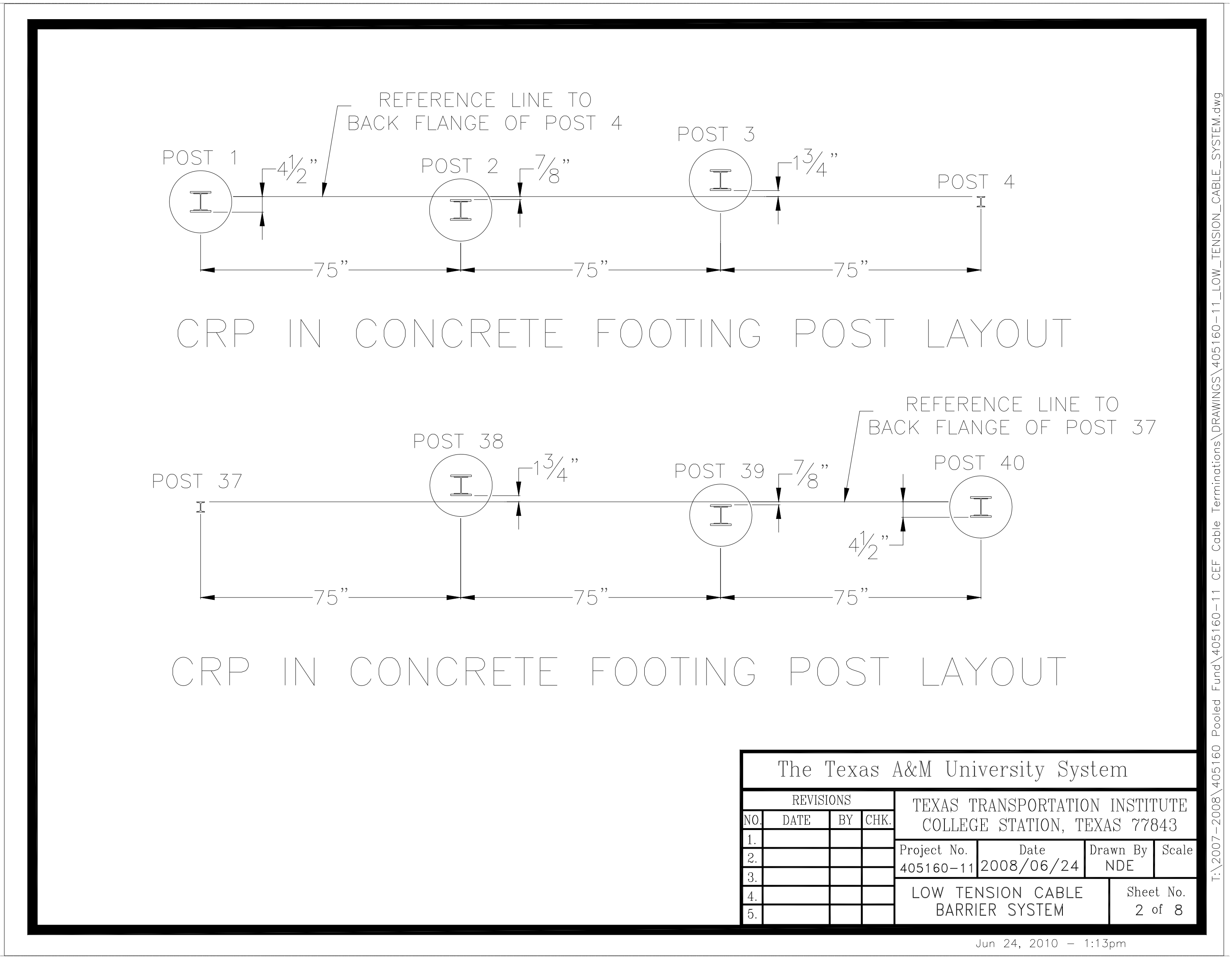


Figure 5.1. Details of retrofitted low-tension wire rope barrier system – installation layout.



The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.			
2.			
3.			
4.			
5.			

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2008/06/24	NDE	

LOW TENSION CABLE
BARRIER SYSTEM

Sheet No.
2 of 8

Figure 5.2. Details of retrofitted low-tension wire rope barrier system – CRP layout.

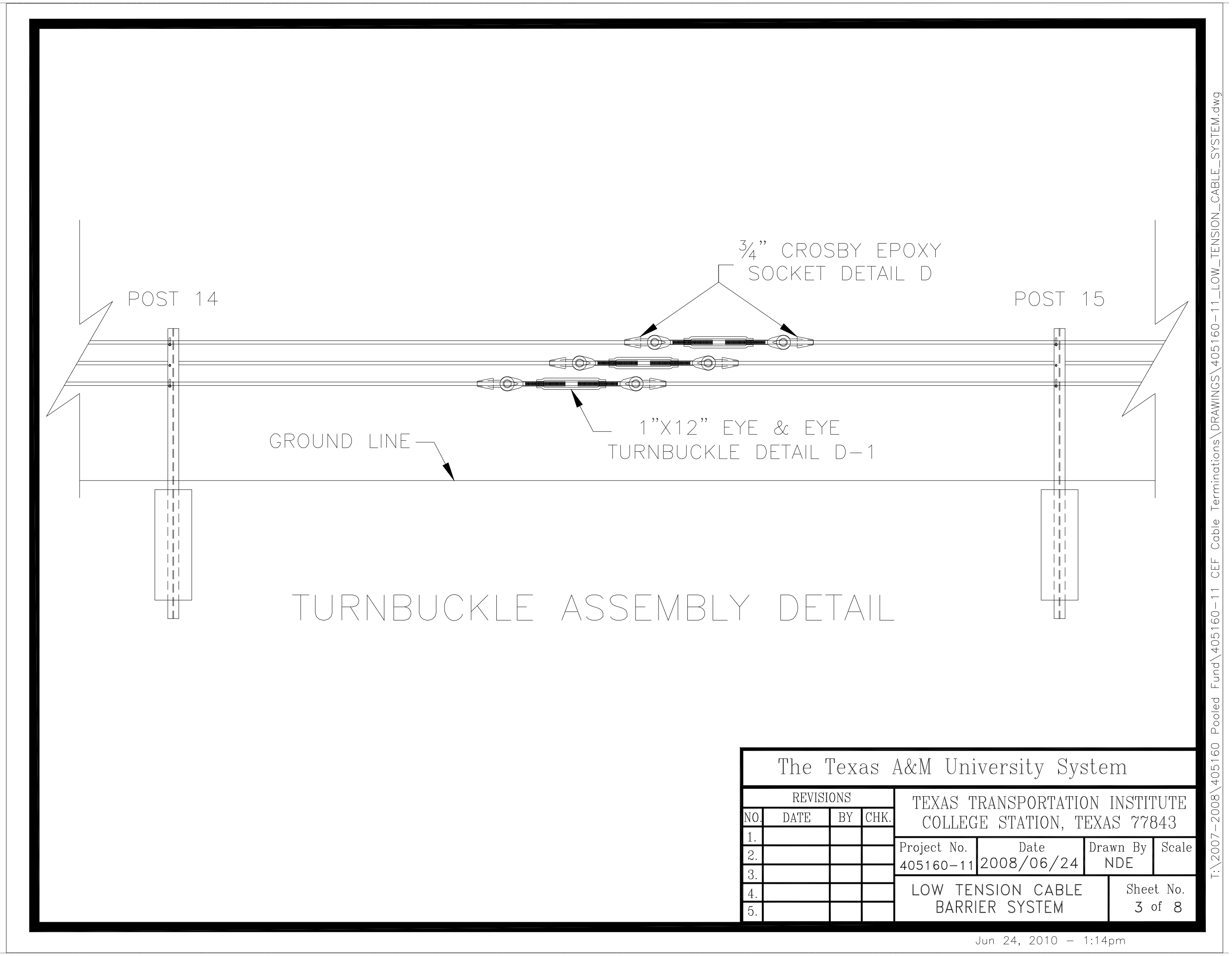


Figure 5.3. Details of retrofitted low-tension wire rope barrier system – turnbuckle assembly.

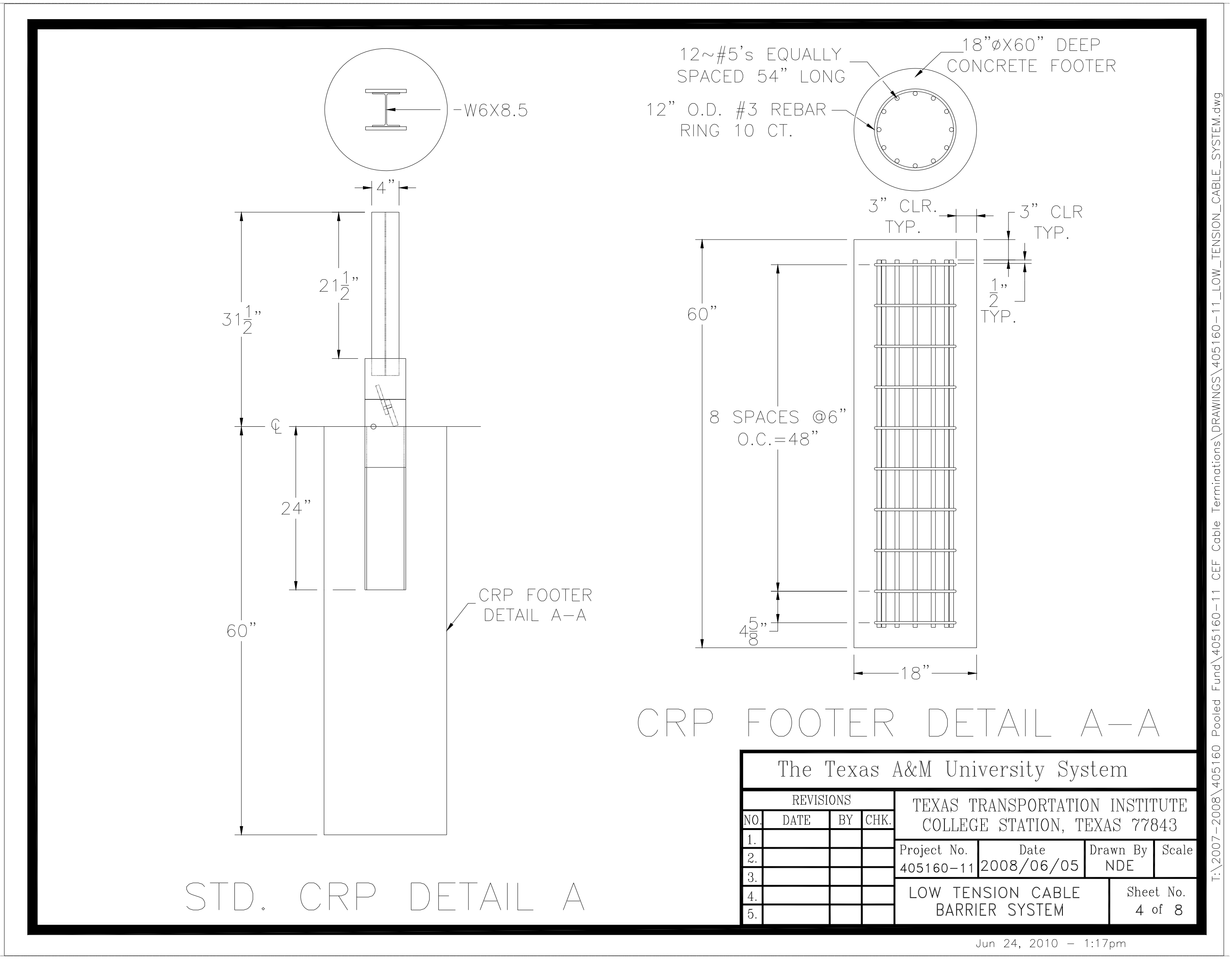


Figure 5.4. Details of retrofitted low-tension wire rope barrier system – CRP detail.

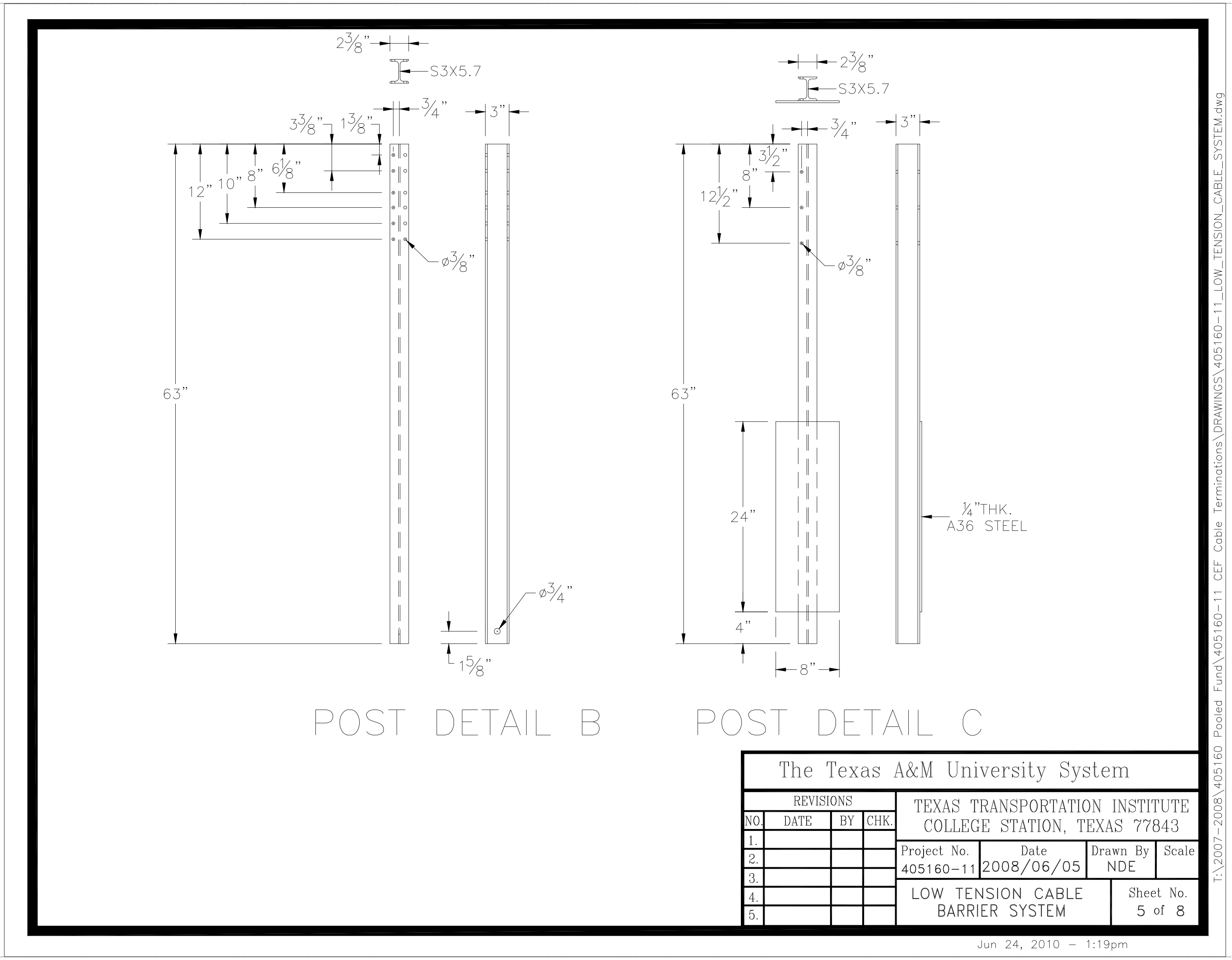


Figure 5.5. Details of retrofitted low-tension wire rope barrier system – post details.

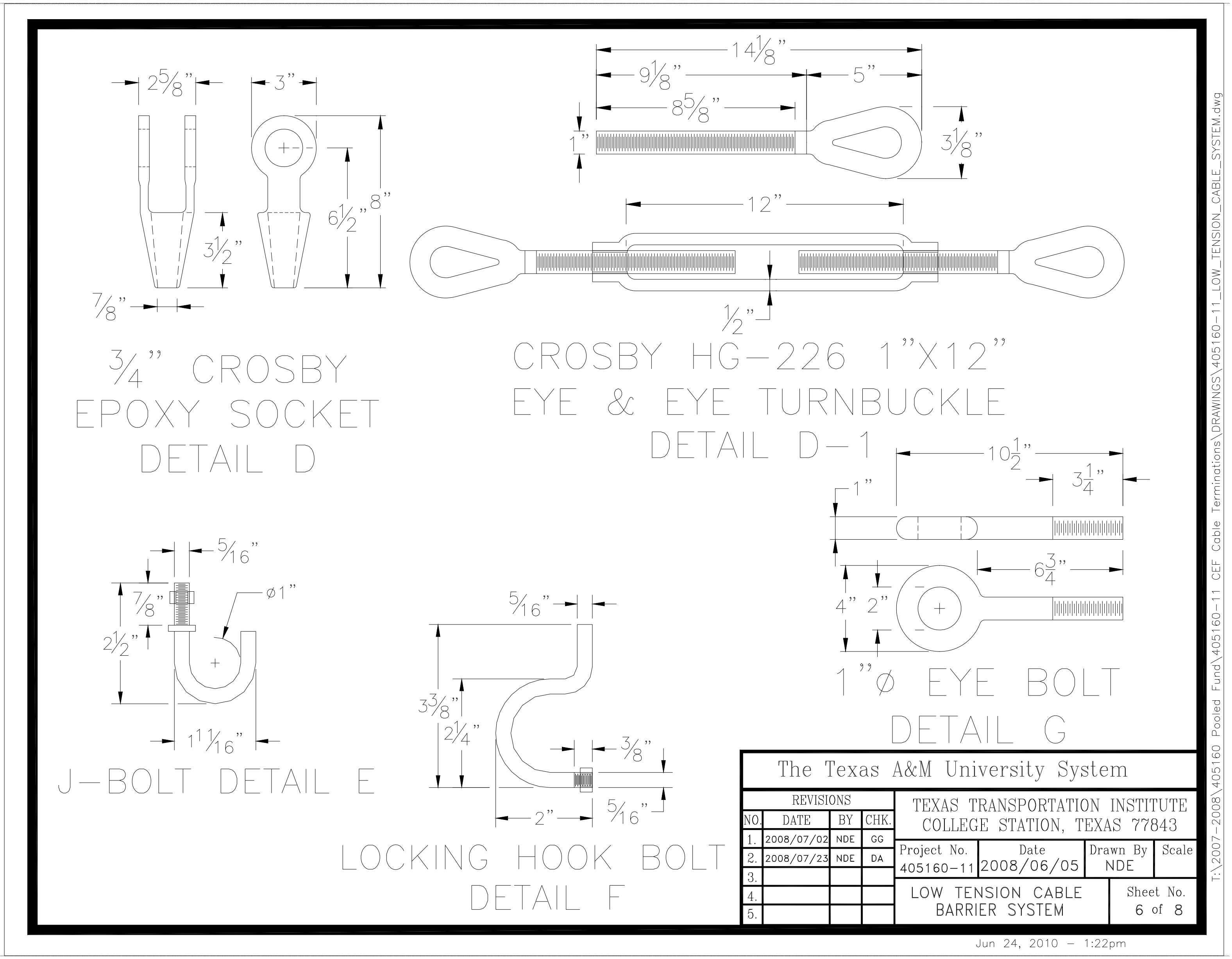


Figure 5.6. Details of retrofitted low-tension wire rope barrier system – CRP layout.

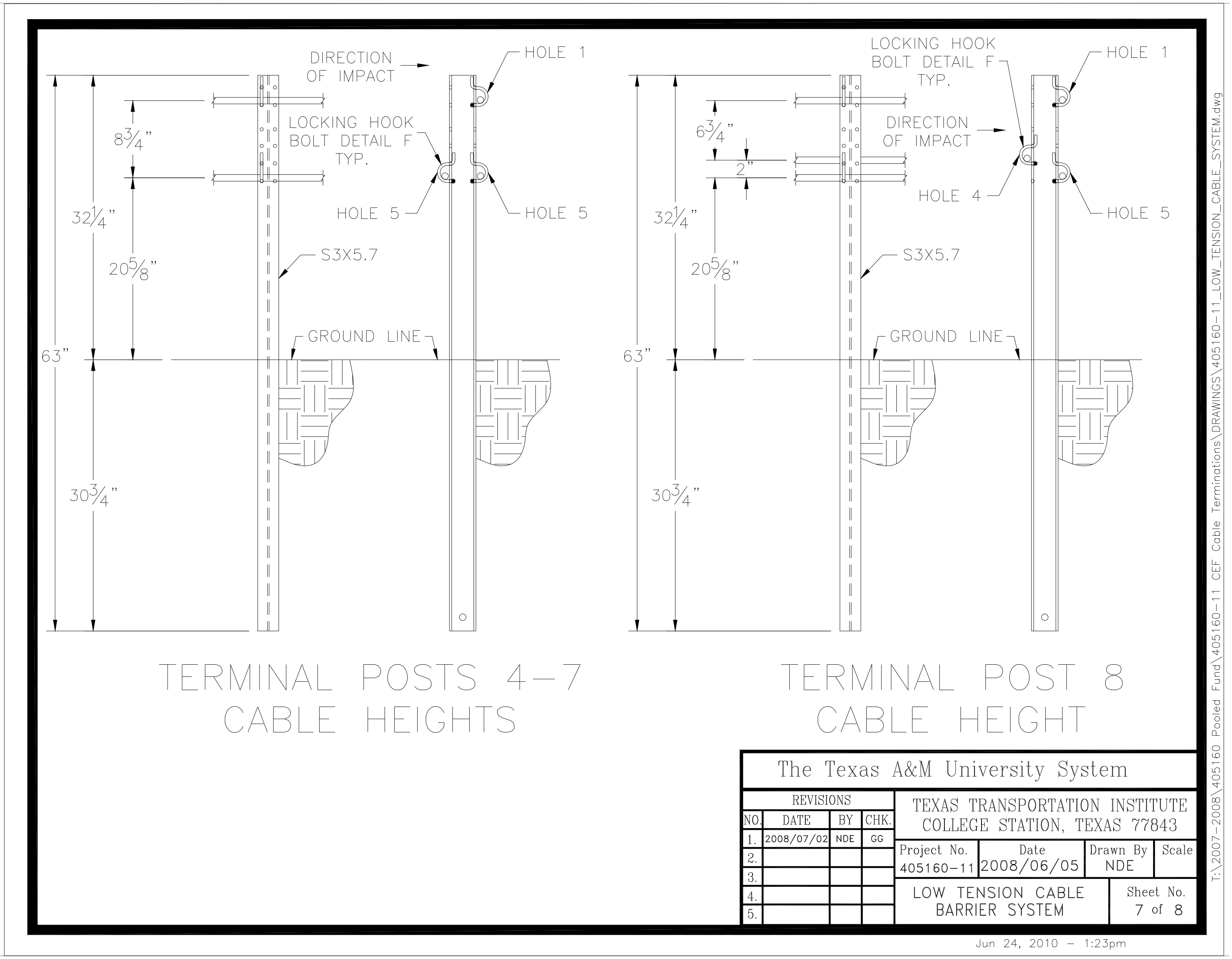


Figure 5.7. Details of retrofitted low-tension wire rope barrier system – terminal post wire rope heights.

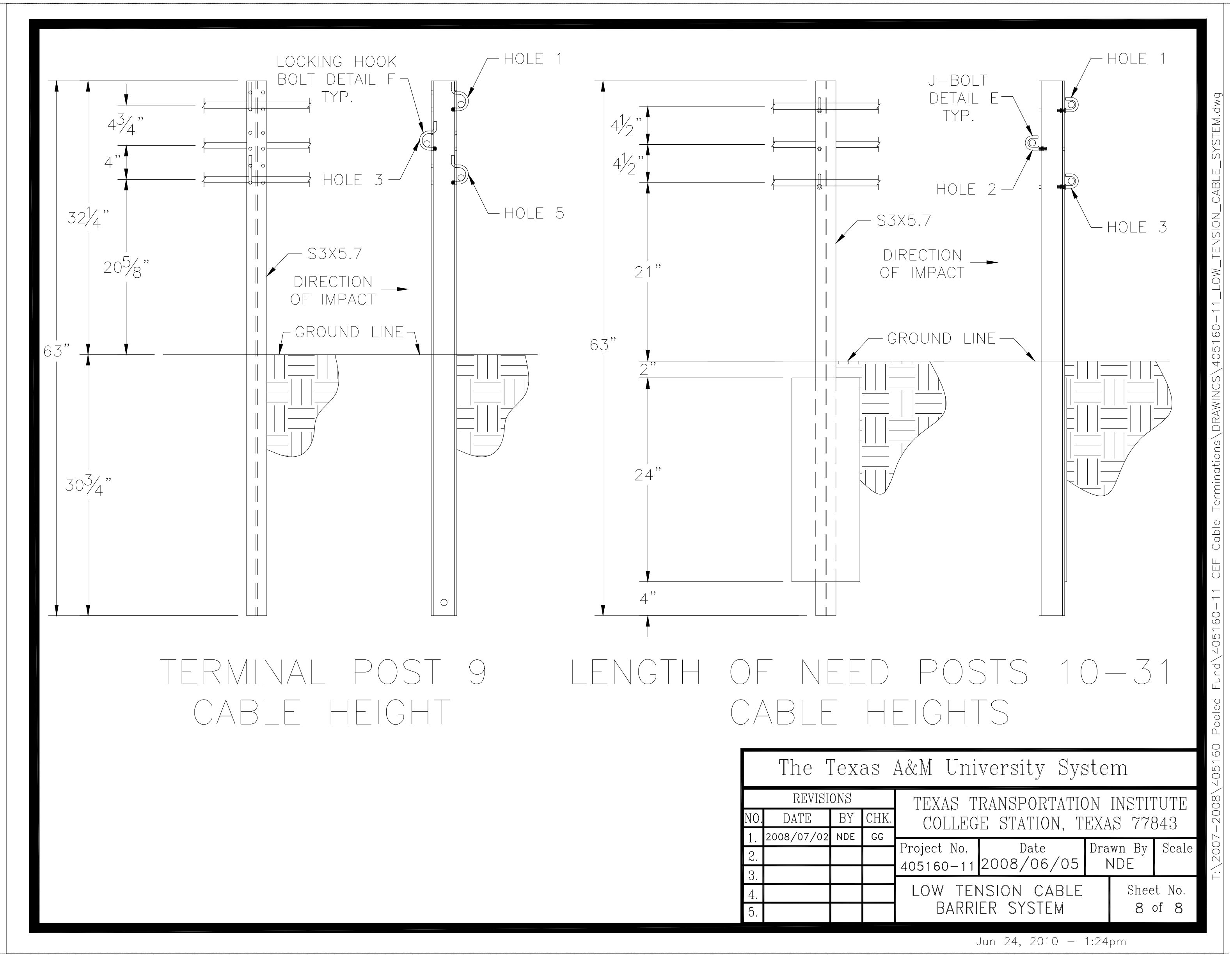


Figure 5.8. Details of retrofitted low-tension wire rope barrier system – LON post wire rope heights.

Figure 5.9. Retrofitted Low-tension wire rope barrier system prior to testing.

5.1.3 Test Conditions

According to *NCHRP Report 350*, two tests are recommended to evaluate longitudinal barriers to test level 3 (TL-3) details of which are described below.

> ***NCHRP Report 350* test designation 3-10**: An 1808 lb passenger car impacting the critical impact point (CIP) of the length-of-need (LON) at a nominal speed and angle of 62 mi/h and 20 degrees, respectively. The purpose of this test is to evaluate the overall performance of the LON section in general, and occupant risk in particular.
>
> ***NCHRP Report 350* test designation 3-11**: A 4409 lb pickup truck impacting the CIP of the LON at a nominal speed and angle of 62 mi/h and 25 degrees, respectively. The test is intended to evaluate the strength of the LON section in containing and redirecting the pickup truck.

The test reported herein corresponds to *NCHRP Report 350* test designation 3-11. Target impact point was post 13.

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*. Appendix D presents brief descriptions of these procedures.

5.1.4 Evaluation Criteria

The crash test was evaluated in accordance with the criteria presented in *NCHRP Report 350*. As stated in *NCHRP Report 350*, "Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision." Safety evaluation criteria from table 5.1 of *NCHRP Report 350* were used to evaluate the crash test reported herein.

5.2 CRASH TEST 405160-11-1 (*NCHRP REPORT 350* TEST NO. 3-11)

5.2.1 Test Vehicle

A 1999 Chevrolet C2500 pickup truck, shown in Fgures 5.10 and 5.11, was used for the crash test. Test inertia weight of the vehicle was 4522 lb, and its gross static weight was 4522 lb. The height to the lower edge of the vehicle front bumper was 16.4 inches, and the height to the upper edge of the front bumper was 25.0 inches. Additional dimensions and information on the vehicle are given in Appendix E, Figure E1. 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.

Figure 5.10. Vehicle/installation geometrics for test 405160-11-1.

Figure 5.11. Vehicle before test 405160-11-1.

5.2.2 Soil and Weather Conditions

The crash test was performed the morning of July 11, 2008. A total of 0.27 inch of rainfall was recorded four days prior to the test. Moisture content of the *NCHRP Report 350* soil in which the test article was installed was 6.8 percent. Weather conditions at the time of testing were: Wind speed: 11 mi/h; wind direction: 180 degrees with respect to the vehicle (vehicle was traveling in a northeasterly direction); temperature: 85 ºF; relative humidity: 68 percent.

5.2.3 Impact Description

The 1999 Chevrolet C2500 pickup truck, traveling at an impact speed of 62.3 mi/h, impacted the wire rope barrier at post 13 at an impact angle of 25.4 degrees. Shortly after impact, post 13 began to deflect toward the field side, and by 0.017 s, the left front tire contacted post 13. At 0.020 s, the middle wire rope contacted the left front fender just above the bumper, and the top wire rope contacted the left front fender 4 inches above the bumper. The wire rope hook released the top wire rope at post 13 at 0.034 s, and the bottom wire rope released from post 14 at 0.044 s. The bottom wire rope contacted the left front tire at 0.057 s, and then released from post 13 at 0.059 s. At 0.064 s, post 12 began to deflect toward impact, and at 0.080 s, the vehicle began to redirect. The left front tire of the vehicle rode over the bottom wire rope at 0.103 s, and post 15 began to deflect toward impact at 0.169 s. The middle wire rope lifted over post 13 at 0.187 s. The vehicle began to yaw clockwise at 0.579 s, and subsequently came to rest within the wire ropes over post 31. Sequential photographs of the test period are shown in Appendix F, Figures F1 and F2.

5.2.4 Damage to Test Article

Damage to the low-tension wire rope barrier system is shown in Figures 5.12 and 5.13. The soil around posts 1 and 2 was disturbed, and the middle wire rope was pulled 0.1 inch in the turnbuckle assembly. The top and bottom wire ropes separated from posts 10 and 11, and post 11 had moved toward the field side 2.4 inches (residual 0.8 inch), and was leaned toward the field side 6 degrees. All wire ropes were released from posts 12-31. Post 12 had moved toward the field side 4.3 inches (residual 2.0 inches) and was leaned toward the field side 12 degrees. Post 13 rotated 45 degrees counterclockwise and was leaning toward the field side and downstream 25 degrees. Post 14 rotated 90 degrees counterclockwise and was leaning toward the field side 60 degrees and downstream 30 degrees. Post 15 had moved toward the field side 0.8 inch and was leaned toward the field side 14 degrees. Post 16 rotated 45 degrees counterclockwise and was leaning toward the field side and downstream 30 degrees. Post 17 had moved toward the field side 0.8 inch and was leaned toward the field side 12 degrees. Post 18 rotated 90 degrees clockwise and was leaning downstream 30 degrees. Posts 19-30 were leaning downstream 70 degrees. Post 31 was under the truck, and post 39 was pulled up 0.4 inch. The soil around posts 38 and 40 was disturbed. Maximum dynamic deflection during the test was 10.2 ft at a point 4.9 ft downstream of post 16.

Figure 5.12. Vehicle trajectory path after test 405160-11-1.

Figure 5.13. Installation after test 405160-11-1.

5.2.5 Vehicle Damage

The pickup truck sustained damage to the front and left side as shown in Figure 5.14. No structural damage occurred. However, the windshield cracked at the left lower corner at the A-pillar, the instrument panel was deformed, and there was a small tear into the occupant compartment in the kickpanel on the left side. Also damaged were the front bumper, hood, grill, right and left front fenders, left door, right and left rear exterior bed, and rear bumper. Maximum exterior crush was 11.8 inches in the left side plane just above bumper height. Maximum occupant compartment deformation was 2.2 inches at the left side kickpanel (laterally across the floor pan). Photographs of the interior of the vehicle are shown in figure 5.15. Exterior vehicle crush and occupant compartment measurements are shown in Appendix E, Tables E1 and E2.

5.2.6 Occupant Risk Factors

Data from the triaxial accelerometer located at the vehicle center of gravity were digitized to compute occupant impact velocity and ridedown accelerations. Only the occupant impact velocity and ridedown accelerations in the longitudinal axis are required from these data for evaluation of criterion L of *NCHRP Report 350*. In the longitudinal direction, occupant impact velocity was 6.9 ft/s (2.1 m/s) at 0.198 s, maximum 0.010-s ridedown acceleration was -16.4 g's from 0.365 to 0.375 s, and the maximum 0.050-s average was -3.8 g's between 0.324 and 0.374 s. In the lateral direction, the occupant impact velocity was 10.5 ft/s (3.2 m/s) at 0.198 s, the highest 0.010-s occupant ridedown acceleration was 15.2 g's from 0.376 to 0.386 s, and the maximum 0.050-s average was 5.5 g's between 0.336 and 0.386 s. These data and other information pertinent to the test are presented in Figure 5.16. Vehicle angular displacements and accelerations versus time traces are shown in Appendix G, Figures G1 through G7.

5.3 ASSESSMENT OF TEST RESULTS

An assessment of the test based on the following applicable *NCHRP Report 350* safety evaluation criteria.

Structural Adequacy

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

Results: The modified low-tension wire rope barrier system contained and redirected the 2000P vehicle. The vehicle rode over two of the wire ropes, which were under the vehicle as it came to rest. Maximum dynamic deflection during the test was 10.2 ft. (PASS)

Figure 5.14. Vehicle after test 405160-11-1.

General Information	
Test Agency	Texas Transportation Institute
Test No.	405160-11-1
Date	2008-07-11
Test Article	
Type	Longitudinal Barrier
Name	Retrofitted wire rope Barrier System
Installation Length (ft)	476
Material or Key Elements	SGR01a-b with 3x7 non-prestretched wire rope tensioned to 5620-5640 lb and epoxy sockets
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1999 Chevrolet C2500 Pickup Truck
Mass (lb)	
Curb	4894
Test Inertial	4522
Dummy	No dummy
Gross Static	4522

Impact Conditions	
Speed (mi/h)	62.3
Angle (deg)	25.4
Exit Conditions	
Speed (mi/h)	N/A
Angle (deg)	N/A
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	6.9
Lateral	10.5
THIV (km/h)	13.5
Ridedown Accelerations (g's)	
Longitudinal	-16.4
Lateral	15.2
PHD (g's)	16.9
ASI	0.67
Max. 0.050-s Average (g's)	
Longitudinal	-3.8
Lateral	5.5
Vertical	-2.3

Test Article Deflections (ft)	
Dynamic	10.2
Permanent	N/A
Working Width	11.0
Vehicle Damage	
Exterior	
VDS	11LD2
CDC	11LDEW2
Max. Exterior Vehicle Crush (inches)	11.8
Interior	
OCDI	LF1000000
Max. Occupant Compartment Deformation (inches)	2.2
Post-Impact Behavior	
(during 1.0 sec after impact)	
Max. Yaw Angle (deg)	33
Max. Pitch Angle (deg)	5
Max. Roll Angle (deg)	17

Figure 5.15. Summary of results for *NCHRP Report 350* test 3-11 on the low-tension wire rope barrier system.

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 that could cause serious injuries should not be permitted.*

Results: The wire ropes detached from some of the posts, however, no loose posts or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2.2 inches laterally across the floorpan. (PASS)

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

Results: The 2000P vehicle remained upright during and after the collision event. (PASS)

Vehicle Trajectory

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

Result: The 2000P vehicle came to rest within the barrier system and did not intrude into adjacent traffic lanes. (PASS)

L. *The occupant impact velocity in the longitudinal direction should not exceed 12 m/s and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.*

Result: Longitudinal occupant impact velocity was 6.9 ft/s (2.1 m/s), and longitudinal ridedown acceleration was -16.4 g's. (PASS)

M. *The exit angle from the test article preferably should be less than 60 percent of the test impact angle, measured at time of vehicle loss of contact with the test device.*

Result: The vehicle did not exit the system. (PASS)

The following supplemental evaluation factors and terminology, as presented in the FHWA memo entitled "Action: Identifying Acceptable Highway Safety Features," were used for visual assessment of test results: (8)

Passenger Compartment Intrusion

1. *Windshield Intrusion*
    - *[✓ a. No windshield contact]*
    - *b. Windshield contact, no damage*
    - *c. Windshield contact, no intrusion*
    - *d. Device embedded in windshield, no significant intrusion*
    - *e. Complete intrusion into passenger compartment*
    - *f. Partial intrusion into passenger compartment*
2. *Body Panel Intrusion* *[✓ yes] or no*

Loss of Vehicle Control

1. *[✓ Physical loss of control]*
2. *Loss of windshield visibility*
3. *Perceived threat to other vehicles*
4. *Debris on pavement*

Physical Threat to Workers or Other Vehicles

1. *Harmful debris that could injure workers or others in the area*
2. *Harmful debris that could injure occupants in other vehicles*

[✓ No debris present.]

Vehicle and Device Condition

1. *Vehicle Damage*
    - *a. None*
    - *b. Minor scrapes, scratches or dents*
    - *c. Significant cosmetic dents*
    - *[✓ d. Major dents to grill and body panels]*
    - *e. Major structural damage*
2. *Windshield Damage*
    - *a. None*
    - *[✓ b. Minor chip or crack]*
    - *c. Broken, no interference with visibility*
    - *d. Broken or shattered, visibility restricted but remained intact*
    - *e. Shattered, remained intact but partially dislodged*
    - *f. Large portion removed*
    - *g. Completely removed*
3. *Device Damage*
    - *a. None*
    - *b. Superficial*
    - *c. Substantial, but can be straightened*
    - *[✓ d. Substantial, replacement parts needed for repair]*
    - *e. Cannot be repaired*

5.4 CONCLUSIONS

The modified low-tension wire rope barrier system meets all requirements for *NCHRP Report 350* test designation 3-11, as shown in Table 5.1.

Table 5.1. Performance evaluation summary for *NCHRP Report 350* test 3-11 on the low-tension wire rope barrier system.

Test Agency: Texas Transportation Institute Test No.: 405160-11-1 Test Date: 2008-07-11

NCHRP Report 350 **Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The low-tension wire rope barrier system contained and redirected the 2000P vehicle. The vehicle rode over two of the wire ropes, which were under the vehicle as it came to rest. Maximum dynamic deflection during the test was 10.2 ft.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*	The wire ropes detached from some of the posts; however, no loose posts or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2.2 inches laterally across the floorpan.	Pass
F. The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.	The 2000P vehicle remained upright during and after the collision event.	Pass
Vehicle Trajectory *K. After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*	The 2000P vehicle did not intrude into adjacent traffic lanes, as it came to rest within the barrier system.	Pass*
L. The occupant impact velocity in the longitudinal direction should not exceed 12 m/s and the occupant ridedown acceleration in the longitudinal direction should not exceed 20 g's.	Longitudinal occupant impact velocity was 6.9 ft/s (2.1 m/s), and longitudinal ridedown acceleration was -16.4 g's.	Pass
M. The exit angle from the test article preferably should be less than 60 percent of test impact angle, measured at time of vehicle loss of contact with test device.	The vehicle did not exit the system.	Pass*

*Criterion K and M are preferable, not required.

CHAPTER 6: ADDITION OF FOURTH WIRE ROPE

6.1 NCAC VEHICLE TRAJECTORY DATA

The National Crash Analysis Center (NCAC) conducted a study on vehicle trajectories crossing various sloped median ditches.(9) This study investigated various ditch slopes and widths to develop design charts to help determine cable barrier rope heights and barrier placement on slopes. Low tension wire rope barrier systems are accepted for use on ditches with a slope of 6:1 or less. For this reason only trajectories across 6:1 slopes were reviewed in this report.

Figure 6.1 is a preliminary design chart developed by NCAC for a 32 ft wide 6:1 V-ditch. The research indicated that most low tension systems are installed on ditches similar to this configuration. The top chart in Figure 6.1 shows an overlay of the three wire rope heights found in a standard low tension wire rope barrier system. As shown in the chart, the system (without an additional wire rope) should contain and redirect a vehicle if the barrier is placed within 9 ft from the slope break. Beyond that point the small car has an increased potential for underriding the barrier.

The second chart in Figure 6.1 shows an overlay of a generic four wire rope system. The bottom wire rope in this system is 13.5 inches above the ground. Notice that the acceptable offset of the barrier, from the slope break point, has increased from 9 ft to approximately11.5 ft. It also should be noted that the acceptable placement region at the center of the ditch has increased to approximately 3 ft from the ditch centerline.

Figure 6.2 is a NCAC preliminary design chart for a 16 ft wide 6:1 V-ditch. This ditch configuration indicates a vulnerability to under ride at all barrier offset distances under 7 ft. This added vulnerability is due to the suspension being compressed while traversing much of the back slope.

The second chart in Figure 6.2 again shows an overlay of a generic four wire rope system. The bottom wire rope in the system is 13.5 inches above the ground. Notice the acceptable offset of the barrier now encompasses the entire ditch profile. According to Figure 6.2, adding a fourth wire rope should have a positive effect on the performance of standard low tension 3-wire rope median barrier placed in 16 ft wide median ditches.

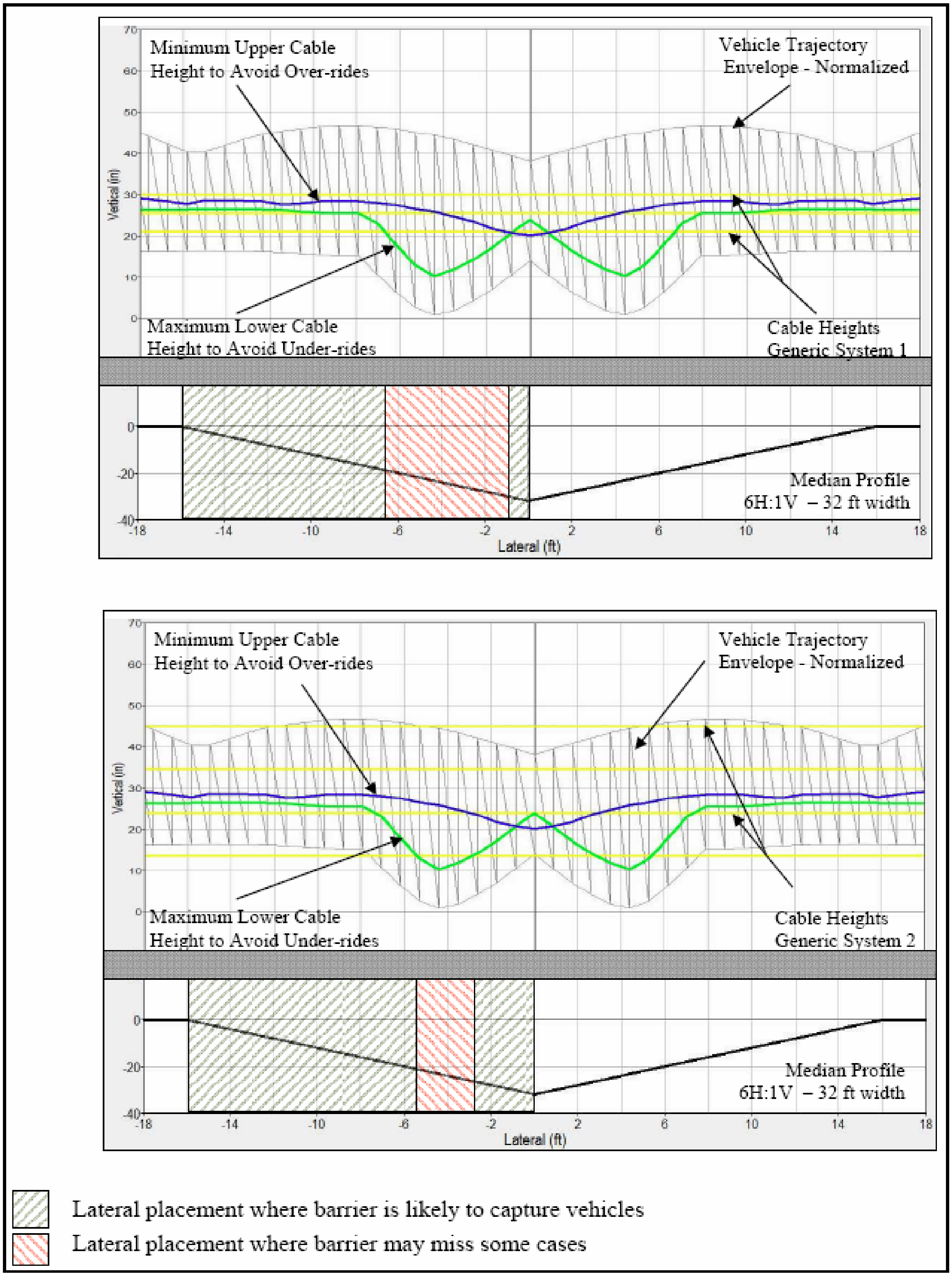


Figure 6.1. Vehicle trajectory envelopes from NCAC for a 6:1-32 ft ditch.

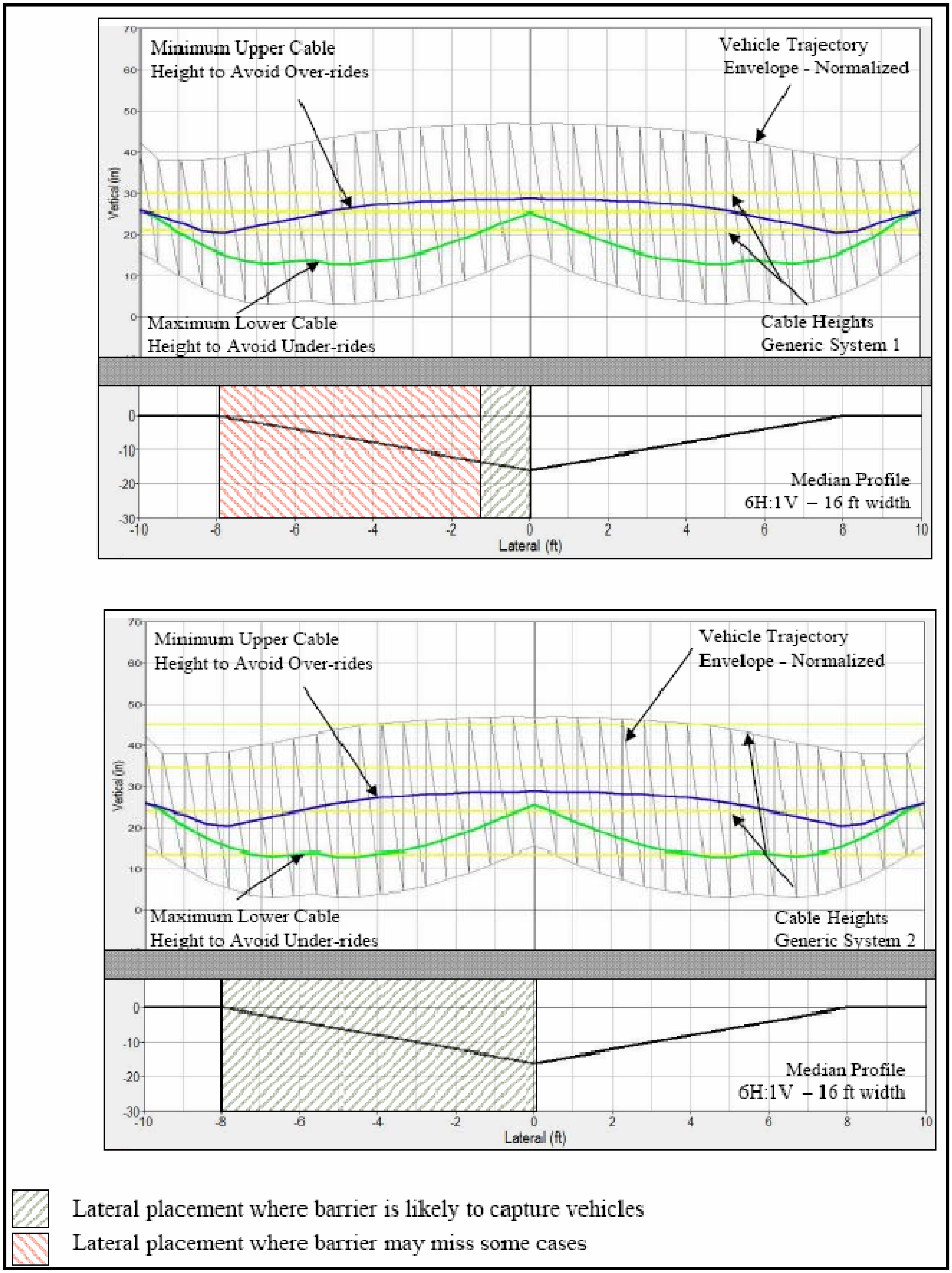


Figure 6.2. Vehicle trajectory envelopes from NCAC for a 6:1-16 ft ditch.

6.2 MWRSF METHOD FOR DETERMINING BOTTOM WIRE ROPE HEIGHT

Midwest Roadside Safety Facility (MwRSF) was contacted regarding any research conducted to determine lower wire rope height for cable barrier systems placed in 6:1 ditches. The MwRSF researchers indicated they had not conducted any research on 6:1 ditches. MwRSF has, however, performed several LS-DYNA simulations for the placement of a wire rope system in a 4:1 ditch. The simulations were used to determine the location in the ditch that presents the highest probability of an under ride by a small car.

According to MwRSF research, the greatest opportunity for vehicle under ride is when a small car has its suspension compressed and its front bumper in contact with the ground. To determine an appropriate wire rope height for this condition, MwRSF did a study of bumper/hood vertical dimensions to identify a critical capture height. MwRSF research showed the critical height to capture most small cars is approximately 10 to 13.5 inches.

6.3 RECOMMENDATION

Low tension systems installed at locations with a demonstrated propensity for vehicle under rides could benefit from the addition of a fourth wire rope. The data from NCAC and MwRSF indicates the lower additional wire rope should not be placed higher than 13.5 inches above grade.

CHAPTER 7: RECOMMENDATIONS

7.1 RECOMMENDATIONS FROM STATIC AND DYNAMIC TESTING OF TERMINATION METHODS

As described in Chapter 2, the Field Swage termination and the Epoxy Socket performed the best under dynamic and static loading conditions. The wire rope end should always be marked with the correct embedment depth before starting the swaging process. This assures the wire rope is inserted the correct distance into the termination and identifies the presence of possible zinc plugs that may accumulate in the terminations. It is also noted that all eyebolts used with the Epoxy Socket termination should utilize two nuts to prevent the stripping of threads (this failure mode was witnessed in dynamic testing, using single nuts, of the Epoxy Sockets) in an impact event. Both terminations will provide the full strength of the connected wire rope if installed properly. Mechanical terminations may have sufficient capacity, however, further testing needs to be done to verify that they will not release wire rope when subjected to rope oscillations during a redirection impact.

7.2 RECOMMENDATIONS FOR CONVERTING FROM LOW TO HIGH TENSION SYSTEM

If accident history indicates a high propensity for cross-over type accidents on an installed low tension system, conversion to a high tension system could improve its ability to contain and redirect secondary impacts that occur before maintenance crews repair impacted barriers. This process will require the low tension terminals to be replaced with FHWA accepted high tension terminals. The spring compensators will need to be removed and the terminations should be replaced.

7.3 RECOMMENDATIONS FROM FULL SCALE CRASH TEST

The retrofitted system as detailed in Chapter 5 has met the criteria for *NCHRP Report 350* TL-3. However, the large size and mass of the Epoxy Socket termination have raised questions about performance when impacted by a smaller vehicle. It is possible that the large Epoxy Socket terminations could cause severe damage and/or snagging in the small car impact. Therefore, it is recommended that a small car test be run on this system. The Field Swage termination should meet all criteria for acceptance under TL-3. A number of similar factory applied swage fittings have performed acceptably with both cars and pickups.

7.4 RECOMMENDATIONS FOR ADDING FOURTH WIRE ROPE TO EXISTING 3 WIRE ROPE SYSTEM

Low tension systems installed at locations with a demonstrated propensity for vehicle under rides could benefit from the addition of a fourth wire rope. The data from NCAC and MwRSF indicates the lower additional wire rope should not be placed higher than 13.5 inches above grade.

7.5 RECOMMENDATIONS FOR RETROFITTING AN EXISTING LOW-TENSION 3-WIRE ROPE SYSTEM

At the request of sponsoring states two detailed retrofit manuals were developed for retrofitting existing low-tension three wire rope systems. The first manual, located in Appendix H, details the conversion process to a three wire rope high tension system. The second manual, located in Appendix I, details the conversion process to a four wire rope high tension system. Each manual describes the retrofit process step by step in a way that it can be easily understood and followed by maintenance personnel.

REFERENCES

1. D. Lance Bullard, Jr., and Wanda L. Menges, *Crash Testing and Evaluation of the WSDOT Three Strand Cable Rail System*, Research Report 270687-WDT2, prepared for Washington State Department of Transportation, Texas Transportation Institute, The Texas A&M University System, College Station, TX, June 1996.

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

3. C. Eugene Buth, Wanda L. Menges, and Sandra K. Schoeneman, *NCHRP Report 350 Assessment of Existing Roadside Safety Hardware*, FHWA-RD-01-042, prepared for Federal Highway Administration, Texas Transportation Institute, The Texas A&M University System, College Station, TX, November 2000.

4. Phillips, R. G., A. B. Tyrell, J. E. Bryden, and J. S. Fortuniewicz. *Cable Guiderail Breakaway Terminal Ends*. Research Report 148. Engineering Research and Development Bureau, New York State Department of Transportation, Albany, March 1990.

5. Mak, K. K., Bligh, R. P., and Menges, W. L. 'Volume XI: Appendix J – Crash Testing and Evaluation of Existing Guardrail Systems." *Report FHWA-RD-98-046*, Texas Transportation Institute, Texas A&M University System, College Station, TX, February 1998.

6. Outcalt, William, *Cable Guardrail,* CDOT-DTD-R-2004-10, Colorado Department of Transportation – Research, Denver, CO, June 2004

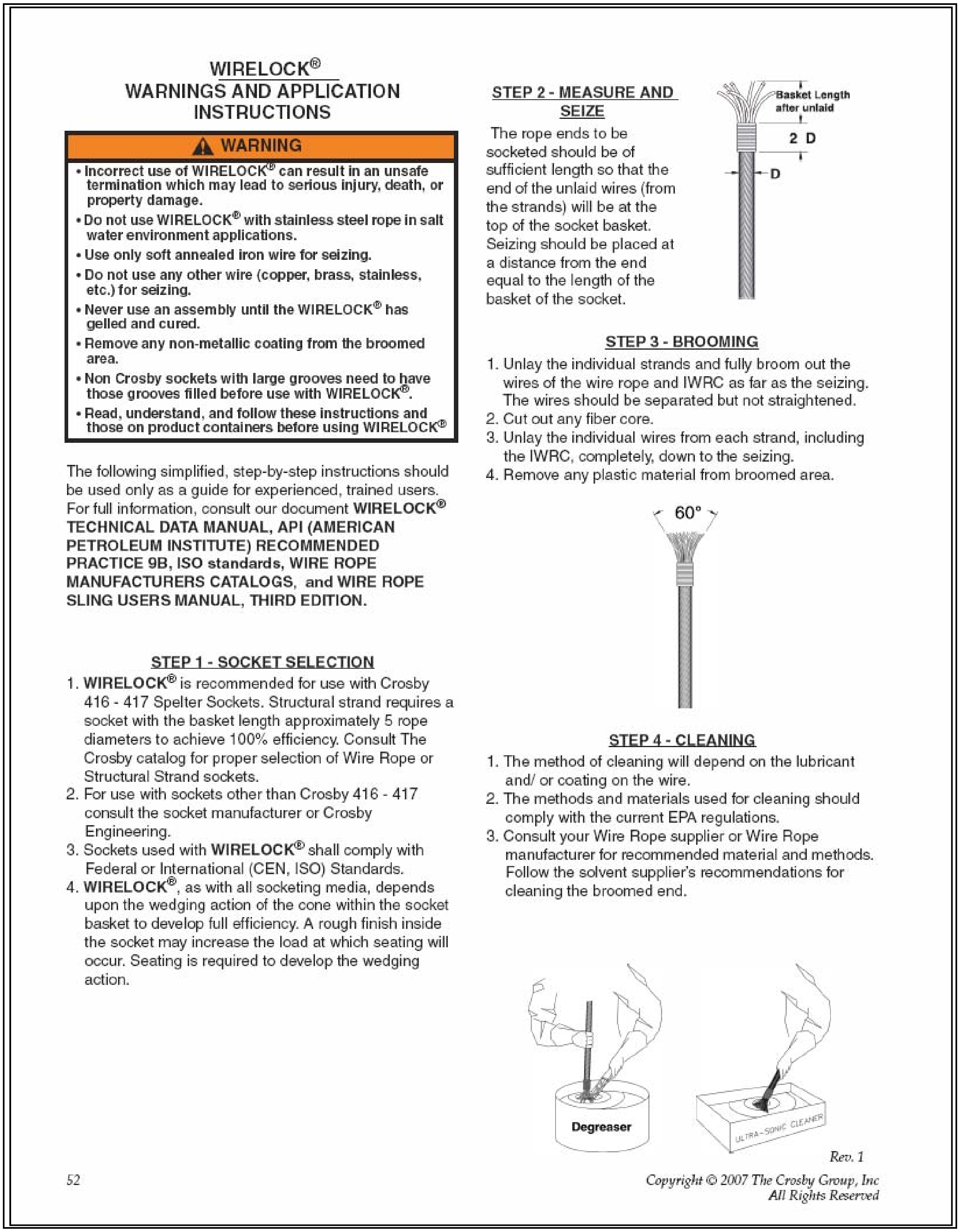
7. American Association of State Highway and Transportation Officials (AASHTO)-Associated General Contractors (AGC)-American Road and Transportation Builders Association (ARTBA). *A Guide to Standardized Highway Barrier Rail Hardware*. November 1999.

8. Federal Highway Administration Memorandum, from the Director, Office of Engineering, entitled: "ACTION: Identifying Acceptable Highway Safety Features," dated July 25, 1997.

9. NCHRP 22-25 *Development of Guidance for Selection, Use, and Maintenance of Cable Barrier Systems (Quarterly Progress Report January 2009 – March 2009)*, prepared for National Cooperative Highway Research Program (NCHRP), The National Crash Analysis Center (NCAC), George Washington University VA Campus, Ashburn, VA, March 2009.

10. WIRELOCK Warnings and Application Instructions. (The Crosby Group, Tulsa, OK, 2007). Available at: http://www.thecrosbygroup.com

APPENDIX A. INSTALLATION INSTRUCTIONS



WIRELOCK®
WARNINGS AND APPLICATION INSTRUCTIONS

⚠ WARNING

- **Incorrect use of WIRELOCK® can result in an unsafe termination which may lead to serious injury, death, or property damage.**
- **Do not use WIRELOCK® with stainless steel rope in salt water environment applications.**
- **Use only soft annealed iron wire for seizing.**
- **Do not use any other wire (copper, brass, stainless, etc.) for seizing.**
- **Never use an assembly until the WIRELOCK® has gelled and cured.**
- **Remove any non-metallic coating from the broomed area.**
- **Non Crosby sockets with large grooves need to have those grooves filled before use with WIRELOCK®.**
- **Read, understand, and follow these instructions and those on product containers before using WIRELOCK®**

The following simplified, step-by-step instructions should be used only as a guide for experienced, trained users. For full information, consult our document **WIRELOCK® TECHNICAL DATA MANUAL, API (AMERICAN PETROLEUM INSTITUTE) RECOMMENDED PRACTICE 9B, ISO standards, WIRE ROPE MANUFACTURERS CATALOGS, and WIRE ROPE SLING USERS MANUAL, THIRD EDITION.**

STEP 1 - SOCKET SELECTION

1. **WIRELOCK®** is recommended for use with Crosby 416 - 417 Spelter Sockets. Structural strand requires a socket with the basket length approximately 5 rope diameters to achieve 100% efficiency. Consult The Crosby catalog for proper selection of Wire Rope or Structural Strand sockets.
2. For use with sockets other than Crosby 416 - 417 consult the socket manufacturer or Crosby Engineering.
3. Sockets used with **WIRELOCK®** shall comply with Federal or International (CEN, ISO) Standards.
4. **WIRELOCK®**, as with all socketing media, depends upon the wedging action of the cone within the socket basket to develop full efficiency. A rough finish inside the socket may increase the load at which seating will occur. Seating is required to develop the wedging action.

STEP 2 - MEASURE AND SEIZE

The rope ends to be socketed should be of sufficient length so that the end of the unlaid wires (from the strands) will be at the top of the socket basket. Seizing should be placed at a distance from the end equal to the length of the basket of the socket.

STEP 3 - BROOMING

1. Unlay the individual strands and fully broom out the wires of the wire rope and IWRC as far as the seizing. The wires should be separated but not straightened.
2. Cut out any fiber core.
3. Unlay the individual wires from each strand, including the IWRC, completely, down to the seizing.
4. Remove any plastic material from broomed area.

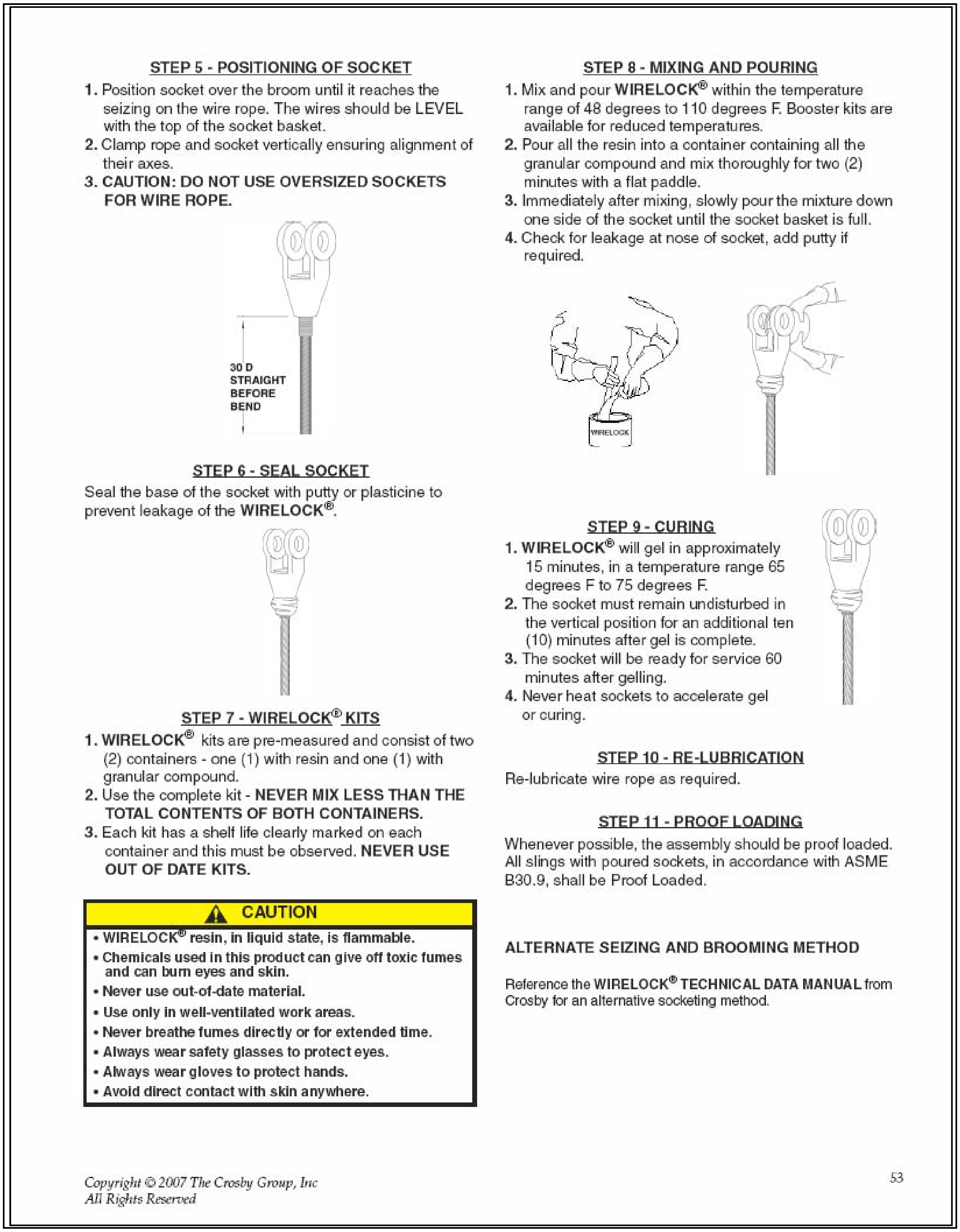
STEP 4 - CLEANING

1. The method of cleaning will depend on the lubricant and/ or coating on the wire.
2. The methods and materials used for cleaning should comply with the current EPA regulations.
3. Consult your Wire Rope supplier or Wire Rope manufacturer for recommended material and methods. Follow the solvent supplier's recommendations for cleaning the broomed end.

Rev. 1

52

Figure A1. Epoxy Socket installation instructions (Page 1).[(10)]



STEP 5 - POSITIONING OF SOCKET

1. Position socket over the broom until it reaches the seizing on the wire rope. The wires should be LEVEL with the top of the socket basket.
2. Clamp rope and socket vertically ensuring alignment of their axes.
3. **CAUTION: DO NOT USE OVERSIZED SOCKETS FOR WIRE ROPE.**

STEP 6 - SEAL SOCKET

Seal the base of the socket with putty or plasticine to prevent leakage of the **WIRELOCK®**.

STEP 7 - WIRELOCK® KITS

1. **WIRELOCK®** kits are pre-measured and consist of two (2) containers - one (1) with resin and one (1) with granular compound.
2. Use the complete kit - **NEVER MIX LESS THAN THE TOTAL CONTENTS OF BOTH CONTAINERS.**
3. Each kit has a shelf life clearly marked on each container and this must be observed. **NEVER USE OUT OF DATE KITS.**

⚠ CAUTION

- **WIRELOCK® resin, in liquid state, is flammable.**
- **Chemicals used in this product can give off toxic fumes and can burn eyes and skin.**
- **Never use out-of-date material.**
- **Use only in well-ventilated work areas.**
- **Never breathe fumes directly or for extended time.**
- **Always wear safety glasses to protect eyes.**
- **Always wear gloves to protect hands.**
- **Avoid direct contact with skin anywhere.**

STEP 8 - MIXING AND POURING

1. Mix and pour **WIRELOCK®** within the temperature range of 48 degrees to 110 degrees F. Booster kits are available for reduced temperatures.
2. Pour all the resin into a container containing all the granular compound and mix thoroughly for two (2) minutes with a flat paddle.
3. Immediately after mixing, slowly pour the mixture down one side of the socket until the socket basket is full.
4. Check for leakage at nose of socket, add putty if required.

STEP 9 - CURING

1. **WIRELOCK®** will gel in approximately 15 minutes, in a temperature range 65 degrees F to 75 degrees F.
2. The socket must remain undisturbed in the vertical position for an additional ten (10) minutes after gel is complete.
3. The socket will be ready for service 60 minutes after gelling.
4. Never heat sockets to accelerate gel or curing.

STEP 10 - RE-LUBRICATION

Re-lubricate wire rope as required.

STEP 11 - PROOF LOADING

Whenever possible, the assembly should be proof loaded. All slings with poured sockets, in accordance with ASME B30.9, shall be Proof Loaded.

ALTERNATE SEIZING AND BROOMING METHOD

Reference the **WIRELOCK® TECHNICAL DATA MANUAL** from Crosby for an alternative socketing method.

Figure A2. Epoxy Socket installation instructions (Page 2).

Trinity Industries did not supply a English language version of installation instructions for its Field Swage terminations.

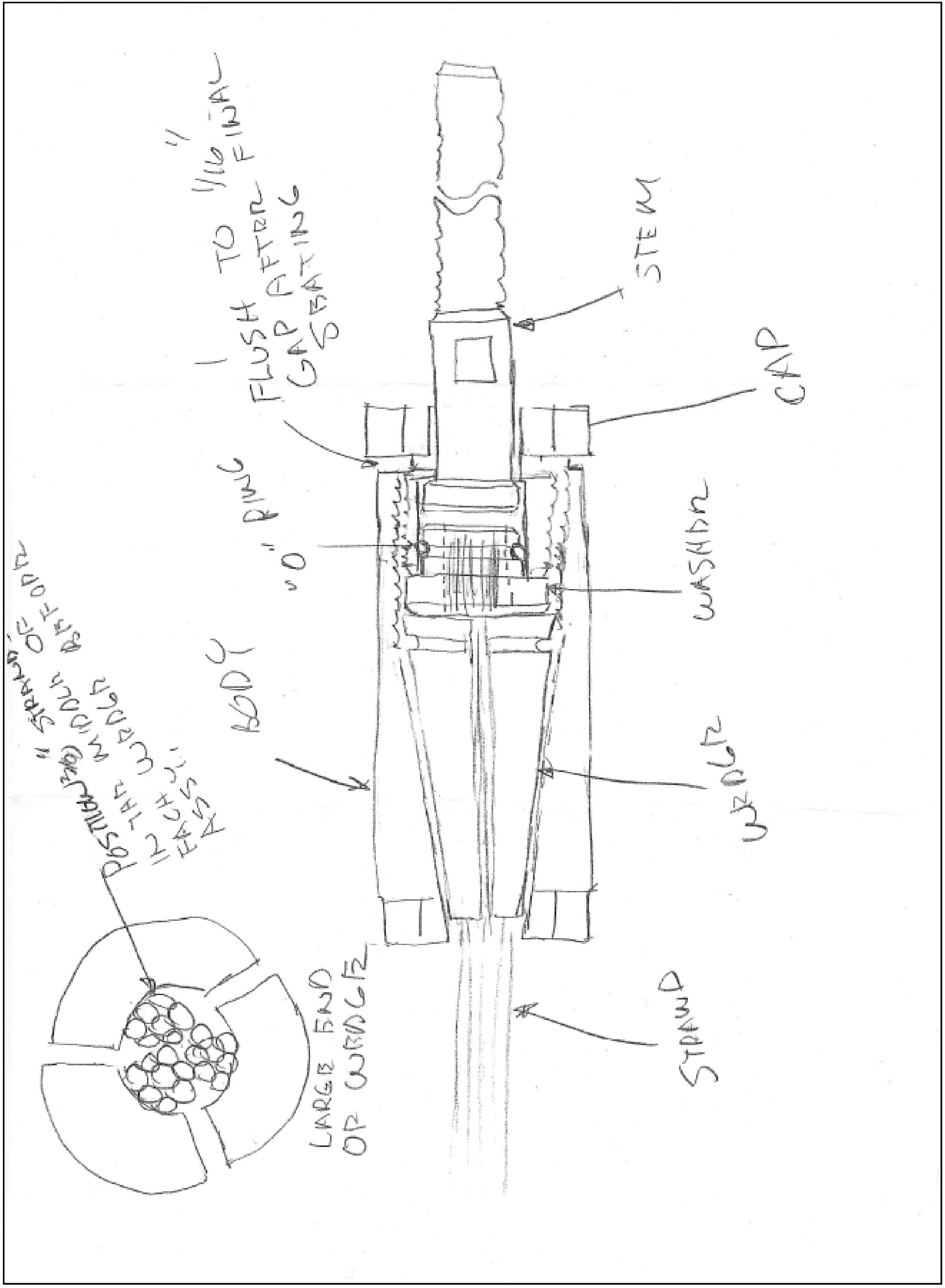


Figure A3. Precision Sure-Lock Prototype 2 installation diagram.

<u>Nucor Steel Marion did not supply installation instructions for its terminations.</u>

APPENDIX B. WIRE ROPE DETAILS

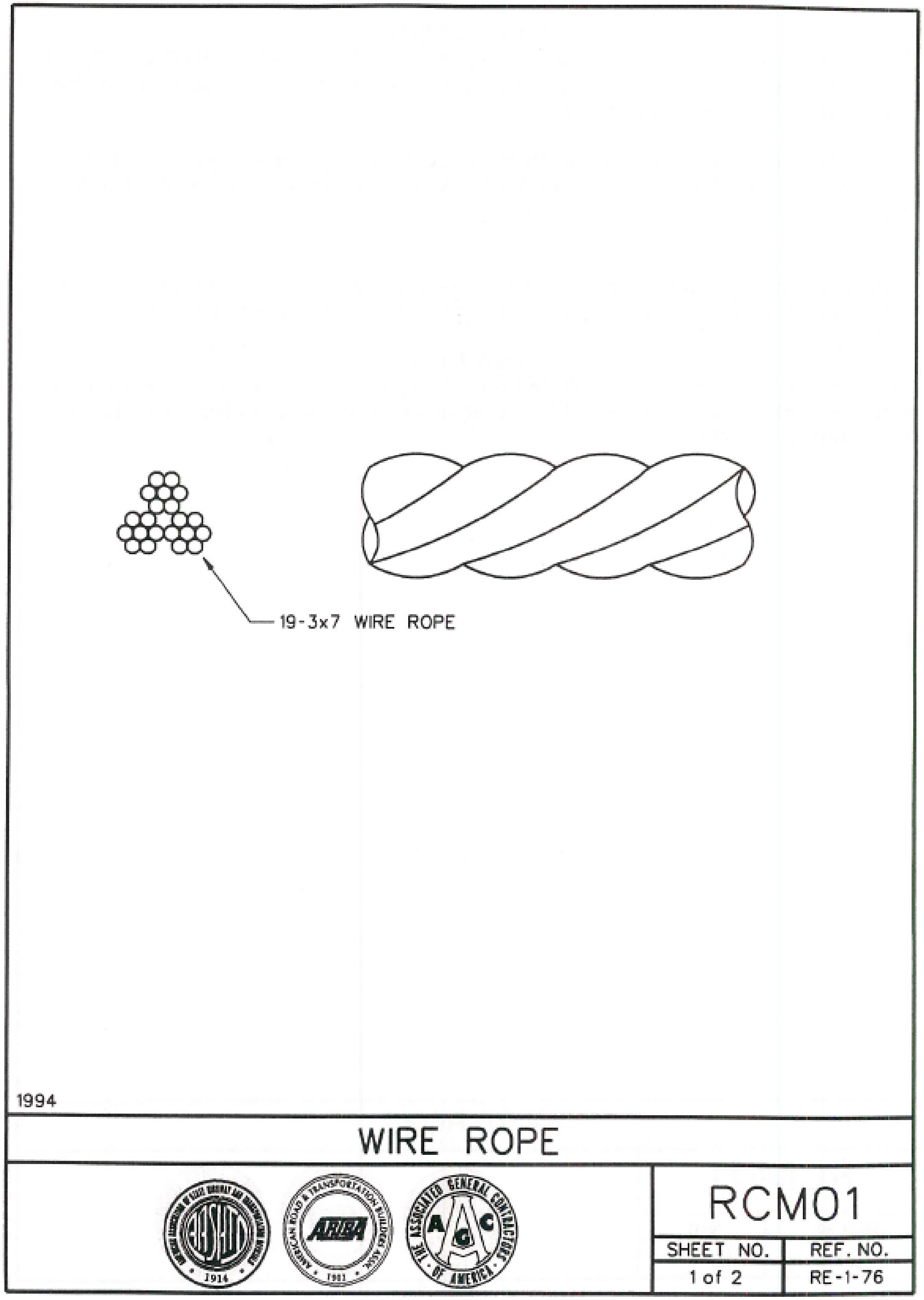
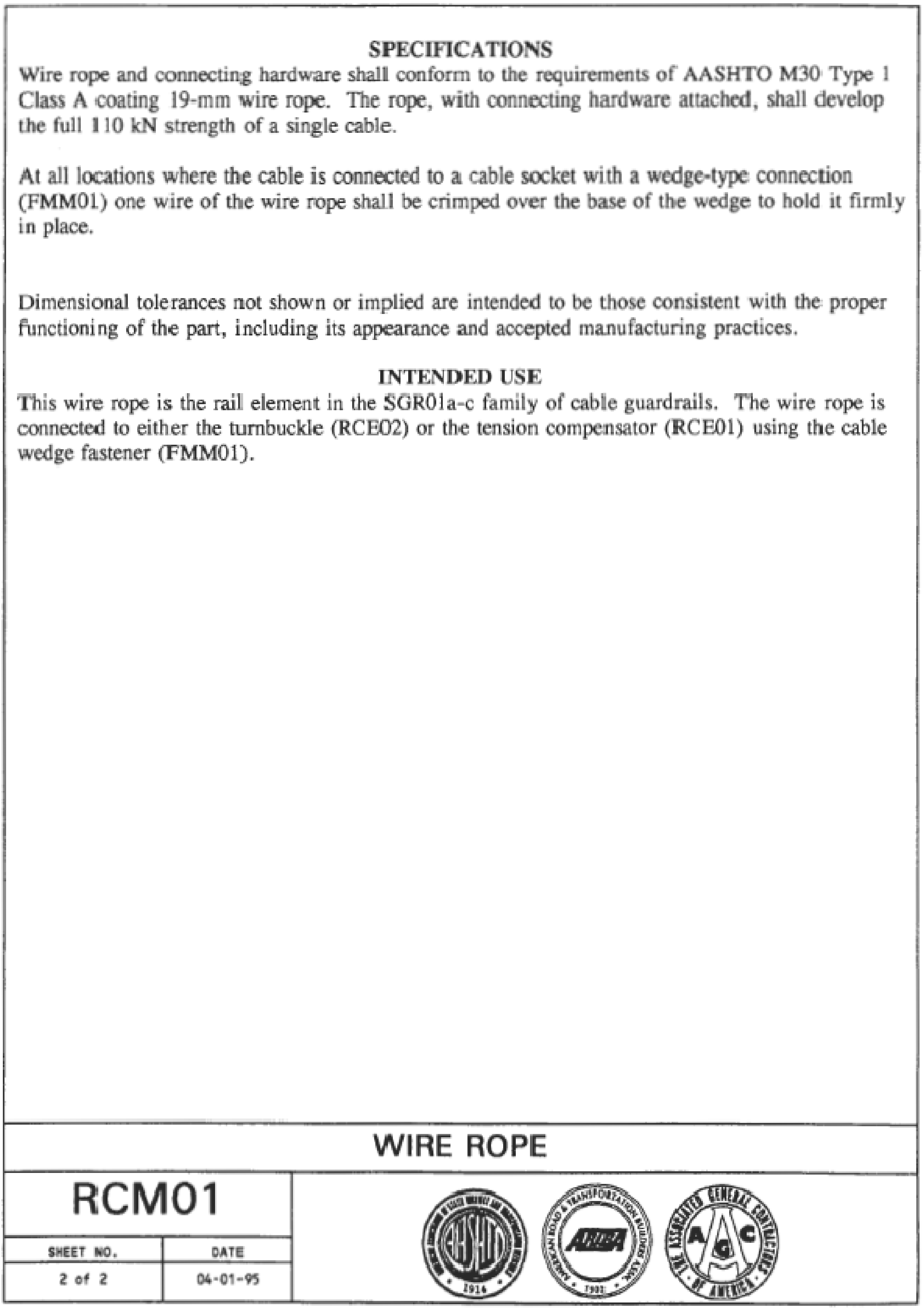


Figure B1. Standard wire rope specifications (Page 1).



SPECIFICATIONS

Wire rope and connecting hardware shall conform to the requirements of AASHTO M30 Type 1 Class A coating 19-mm wire rope. The rope, with connecting hardware attached, shall develop the full 110 kN strength of a single cable.

At all locations where the cable is connected to a cable socket with a wedge-type connection (FMM01) one wire of the wire rope shall be crimped over the base of the wedge to hold it firmly in place.

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

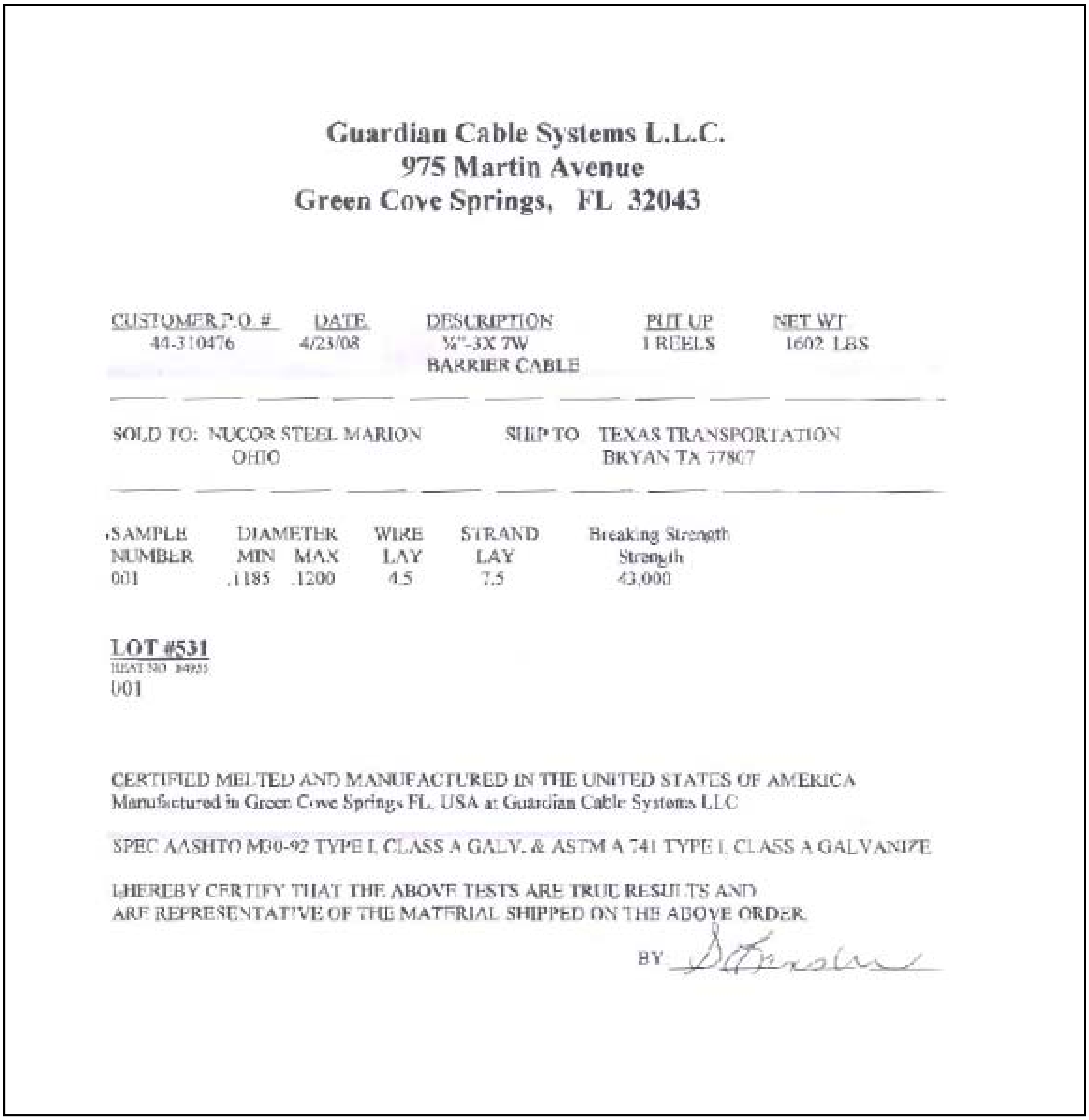
This wire rope is the rail element in the SGR01a-c family of cable guardrails. The wire rope is connected to either the turnbuckle (RCE02) or the tension compensator (RCE01) using the cable wedge fastener (FMM01).

WIRE ROPE

RCM01

SHEET NO.	DATE
2 of 2	04-01-95

Figure B2. Standard wire rope specifications (Page 2).



Guardian Cable Systems L.L.C.
975 Martin Avenue
Green Cove Springs, FL 32043

CUSTOMER P.O. #	DATE	DESCRIPTION	PUT UP	NET WT
44-310476	4/23/08	¾"-3X 7W BARRIER CABLE	1 REELS	1602 LBS

SOLD TO: NUCOR STEEL MARION
OHIO

SHIP TO TEXAS TRANSPORTATION
BRYAN TX 77807

SAMPLE NUMBER	DIAMETER		WIRE LAY	STRAND LAY	Breaking Strength Strength
	MIN	MAX			
001	.1185	.1200	4.5	7.5	43,000

LOT #531
HEAT NO [illegible]
001

CERTIFIED MELTED AND MANUFACTURED IN THE UNITED STATES OF AMERICA
Manufactured in Green Cove Springs FL. USA at Guardian Cable Systems LLC

SPEC AASHTO M30-92 TYPE I, CLASS A GALV. & ASTM A 741 TYPE I, CLASS A GALVANIZE

I HEREBY CERTIFY THAT THE ABOVE TESTS ARE TRUE RESULTS AND
ARE REPRESENTATIVE OF THE MATERIAL SHIPPED ON THE ABOVE ORDER.

BY

Figure B3. Wire rope certification sheet.

APPENDIX C. ARTBA SGR-01a-b DRAWINGS

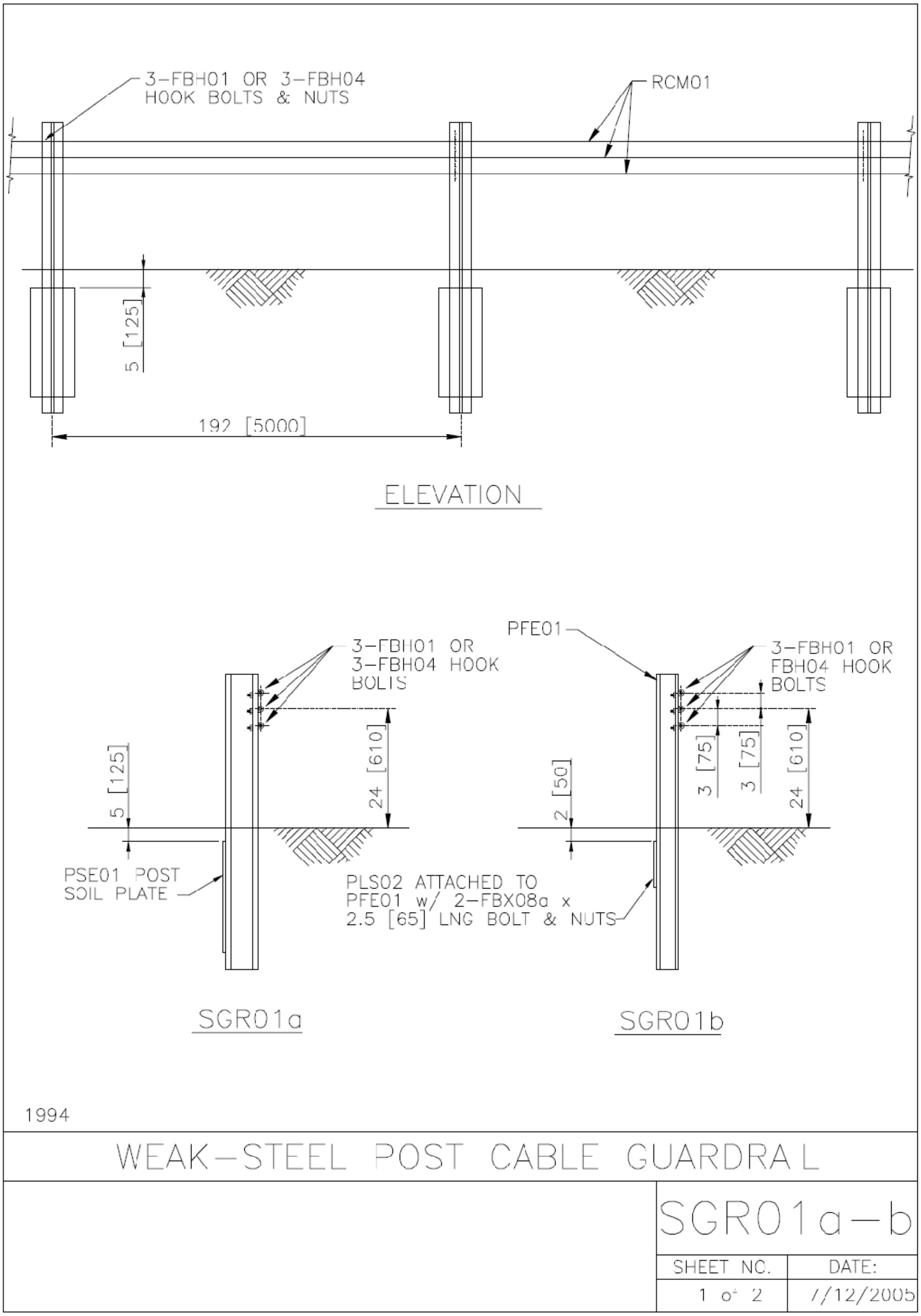


Figure C1. SGR01a-b weak-steel post cable guardrail details (Page1).

INTENDED USE

Cable guardrails are commonly used where there is adequate room behind the barrier to allow a dynamic deflection of up to 138 inches [3500 mm]. This system must be anchored using a cable anchor and terminal system like SEC01. SGR-01a and SGR-01b are both test level 3 barriers.

COMPONENTS

Unit length = 192 inches [5000 mm]

	Designator	Component	System	Number
	FBH01	Hook bolts and nuts	a-b	3
or	FBH04	Hook bolts and nuts	a-b	3
or	FBH03	Hook bolts and nuts	a	3
	PFE01	Post	b	1
with	PLS02	Soil plate	b	1
and	FBX08a	Bolt (2.5 in [65 mm]) and nut	b	2
	PSE01	Post	a	1
	RCM01	Cable (984 ft [300 m] typical)	a-b	3

APPROVALS

FHWA Acceptance Letter B-64, 2/14/00.

REFERENCES

M.D. Graham, W.C. Burnett, J.L. Gibson, R.H. Freer, *New Highway Barriers: The Practical Application of Theoretical Design*, Highway Research Record 174, Highway Research Board, Washington, DC, 1967, pp. 88-183.

M.E. Bronstad, J.E. Michie and J.D. Mayer, Jr., *Performance of Longitudinal Traffic Barriers*, National Cooperative Highway Research Program Report Number 289, Transportation Research Board, June, 1987.

J.B. Mayer, Jr., *Crash-Test Evaluation of a Franklin Post and Cable Guardrail System*, Southwest Research Institute Test Reports prepared for the South Dakota Department of Transportation, Pierre, SD, August, 1989.

CONTACT INFORMATION

Federal Highway Administration
Office of Safety
400 Seventh Street, SW
Washington, DC 20590
202-366-2288

WEAK-STEEL POST CABLE GUARDRAIL

SGR01a-b

SHEET NO.	DATE
2 of 2	7/12/05

Figure C2. SGR01a-b weak-steel post cable guardrail details (Page 2).

APPENDIX D. CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*. Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity (c.g.) to measure longitudinal, lateral, and vertical acceleration levels; and a backup biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. These accelerometers were ENDEVCO® Model 2262CA, piezoresistive accelerometers with a ±100 g range.

The accelerometers are strain gage type with a linear millivolt output proportional to acceleration. Angular rate transducers are solid state, gas flow units designed for high-"g" service. Signal conditioners and amplifiers in the test vehicle increase the low-level signals to a ±2.5 volt maximum level. The signal conditioners also provide the capability of an R-cal (resistive calibration) or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant-bandwidth, Inter-Range Instrumentation Group (IRIG), FM/FM telemetry link for recording and for display. Calibration signals from the test vehicle are recorded before the test and immediately afterwards. A crystal-controlled time reference signal is simultaneously recorded with the data. Wooden dowels actuate pressure-sensitive switches on the bumper of the impacting vehicle prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produces an "event" mark on the data record to establish the instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, is received and demultiplexed onto TEAC® instrumentation data recorder. After the test, the data are played back from the TEAC® recorder and digitized. A proprietary software program (WinDigit) converts the analog data from each transducer into engineering units using the R-cal and pre-zero values at 10,000 samples per second, per channel. WinDigit also provides Society of Automotive Engineers (SAE) J211 class 180 phaseless digital filtering and vehicle impact velocity.

All accelerometers are calibrated annually according to the (SAE) J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are made any time data are suspect.

The Test Risk Assessment Program (TRAP) uses the data from WinDigit to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-milliseconds (ms) average ridedown acceleration. WinDigit 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.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

Use of a dummy in the 2000P vehicle is optional according to *NCHRP Report 350*, and there was no dummy used in the test with the 2000P vehicle.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

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

TEST VEHICLE PROPULSION AND GUIDANCE

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

APPENDIX E. TEST VEHICLE PROPERTIES AND INFORMATION

Vehicle Inventory Number: 778

Date: 2008-07-07 Test No.: 405160-11-1 VIN No.: 1GCGC24R9XR712815

Year: 1999 Make: Chevrolet Model: C2500

Tire Inflation Pressure: 60 psi Odometer: 176396 Tire Size: 245/75R16

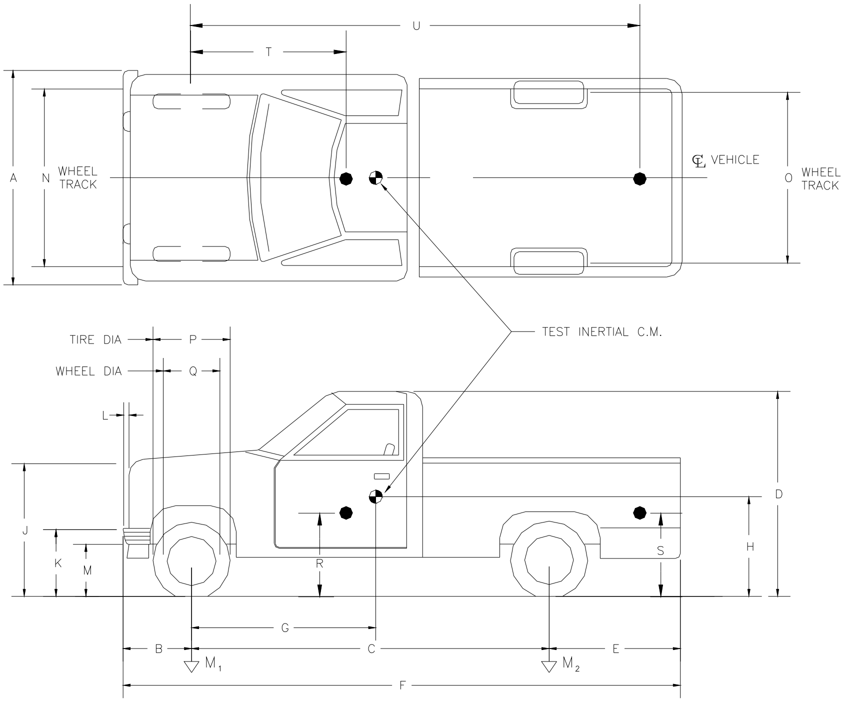
Describe any damage to the vehicle prior to test:

● Denotes accelerometer location.

NOTES:
8-lug

Engine Type: V-8
Engine CID: 5.7 liter
Transmission Type:
x Auto
Manual
Optional Equipment:

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



Geometry (inches)

A	74.0	E	51.6	J	40.9	N	62.6	R	29.5
B	31.9	F	215.4	K	25.0	O	63.4	S	35.4
C	131.9	G	57.6	L	2.8	P	28.5	T	57.5
D	71.6	H		M	16.3	Q	17.3	U	132.3

Mass (lb)	Curb	Test Inertial	Gross Static
M_1	2667	2548	
M_2	2227	1974	
M_{Total}	4894	4522	

Mass Distribution (lb): LF: 1301 RF: 1245 LR: 946 RR: 1028

Figure E1. Vehicle properties for test 405160-11-1.

Table E1. Exterior crush measurements for test 405160-11-1.

Vehicle Inventory Number: 778

Date: 2008-07-07 Test No.: 405160-11-1 VIN No.: 1GCGC24R9XR712815

Year: 1999 Make: Chevrolet Model: C2500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

Note: Measure C_1 to C_6 from Driver to Passenger side in Front or Rear impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
	Wire rope rode over										
	front bumper										

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

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

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

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

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

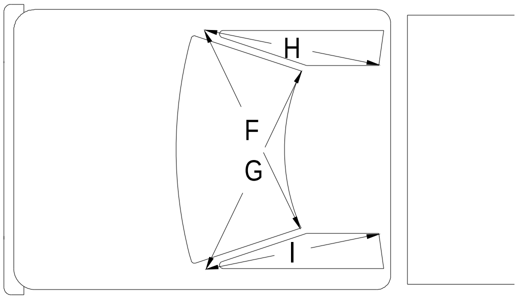
Note: Use as many lines/columns as necessary to describe each damage profile.

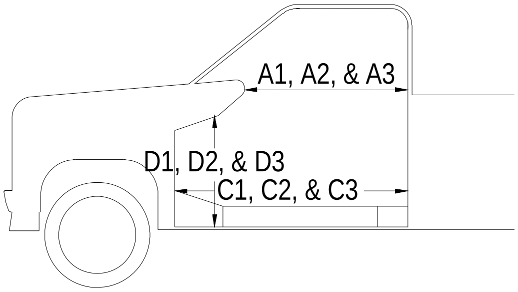
Table E2. Occupant compartment measurements for test 405160-11-1.

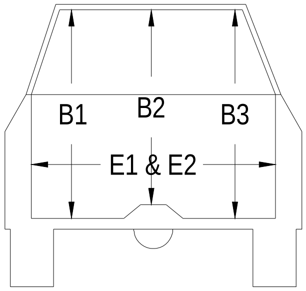
Vehicle Inventory Number: 778

Date: 2008-07-07 Test No.: 405160-11-1 VIN No.: 1GCGC24R9XR712815

Year: 1999 Make: Chevrolet Model: C2500





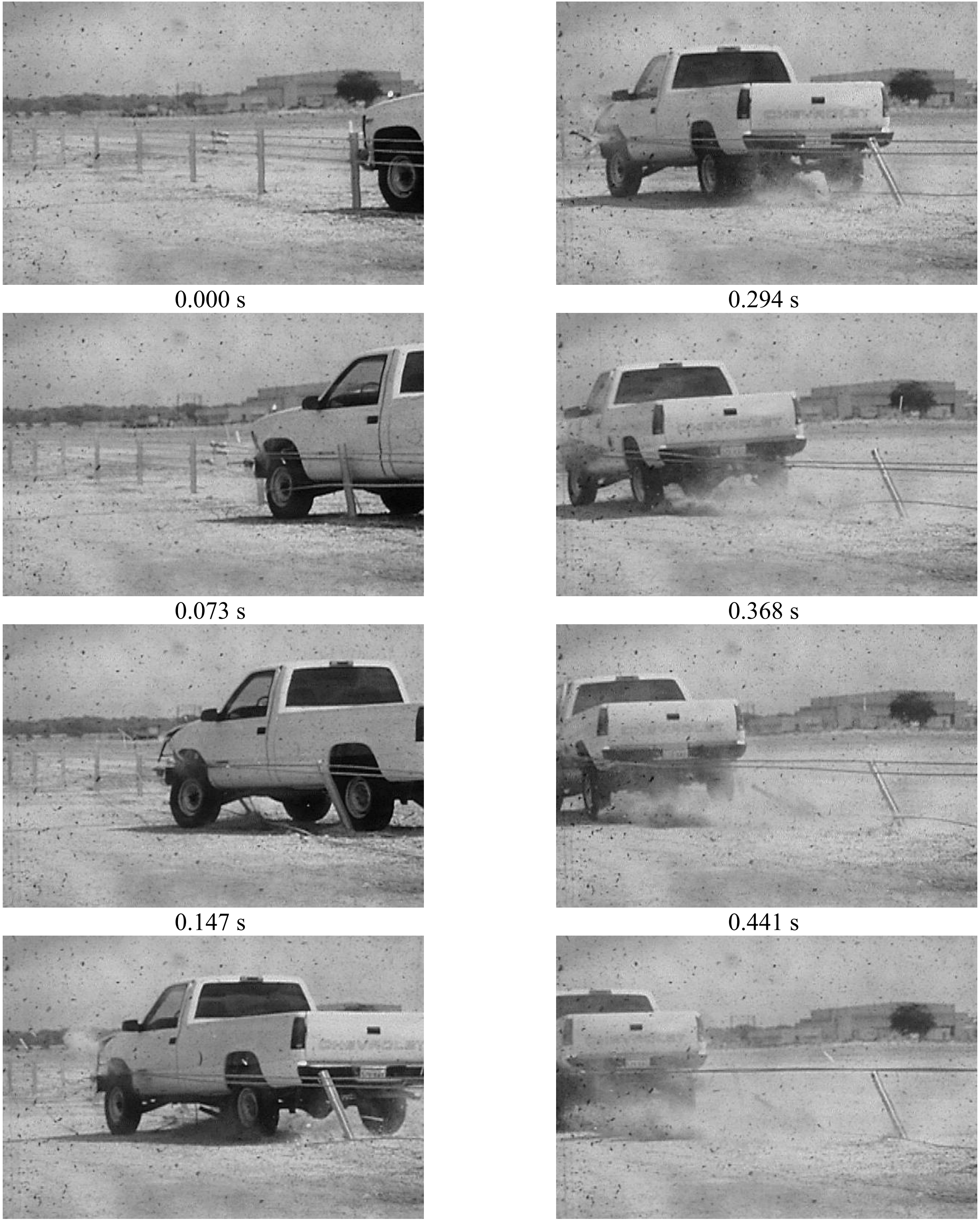


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	34.2	32.6
A2	37.4	37.0
A3	36.7	36.7
B1	42.5	43.2
B2	37.4	37.7
B3	42.1	42.1
C1	53.7	NA
C2	-----	-----
C3	53.8	53.8
D1	12.8	13.5
D2	6.1	6.4
D3	14.9	14.9
E1	62.2	62.8
E2	62.4	63.2
F	57.9	57.5
G	57.9	57.8
H	41.7	41.3
I	41.7	41.7
J*	59.8	57.6

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

APPENDIX F. SEQUENTIAL PHOTOGRAPHS



0.000 s

0.073 s

0.147 s

0.220 s

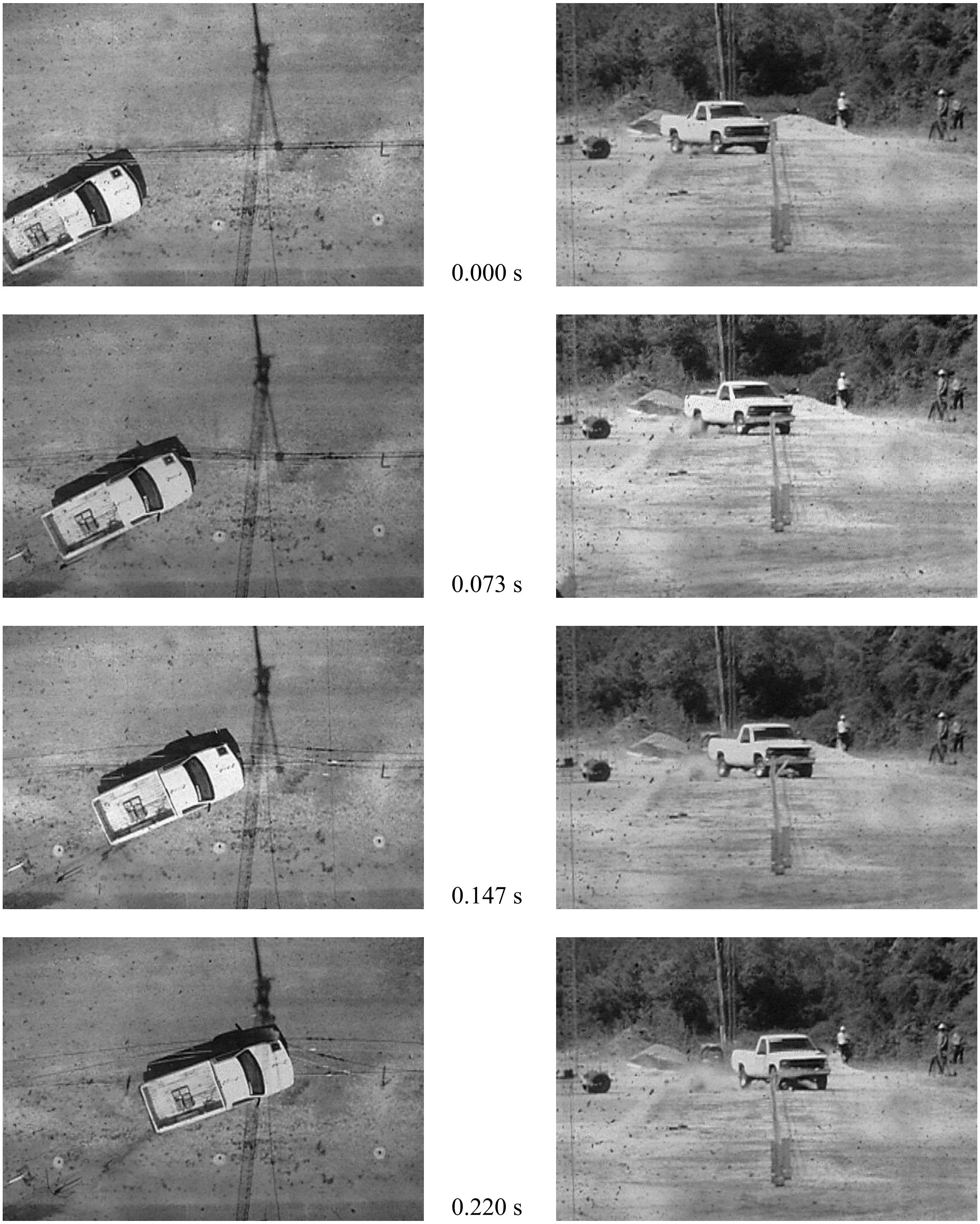
0.294 s

0.368 s

0.441 s

0.515 s

Figure F1. Sequential photographs for test 405160-11-1
(rear view).



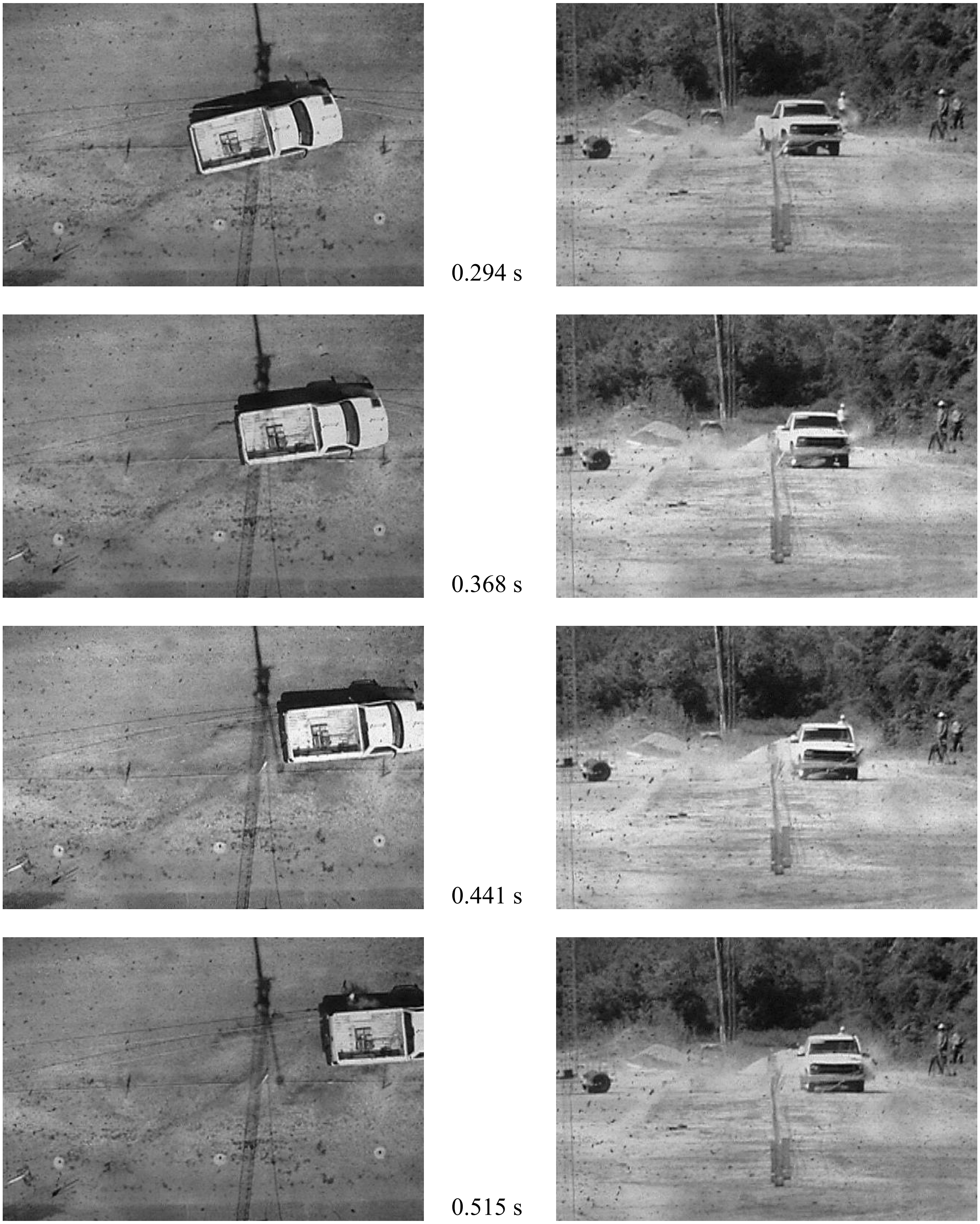
0.000 s

0.073 s

0.147 s

0.220 s

Figure F2. Sequential photographs for test 405160-11-1
(overhead and frontal views).



0.294 s

0.368 s

0.441 s

0.515 s

Figure F2. Sequential photographs for test 405160-11-1
(overhead and frontal views) (continued).

APPENDIX G. VEHICLE ANGULAR DISPLACEMENTS AND ACCELERATIONS

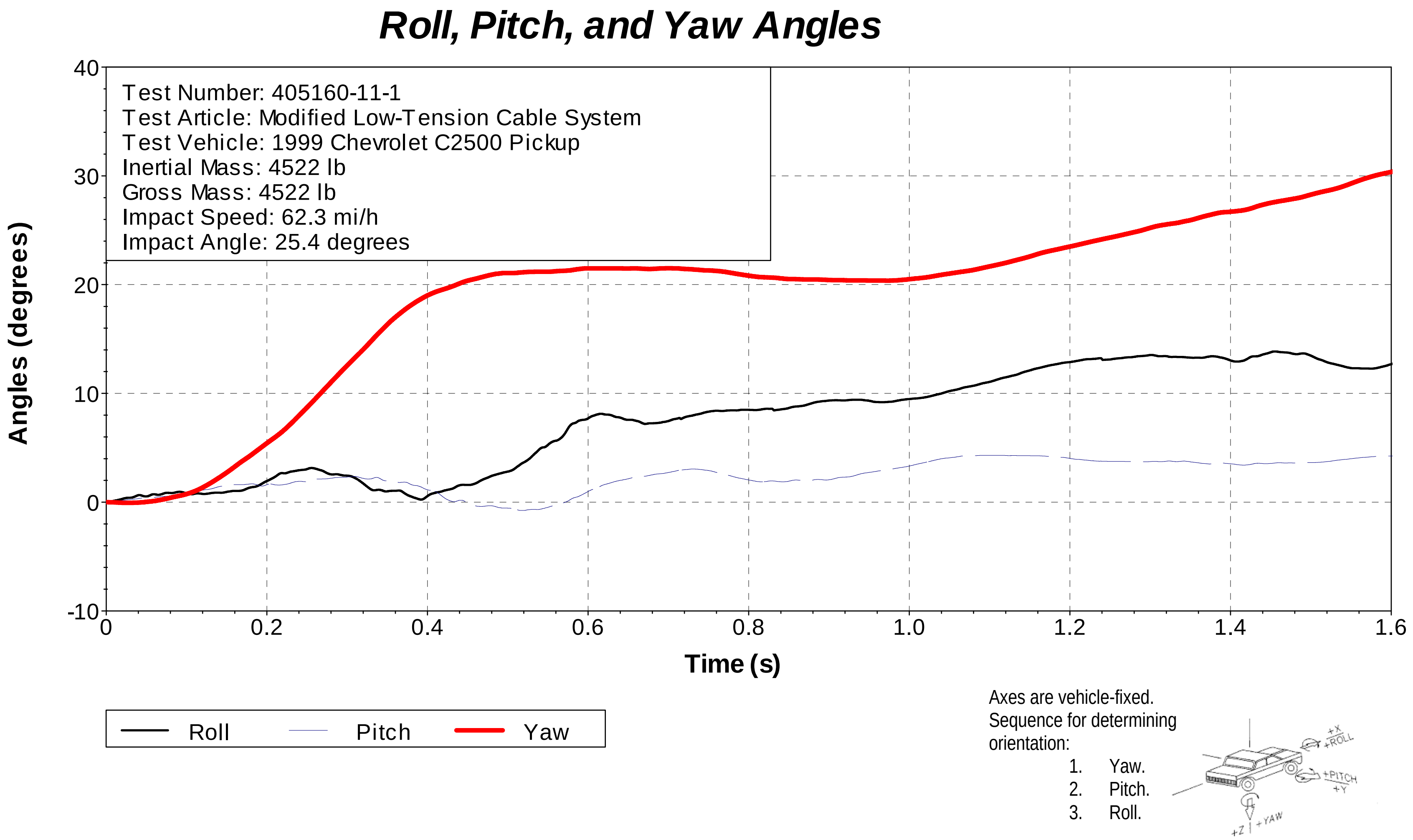


Figure G1. Vehicle angular displacements for test 405160-11-1.

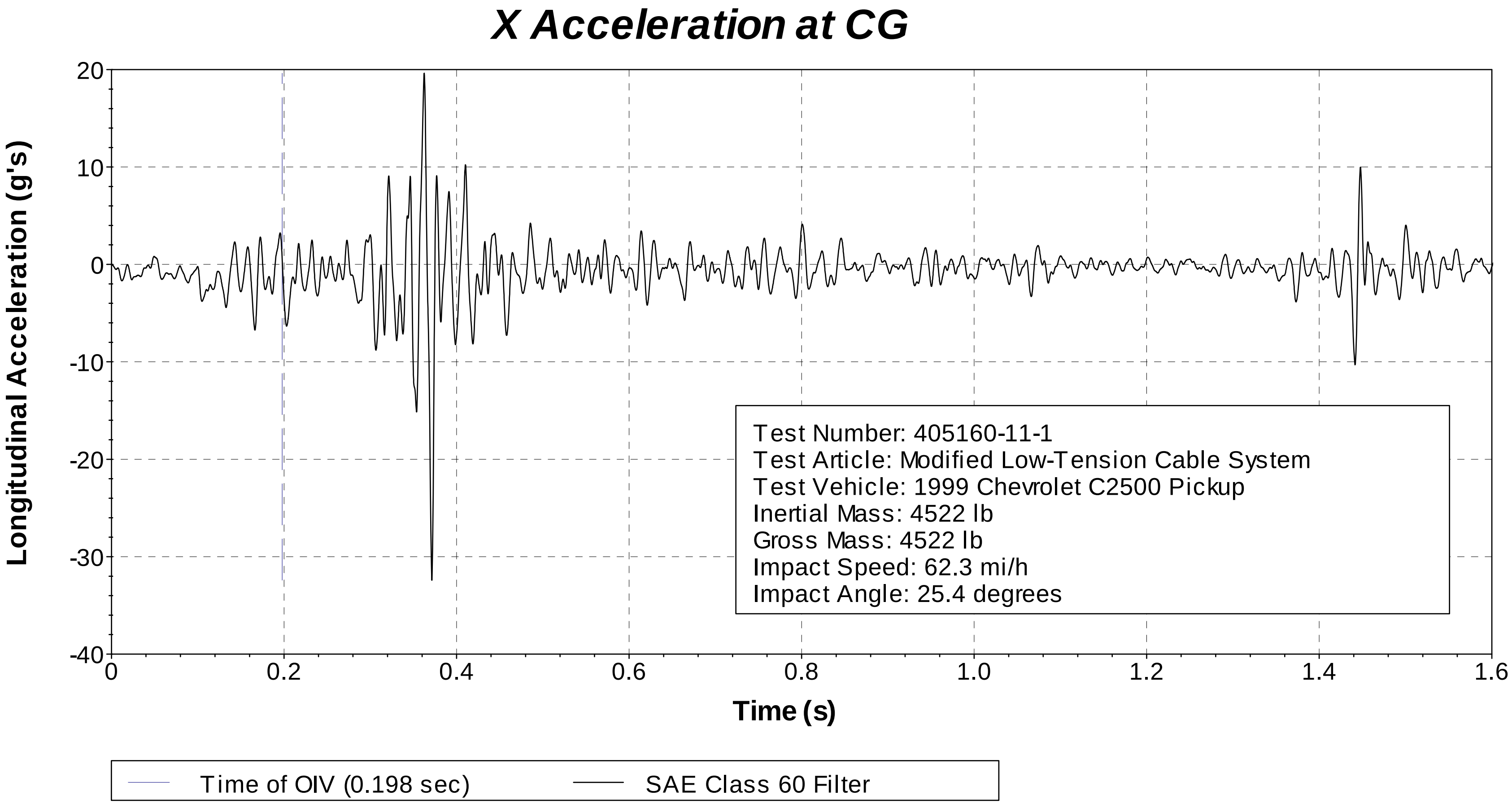


Figure G2. Vehicle longitudinal accelerometer trace for test 405160-11-1
(accelerometer located at center of gravity).

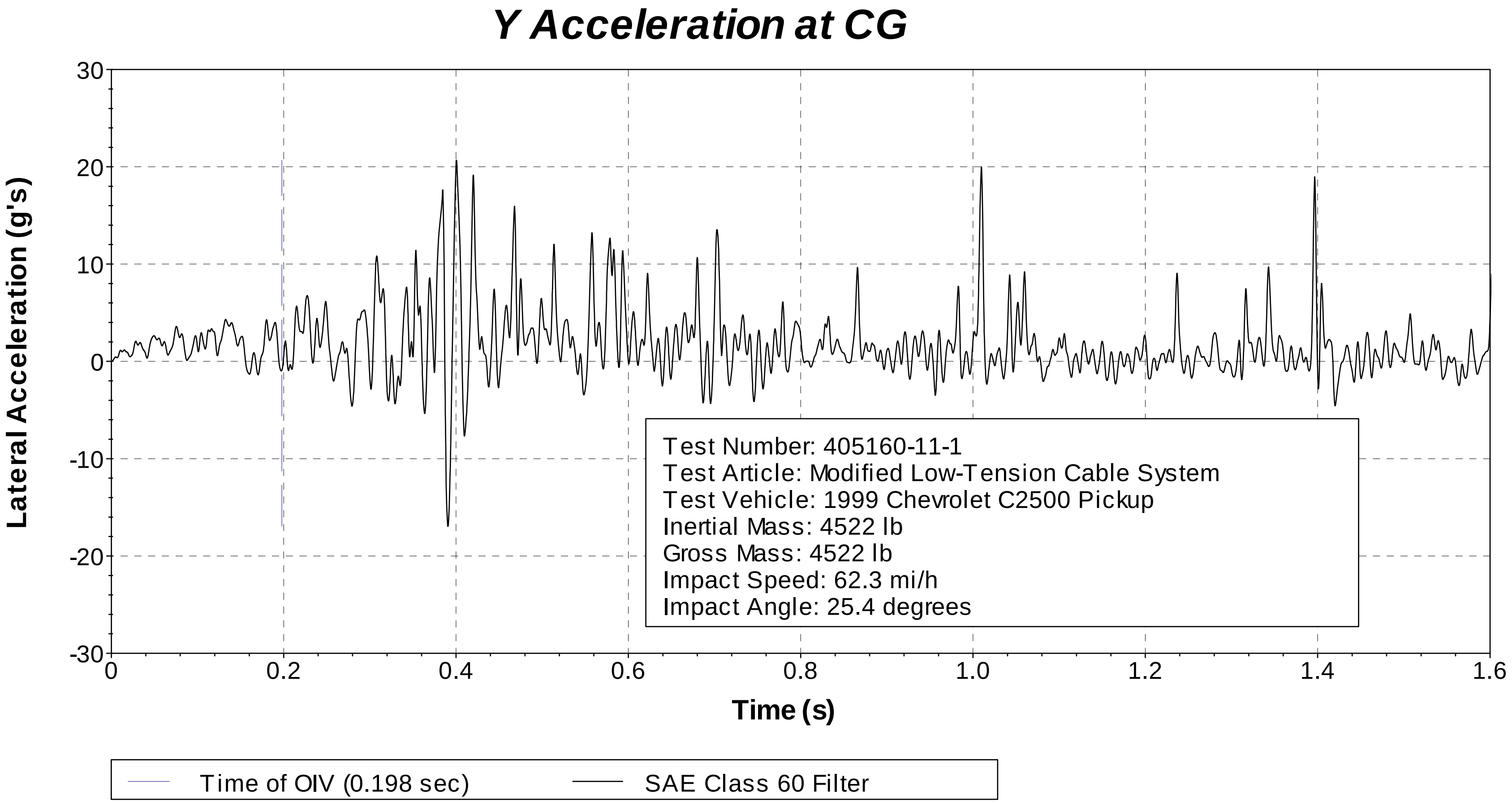


Figure G3. Vehicle lateral accelerometer trace for test 405160-11-1 (accelerometer located at center of gravity).

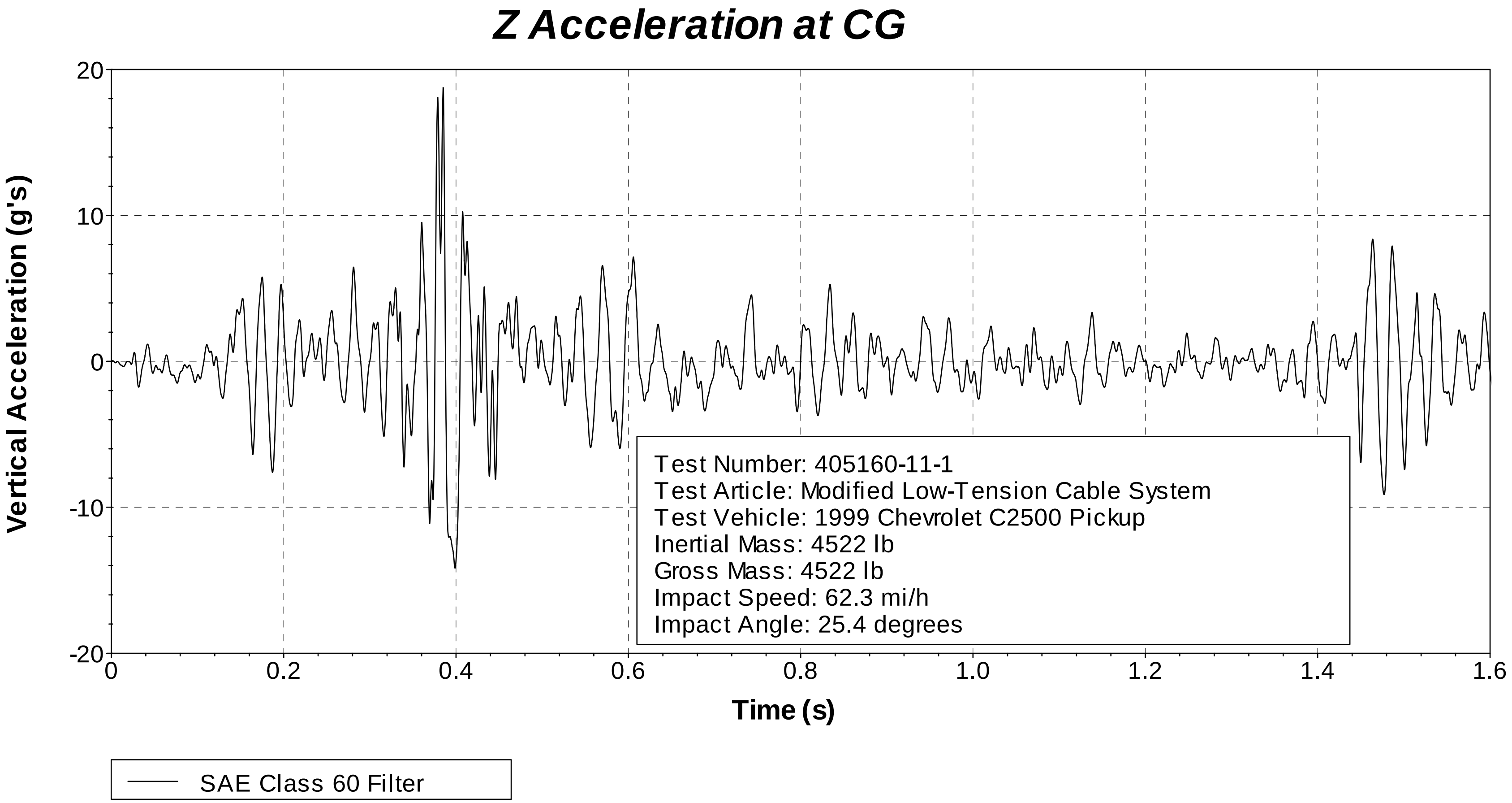


Figure G4. Vehicle vertical accelerometer trace for test 405160-11-1 (accelerometer located at center of gravity).

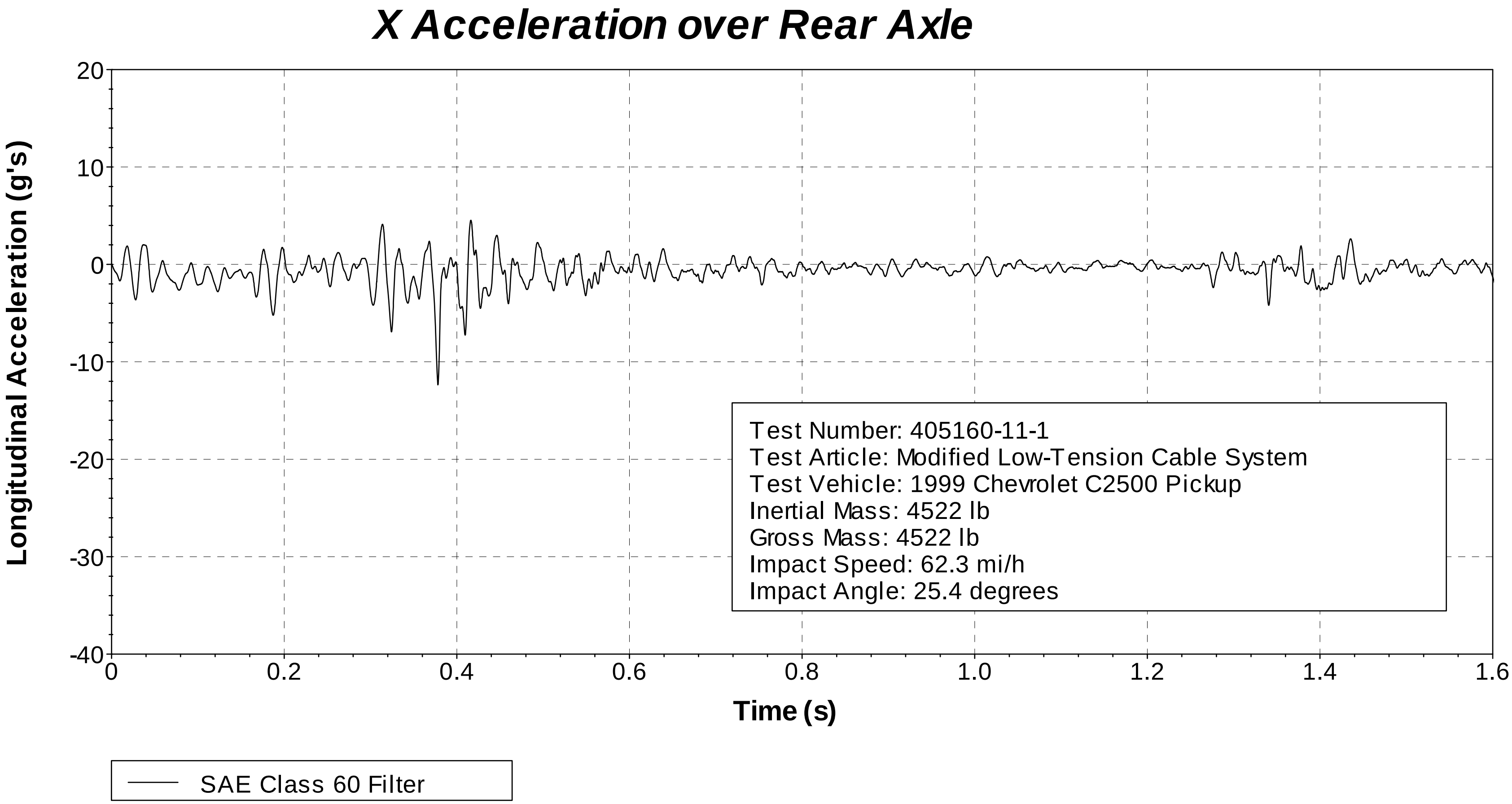


Figure G5. Vehicle longitudinal accelerometer trace for test 405160-11-1 (accelerometer located over rear axle).

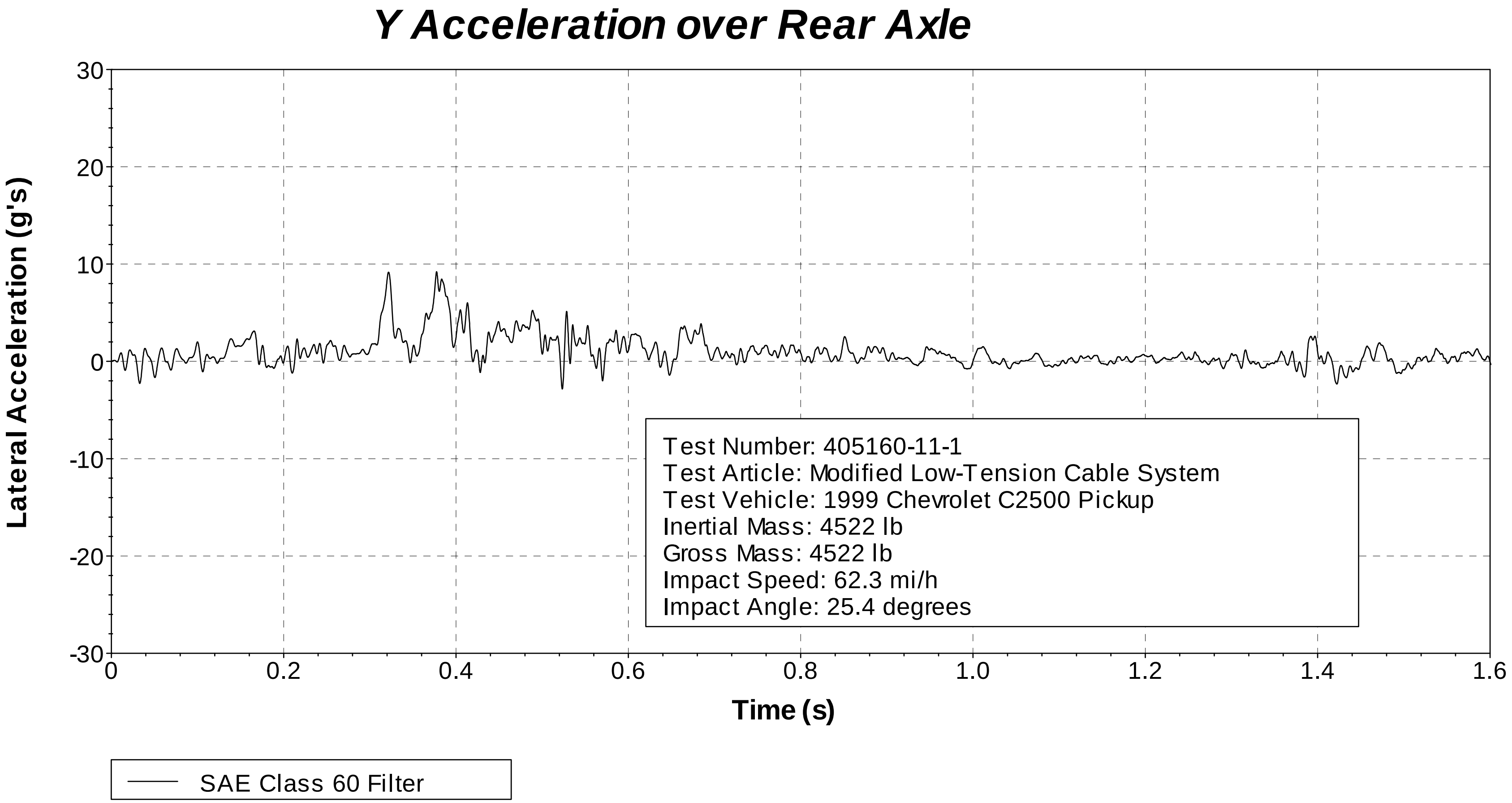


Figure G6. Vehicle lateral accelerometer trace for test 405160-11-1
(accelerometer located over rear axle).

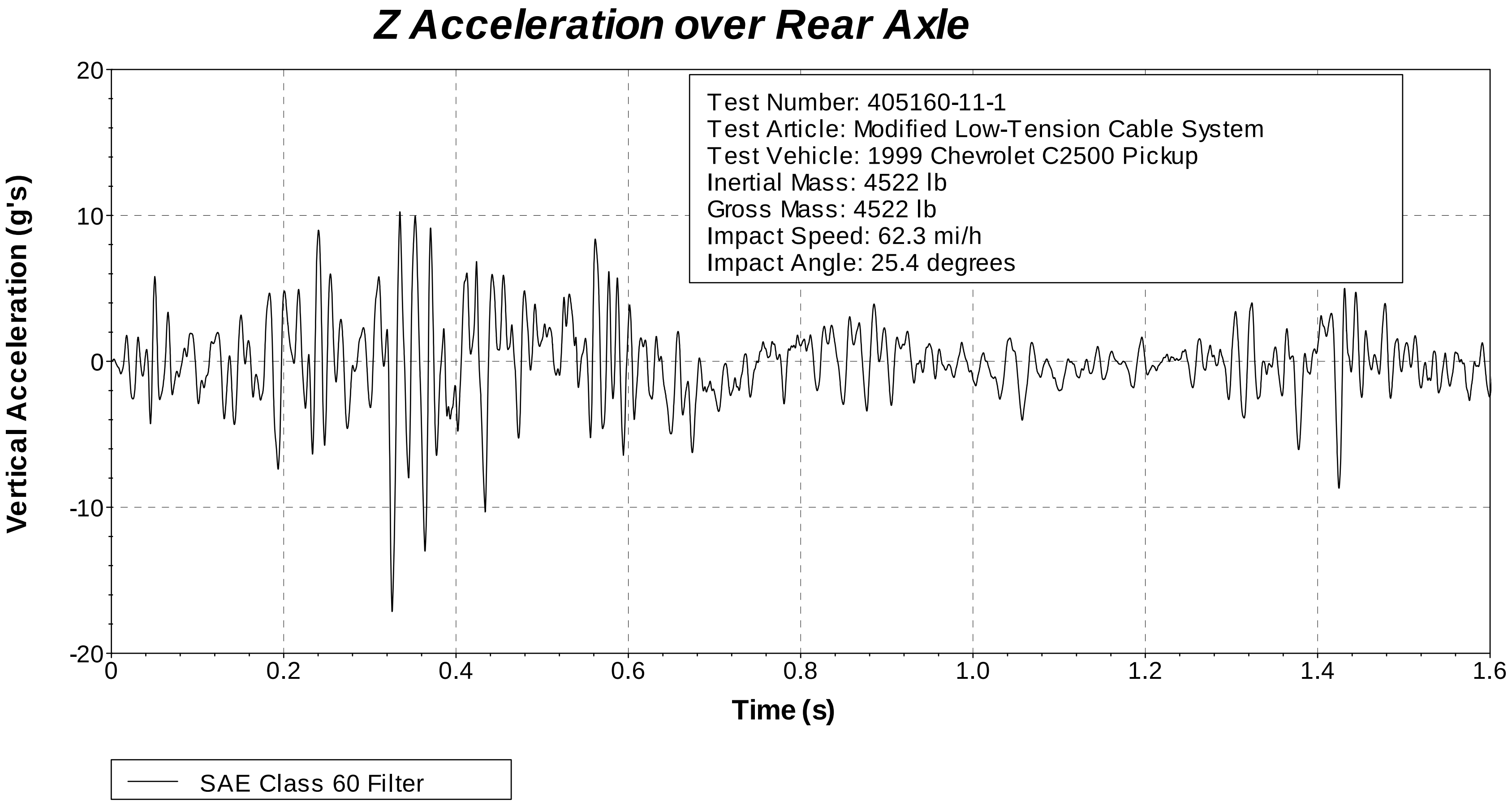


Figure G7. Vehicle vertical accelerometer trace for test 405160-11-1
(accelerometer located over rear axle).

APPENDIX H. THREE WIRE ROPE SYSTEM RETROFIT MANUAL

Retrofit Manual

Low Tension System → High Tension 3 Wire Rope System

Table of Contents

Converting Low Tension System to a 3 Wire Rope High Tension System

Materials and Parts Required

1) Two-FHWA accepted high tension wire rope terminals.
2) Three-wire rope splice connections (per splice location).
    a) Field swage terminations (see Installing a Turnbuckle with Field Swage Terminations).
    b) Epoxy socket terminations (see Splicing a Wire Rope with Epoxy Socket Terminations).
3) Three-wire rope turnbuckle connections (per turnbuckle location).
    a) Field swage terminations (see Installing a Turnbuckle with Field Swage Terminations).
    b) Epoxy socket terminations (see Installing a Turnbuckle with Epoxy Socket Terminations).
4) Six-wire rope terminations.
    a) Field swage terminations (see Installation of Field Applied Swage Termination).
    b) Epoxy socket terminations (see Installation of Epoxy Socket Termination).
5) Spool of 3x7 stranded wire rope prestreched or non-prestretched.
6) Calibrated tension meter.
7) Method of determining the cable temperature (thermometer).

Procedure

1) Remove low tension terminals as shown in Figure 1
    a) Release tension in system.
    b) Cut wire rope near the end of length of need (LON)/beginning of low tension terminal.
    c) Remove all structures above ground that were components of the low tension terminal, and consider removing all structures below ground that were components of the low tension terminal.
2) Existing low tension systems may be spliced together to form longer systems (see Figure 1 and 2 and “Splicing a Wire Rope with Field Applied Swage” or “Splicing a Wire Rope with Epoxy Socket Terminations” for instructions). The new systems must maintain a maximum spacing of turnbuckles listed below.
    a) 750 ft for non-prestretched wire rope.
    b) 1000 ft for prestretched wire rope.

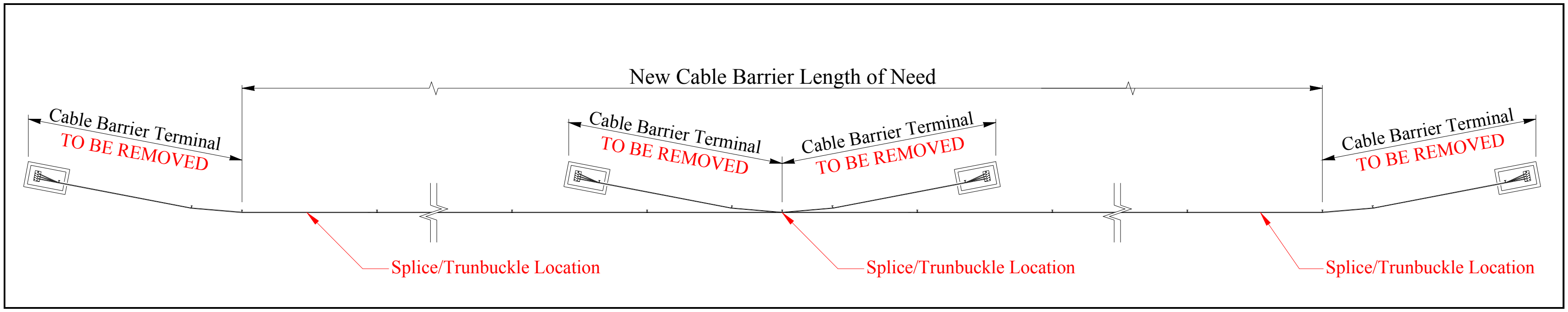


Figure 1. Drawing Indicating Portions of Barrier to be Removed or Replaced.

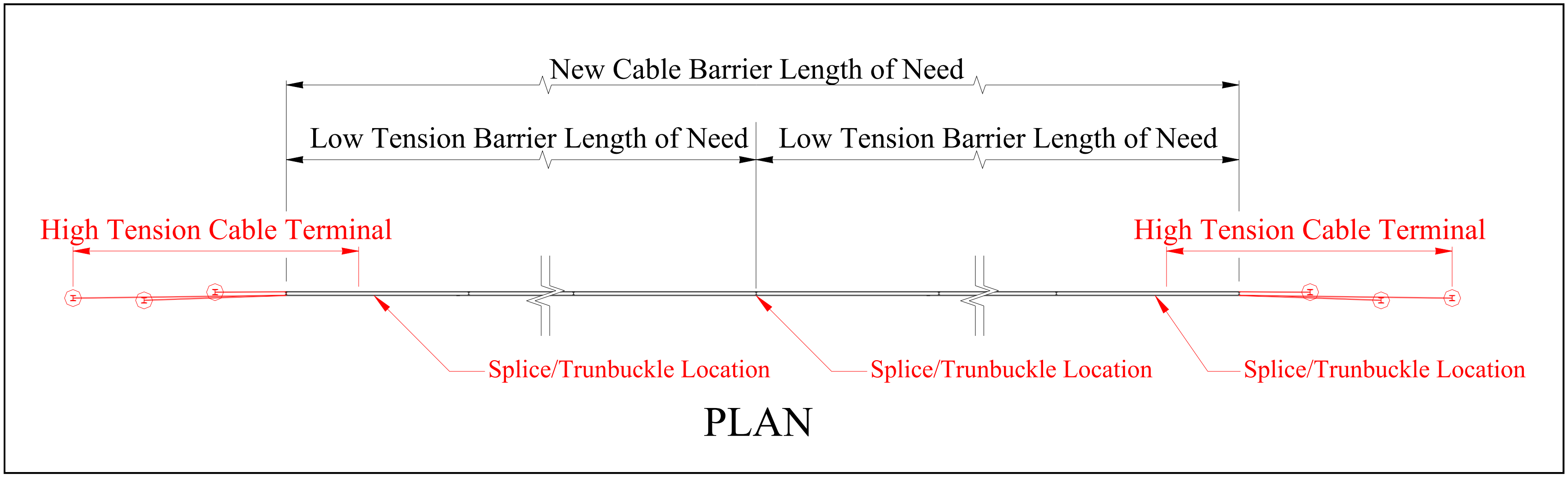


Figure 2. Drawing Showing New Terminal Installation Locations.

3) Install a FHWA accepted high tension terminal at each end of the system as shown in Figure 2. Lists of accepted systems are available at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/.

4) Install turnbuckles on each of the three wire ropes at the mid-length of the cumulative system. Turnbuckles shall be installed no more than 1000 ft apart for prestretched wire rope (750 ft for non-prestretched wire rope). A splice connection may be used at all other locations. At each end of the cumulative system a new strand of wire rope will be connected to the existing system that will be long enough to be terminated at the end of the newly installed terminal. Special care is to be taken to provide the same length-of-need as previously provided by the low tension system. A detailed drawing of retrofitted high tension system can be found in Appendix A.

5) Install the newly attached wire ropes at the appropriate wire rope heights described in Appendix A.

6) Terminate each of the three wire ropes at the appropriate terminal locations.

7) The turnbuckles installed in previous steps will be utilized to tension the wire ropes to correct levels. An ambient temperature reading will be taken at the installation site. Using this value a correct target tension value will be determined using chart in Appendix B.

Splicing a Wire Rope with Field Applied Swage

See "Installing a Turnbuckle with Field Swage Terminations"

Installing a Turnbuckle with Field Swage Terminations

Materials and Parts Required

1) One 5873G wire rope fitting with left-hand threads.
2) One 5874G wire rope fitting with right-hand threads.
3) One 5826G 1-inch wire rope turnbuckle.

Procedure

1) Install a 5873G wire rope fitting with left-hand threads on one of the two wire rope ends that will be joined together using a turnbuckle (see Installation of Field Applied Swage Termination).
2) Install a 5874G wire rope fitting with right hand threads on the opposing end not utilized in step 1 (see Installation of Field Applied Swage Termination).
3) Use a 5826G 1-inch wire rope turnbuckle to connect the two fittings installed in steps 1 and 2.
4) See Figure 3 for an assembled view of the turnbuckle with field applied terminations.

Figure 3. Image of Turnbuckle with Field Applied Terminations Installed.

Installation of Field Applied Swage Termination

Materials and Parts Required

1) Power supply/hydraulic motor.
2) 5875B swaging machine for wire rope fittings (available from Trinity Industries).
3) Field swage termination.
    a) 5873G wire rope fitting with left-hand threads.
    b) 5874G wire rope fitting with right-hand threads.
4) Measuring tape.
5) Marking pen.

Procedure

1) Cut wire rope to correct length.
2) Mark wire rope for correct embedment depth from cut end (5¼ inches for Trinity Highway Products, LLC parts numbered 5873G and 5874G) as shown in Figure 4.

Figure 4. Image of Marking of Wire Rope.

3) Insert swage termination (5873G or 5874G) into swaging machine (5875B) and secure with at least two nuts as shown in Figure 5.

Figure 5. Image of Installation of Field Swage Termination in Swaging Machine.

4) Insert the marked wire rope end into the open end of field swage termination. Verify that when the wire rope is fully inserted the mark previously placed on the wire rope is inside or flush with the end of the swage termination. **WARNING: discard any swage terminations that do not allow for proper embedment of the wire rope. A shallow embedment depth may lead to a premature failure of the termination.** See Figure 6 for an example of a properly embedded wire rope. Notice the mark is flush with the end of the termination.

Figure 6. Image of a Properly Embedded Wire Rope Ready for Swaging.

5) Next, apply moderate force to compression dies to cause them to engage the swage once the swaging process has begun. During the swaging process maintain a moderate force on the wire rope forcing it into the termination ensuring the wire rope is fully embedded during the swaging process. See Figure 7 for proper location to apply force to the compression dies. Always keep extremities away from the throat between compression dies and the gears on the underside of the swaging machine. These parts can do severe bodily harm if extremities get caught during the swaging process.

Figure 7. Image of a Proper Hand Placement during Wire Rope Swaging Process.

6) While maintaining force discussed in step 5, turn on hydraulic pump so that the hydraulic cylinder will pull the swage termination through the throat between the compression dies. Once the compression dies have engaged the swage termination, as shown in Figure 8, remove your hand from the compression dies to prevent bodily injury.

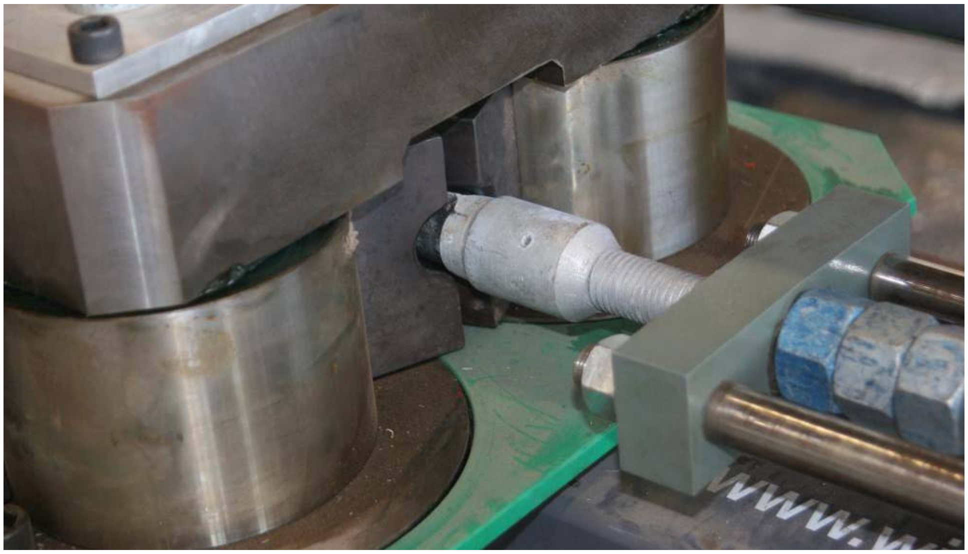


Figure 8. Image Showing Initial Engagement of Compression Dies.

7) Allow the cylinder to pull the swage termination completely through the compression dies. The compression dies should disengage from the termination automatically once the fitting is fully swaged.

8) Remove the termination from the swaging machine

9) The swaged termination should look similar to the one displayed in Figure 9. Check to see that you can no longer see the marking on the wire rope. If you can still see the marking on the wire rope, cut the wire rope just past the end of the termination and start over with a new termination. Discard the improperly swaged termination because it may have a reduced load capacity.

Figure 9. Image of a Properly Swaged Termination.

Splicing a Wire Rope with Epoxy Socket Terminations

Materials and Parts Required

1) One G-417 ¾-inch closed spelter socket.
2) One G-416 ¾-inch open spelter socket.
3) Two W416-7 Crosby 100cc wirelock socket compound.

Procedure

1) Install the G-417 ¾-inch closed spelter socket on one of the two ends of wire rope being spliced (see Installation of Epoxy Socket Termination).
2) Install the G-416 ¾-inch open spelter socket on the opposing end of wire rope being spliced (see Installation of Epoxy Socket Termination).
3) Splice the wire rope using the pin incorporated in the open spelter socket design. Figure 10 is a drawing of a splice connection using an epoxy spelter socket termination.

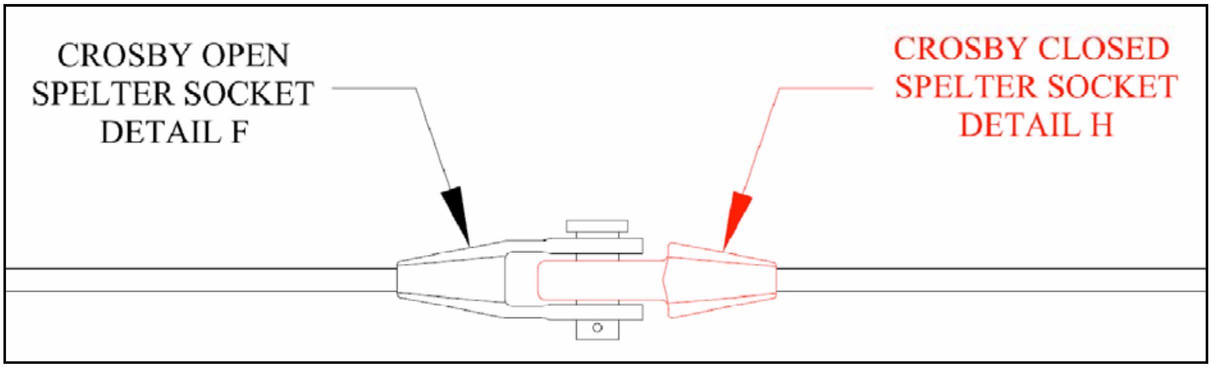


Figure 10. Drawing Showing Epoxy Spelter Socket Termination Splice Detail.

Installing a Turnbuckle with Epoxy Socket Terminations

Materials and Parts Required

1) Two G-416 ¾-inch open spelter sockets.
2) Two W416-7 Crosby 100cc wirelock socket compound.
3) One HG-226 Crosby eye and eye 1x12 turnbuckle.

Procedure

1) Install a G-416 ¾-inch open spelter socket on both ends of wire rope that will be spliced using a turnbuckle (see Installation of Epoxy Socket Termination).
2) Connect both open spelter sockets to the eye and eye turnbuckle using the pin incorporated in their design.
3) Final product should look similar to Figure 11.

Figure 11. Image of Turnbuckle with Epoxy Socket Terminations Installed.

Terminating a Wire Rope with Epoxy Socket Terminations

Use of the field swaged termination is recommended pending small car testing with the epoxy socket connection.

Materials and Parts Required

1) One G-416 ¾-inch open spelter socket.
2) One W416-7 Crosby 100cc wirelock socket compound.
3) One G-291 ¾-inch × 8-inch regular nut eye bolt.
4) Two ¾-inch nuts.

Procedure

1) Install a G-416 ¾-inch open spelter socket on the end of the wire rope that will be terminated (see Installation of Epoxy Socket Termination).
2) Attach a G-291 ¾-inch × 8-inch regular nut eye bolt using the pin incorporated in the design of the open spelter socket.
3) All G-291 eyebolts will utilize a double nut configuration when terminating a wire rope end.
4) Figure 12 is an example of how to correctly terminate a wire rope with an epoxy socket termination. Sheet 5 of Appendix A details how to install nuts on each end termination.

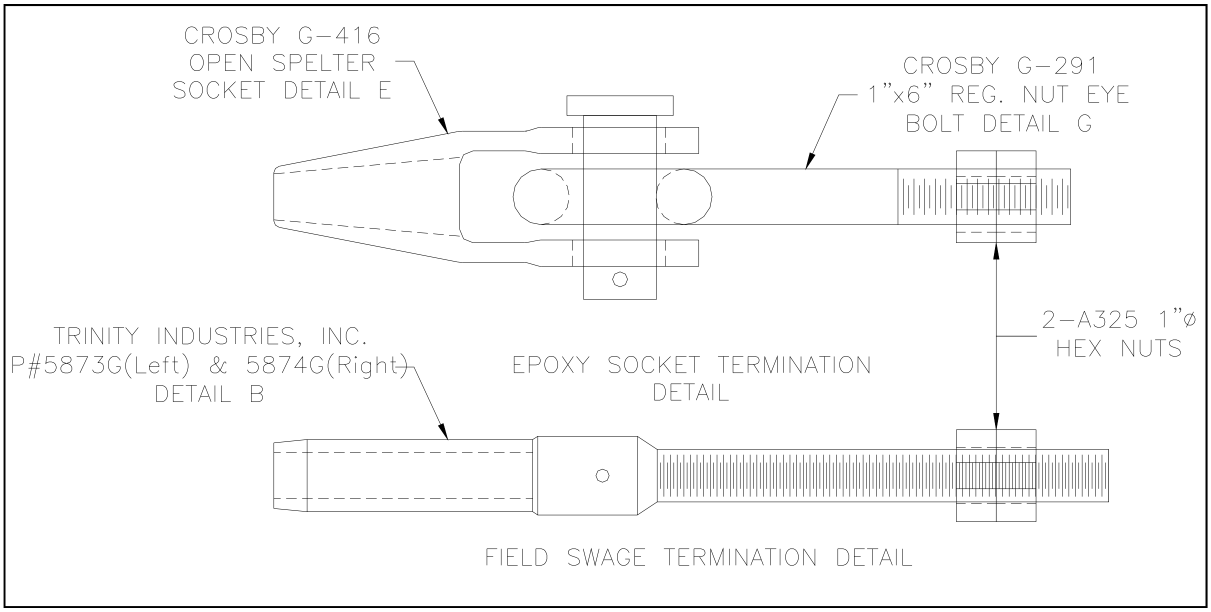


Figure 12. Image of Properly Terminated Epoxy Socket Termination.

Installation of Epoxy Socket Termination

Materials and Parts Required

1) G-417/G-416 Crosby ¾-inch closed/open eye epoxy spelter socket
2) W416-7 Crosby 100cc wirelock socket compound
3) Booster packs for temperatures between 48 and 27 deg F.
4) Banding wire
5) Silicone putty or plasticine
6) Stand to hold socket and wire rope
7)

Procedure

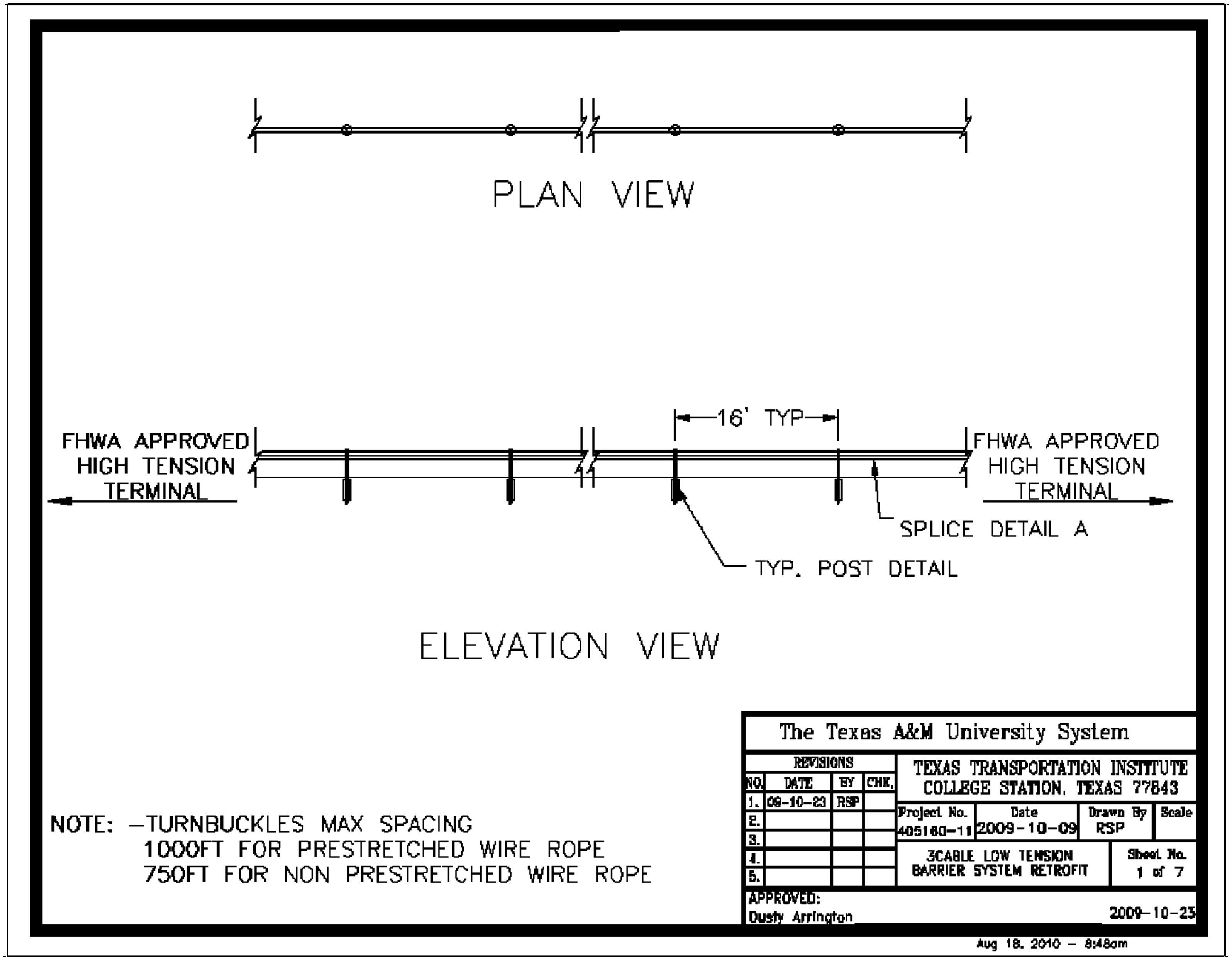
1) Please refer to Appendix C for Instructions provided by Crosby for preparing and curing of epoxy sockets.
2) Preparation time for the wire rope will vary based on skill level of installer
3) Gel time for the epoxy is approximately 15 minutes in a temp range of 65 to 75 deg F.
4) The Epoxy socket **MUST REMAIN UPRIGHT** for 10 minutes after gelling has occurred. This is a total of 25 minutes for a temperature range of 65 to 75 deg F. It is suggested to use a stand similar to the one shown in Figure 13 to hold the socket upright during the initial curing process.

Figure 13. Suggested Method of Supporting Termination During Initial Curing Process.

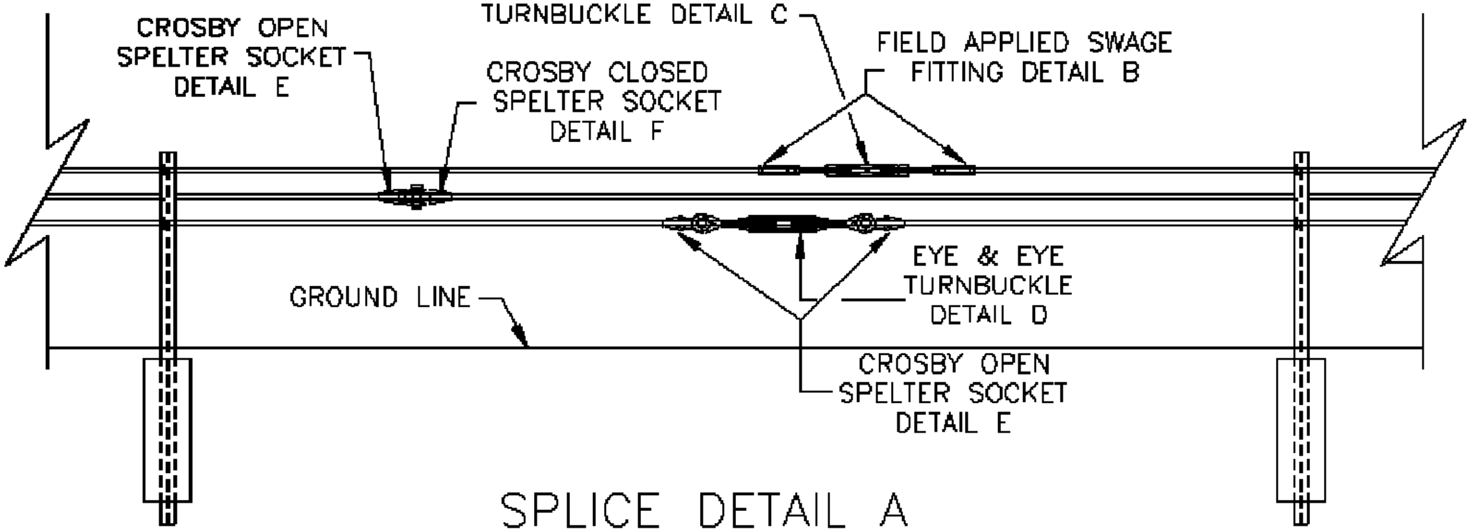
5) The Epoxy socket will be ready for service 60 minutes after gelling is complete. This is a total of 75 minutes for a temperature range of 65 to 75 deg F.

6) The socket should **NEVER** be submitted to loading until the socket is fully cured (75 minutes). **NEVER** heat the socket or wirelock in an attempt to speed up the curing process.

Appendix A: Detailed Drawings of Retrofitted High Tension System



NOTE: -TURNBUCKLES MAX SPACING
1000FT FOR PRESTRETCHED WIRE ROPE
750FT FOR NON PRESTRETCHED WIRE ROPE



SPLICE DETAIL A

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

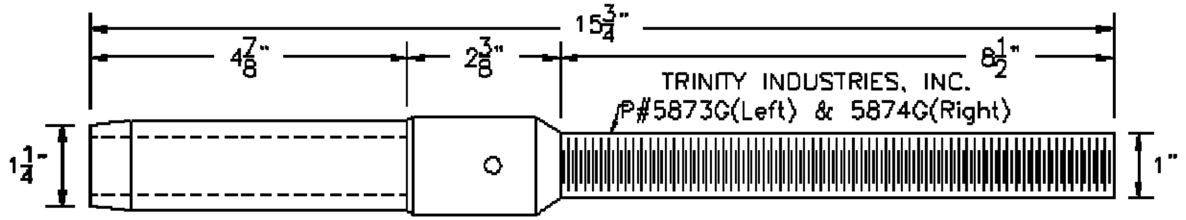
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

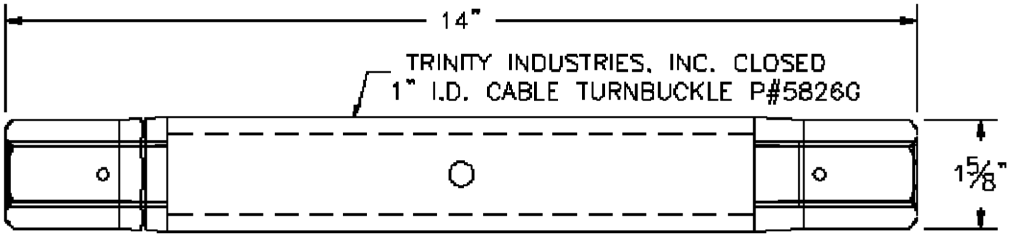
3CABLE LOW TENSION BARRIER SYSTEM RETROFIT

Sheet No. 2 of 7

Aug 18, 2010 - 8:47am



FIELD APPLIED SWAGE FITTING
DETAIL B



TURNBUCKLE DETAIL C

The Texas A&M University System

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

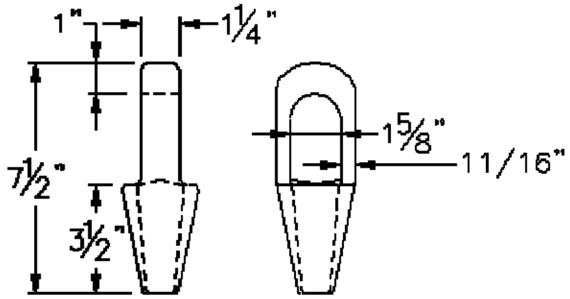
REVISIONS			
NO	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

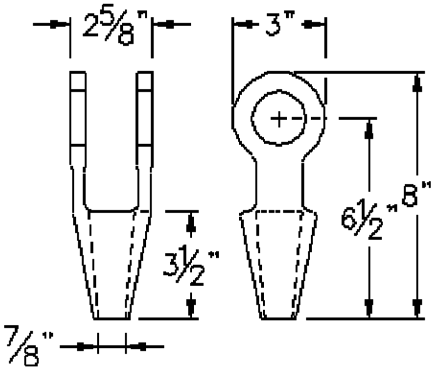
3CABLE LOW TENSION BARRIER SYSTEM RETROFIT

Sheet No. 3 of 7

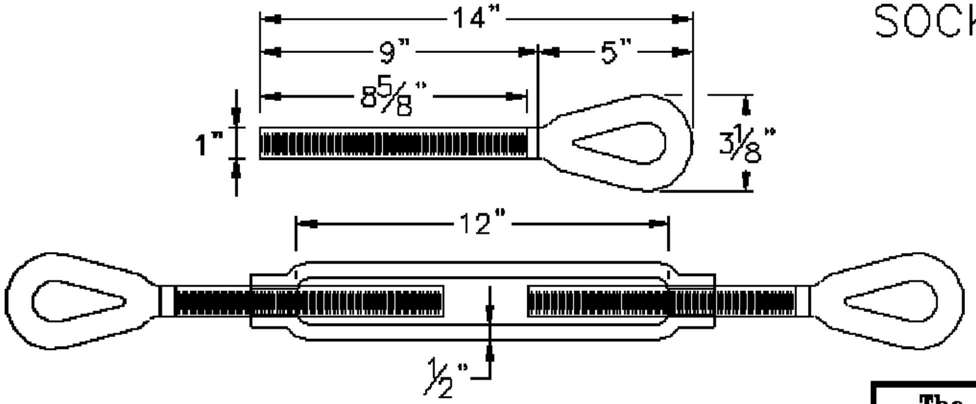
Aug 18, 2010 - 8:46am



CROSBY G-417 ¾"
CLOSED SPELTER
SOCKET DETAIL F



CROSBY G-416 ¾"
OPEN SPELTER
SOCKET DETAIL E



CROSBY HG-226 1"X12"
EYE & EYE TURNBUCKLE
DETAIL D

The Texas A&M University System

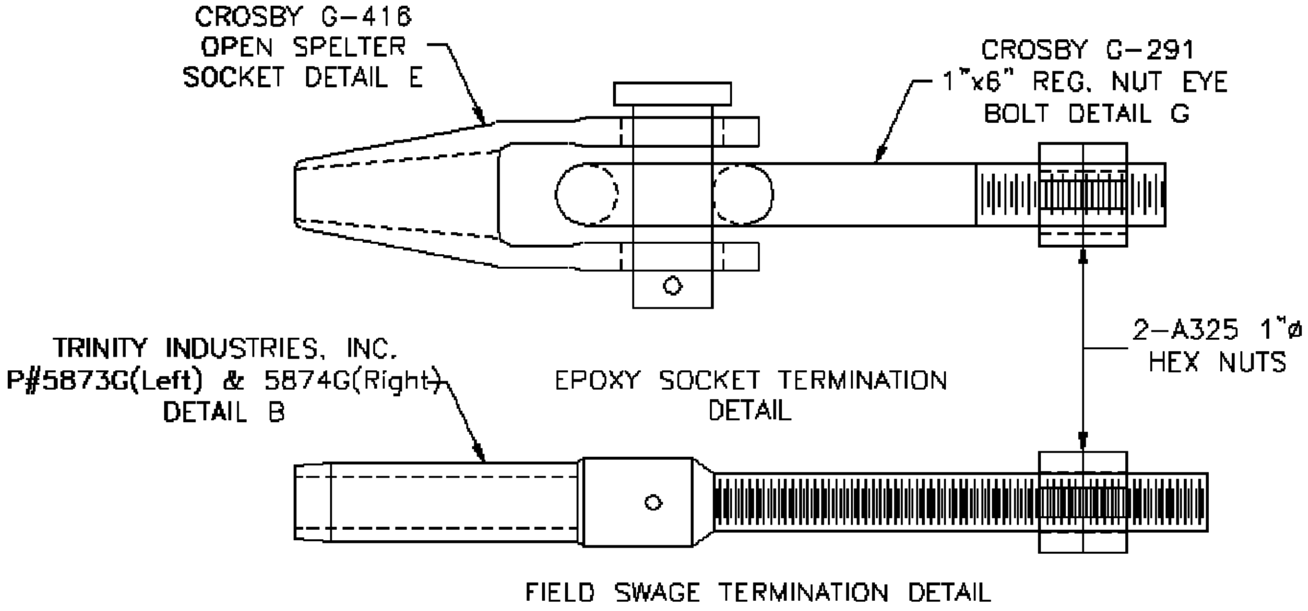
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2			
3			
4.			
5.			

Project No	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

3CABLE LOW TENSION BARRIER SYSTEM RETROFIT	Sheet No 4 of 7

Aug 18, 2010 – 8:41am



EPOXY SOCKET TERMINATION DETAIL

FIELD SWAGE TERMINATION DETAIL

CABLE TERMINATION DETAILS

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1	09-10-23	RSP	
2.			
3.			
4.			
6.			

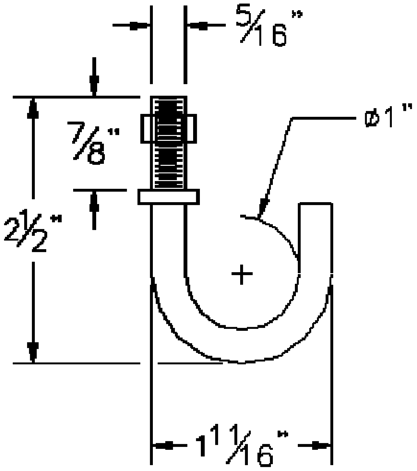
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

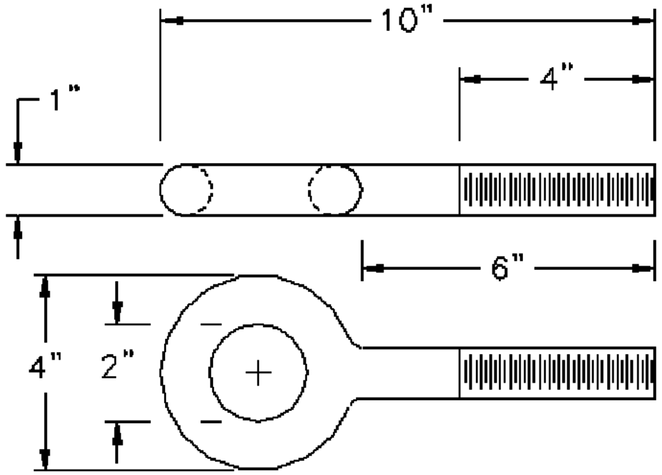
3CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
5 of 7

Aug 18, 2010 – 8:42am



J–BOLT
DETAIL J



CROSBY G–291 1"x6" REG.
NUT EYE BOLT DETAIL G

The Texas A&M University System

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

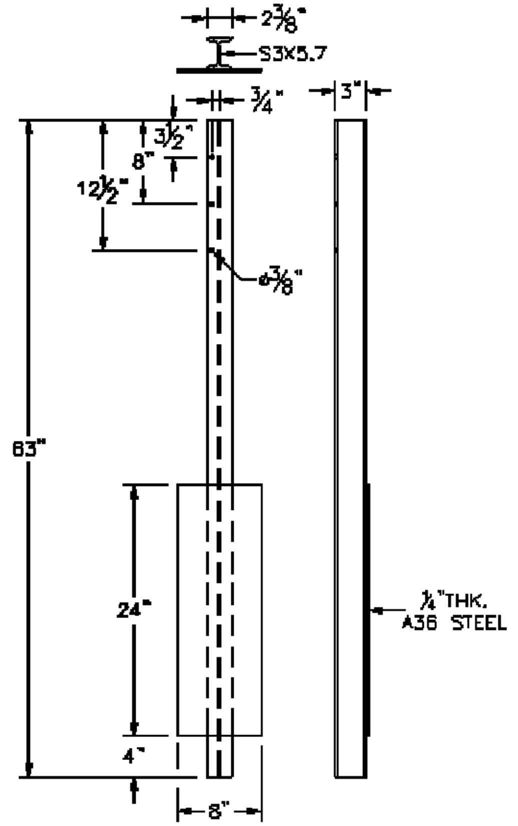
REVISIONS			
NO.	DATE	BY	CHK
1.	09-10-23	RSP	
2			
3			
4.			
5.			

Project No	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

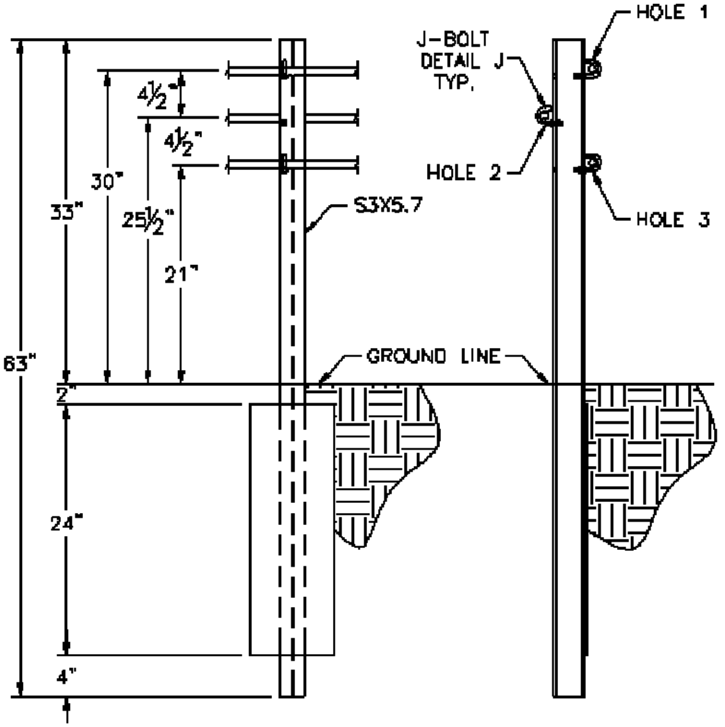
3CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
6 of 7

Aug 18, 2010 – 8:44am



TYP. POST DETAIL



LENGTH OF NEED POSTS
CABLE HEIGHTS

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CBK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

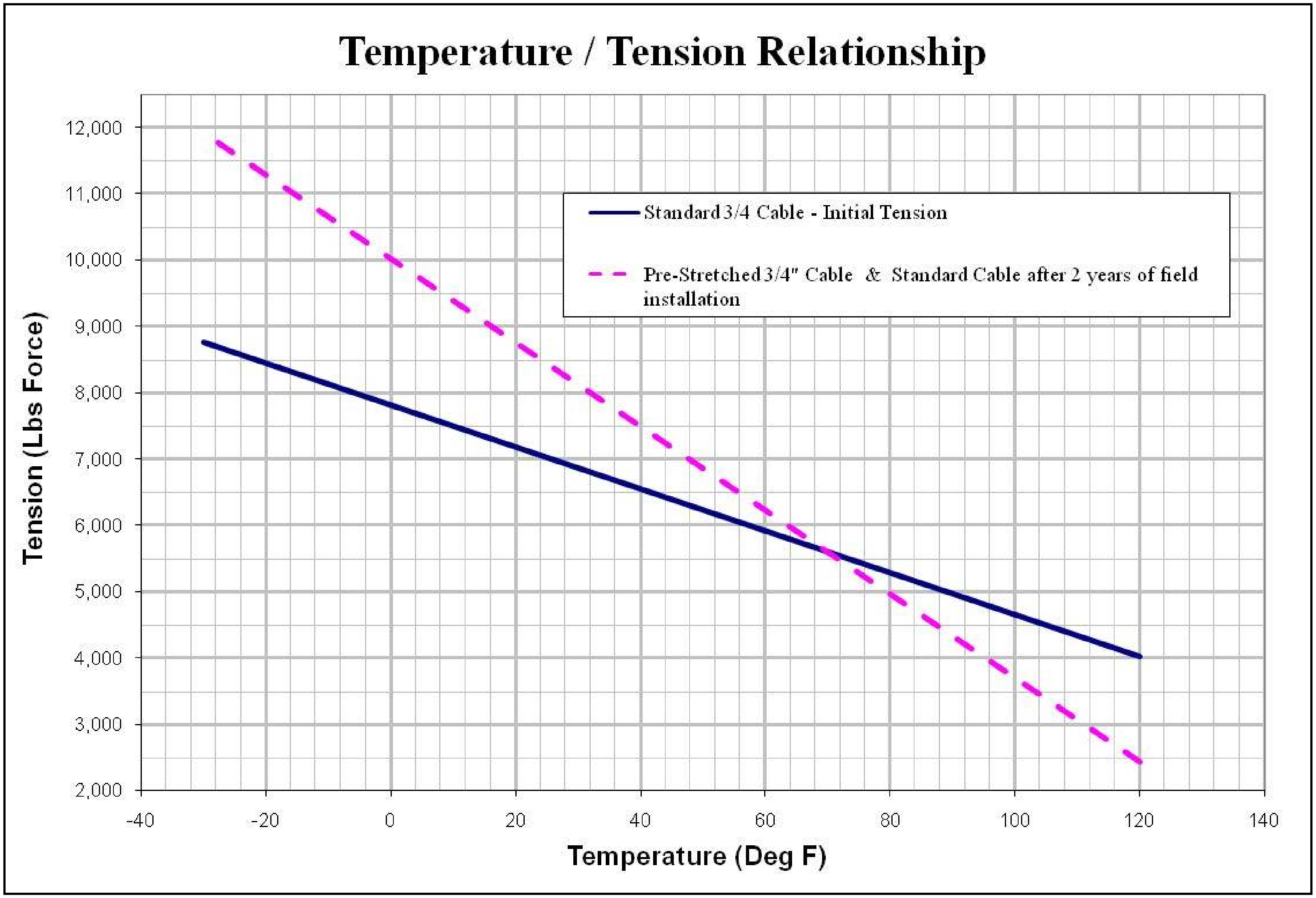
Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

3CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

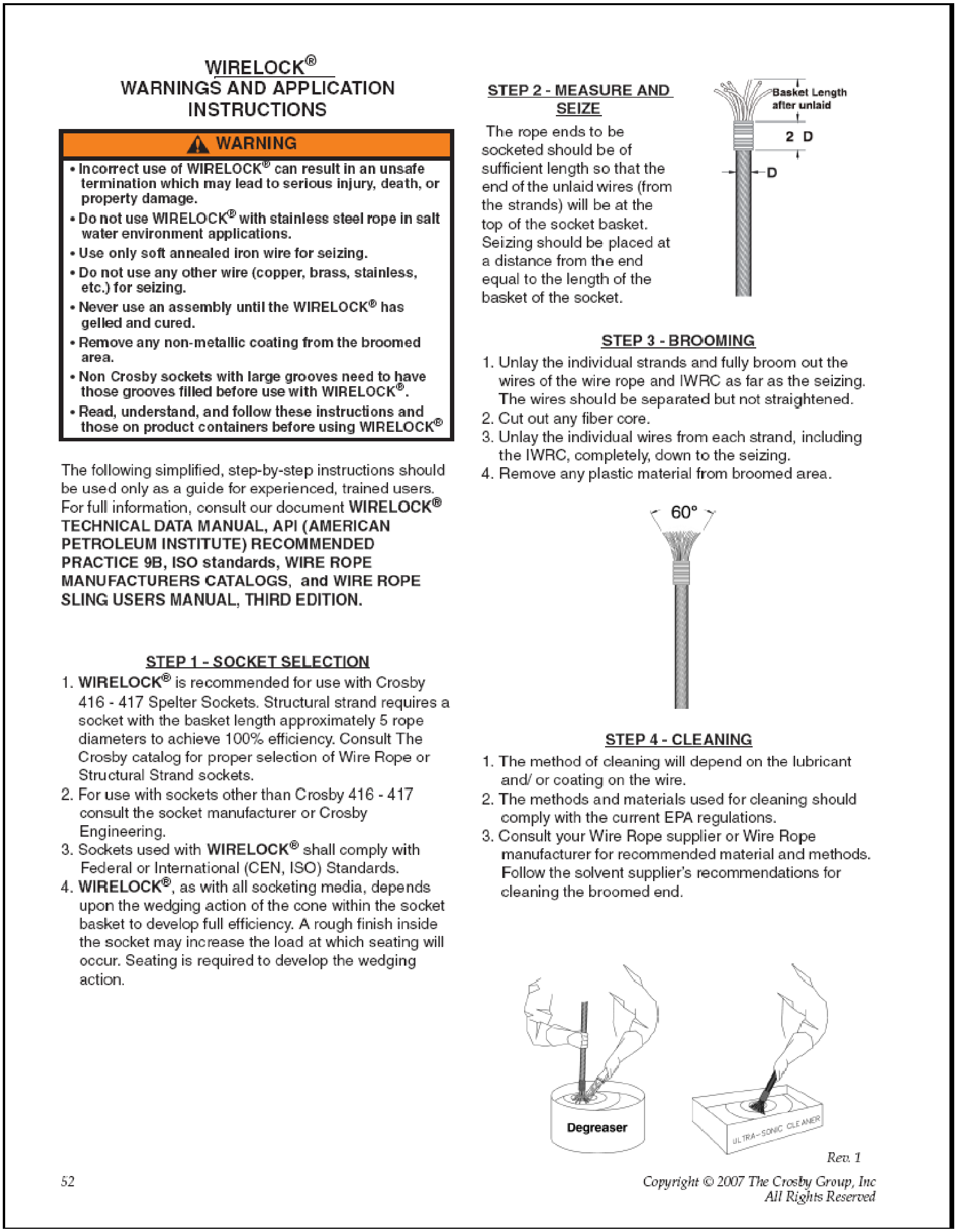
Sheet No
7 of 7

Aug 18, 2010 - 8:45am

Appendix B: Tension/Temperature Relationship



Appendix C: Manufacture Supplied Installation Instructions (10)



WIRELOCK®
WARNINGS AND APPLICATION INSTRUCTIONS

⚠ WARNING

- **Incorrect use of WIRELOCK® can result in an unsafe termination which may lead to serious injury, death, or property damage.**
- **Do not use WIRELOCK® with stainless steel rope in salt water environment applications.**
- **Use only soft annealed iron wire for seizing.**
- **Do not use any other wire (copper, brass, stainless, etc.) for seizing.**
- **Never use an assembly until the WIRELOCK® has gelled and cured.**
- **Remove any non-metallic coating from the broomed area.**
- **Non Crosby sockets with large grooves need to have those grooves filled before use with WIRELOCK®.**
- **Read, understand, and follow these instructions and those on product containers before using WIRELOCK®**

The following simplified, step-by-step instructions should be used only as a guide for experienced, trained users. For full information, consult our document **WIRELOCK® TECHNICAL DATA MANUAL, API (AMERICAN PETROLEUM INSTITUTE) RECOMMENDED PRACTICE 9B, ISO standards, WIRE ROPE MANUFACTURERS CATALOGS, and WIRE ROPE SLING USERS MANUAL, THIRD EDITION.**

STEP 1 - SOCKET SELECTION

1. **WIRELOCK®** is recommended for use with Crosby 416 - 417 Spelter Sockets. Structural strand requires a socket with the basket length approximately 5 rope diameters to achieve 100% efficiency. Consult The Crosby catalog for proper selection of Wire Rope or Structural Strand sockets.
2. For use with sockets other than Crosby 416 - 417 consult the socket manufacturer or Crosby Engineering.
3. Sockets used with **WIRELOCK®** shall comply with Federal or International (CEN, ISO) Standards.
4. **WIRELOCK®**, as with all socketing media, depends upon the wedging action of the cone within the socket basket to develop full efficiency. A rough finish inside the socket may increase the load at which seating will occur. Seating is required to develop the wedging action.

STEP 2 - MEASURE AND SEIZE

The rope ends to be socketed should be of sufficient length so that the end of the unlaid wires (from the strands) will be at the top of the socket basket. Seizing should be placed at a distance from the end equal to the length of the basket of the socket.

STEP 3 - BROOMING

1. Unlay the individual strands and fully broom out the wires of the wire rope and IWRC as far as the seizing. The wires should be separated but not straightened.
2. Cut out any fiber core.
3. Unlay the individual wires from each strand, including the IWRC, completely, down to the seizing.
4. Remove any plastic material from broomed area.

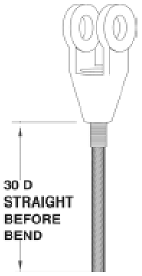
STEP 4 - CLEANING

1. The method of cleaning will depend on the lubricant and/ or coating on the wire.
2. The methods and materials used for cleaning should comply with the current EPA regulations.
3. Consult your Wire Rope supplier or Wire Rope manufacturer for recommended material and methods. Follow the solvent supplier's recommendations for cleaning the broomed end.

Rev. 1

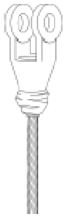
STEP 5 - POSITIONING OF SOCKET

1. Position socket over the broom until it reaches the seizing on the wire rope. The wires should be LEVEL with the top of the socket basket.
2. Clamp rope and socket vertically ensuring alignment of their axes.
3. **CAUTION: DO NOT USE OVERSIZED SOCKETS FOR WIRE ROPE.**



STEP 6 - SEAL SOCKET

Seal the base of the socket with putty or plasticine to prevent leakage of the **WIRELOCK®**.



STEP 7 - WIRELOCK® KITS

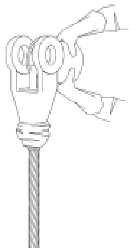
1. **WIRELOCK®** kits are pre-measured and consist of two (2) containers - one (1) with resin and one (1) with granular compound.
2. Use the complete kit - **NEVER MIX LESS THAN THE TOTAL CONTENTS OF BOTH CONTAINERS.**
3. Each kit has a shelf life clearly marked on each container and this must be observed. **NEVER USE OUT OF DATE KITS.**

⚠ CAUTION

- **WIRELOCK® resin, in liquid state, is flammable.**
- **Chemicals used in this product can give off toxic fumes and can burn eyes and skin.**
- **Never use out-of-date material.**
- **Use only in well-ventilated work areas.**
- **Never breathe fumes directly or for extended time.**
- **Always wear safety glasses to protect eyes.**
- **Always wear gloves to protect hands.**
- **Avoid direct contact with skin anywhere.**

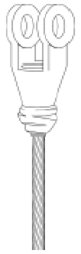
STEP 8 - MIXING AND POURING

1. Mix and pour **WIRELOCK®** within the temperature range of 48 degrees to 110 degrees F. Booster kits are available for reduced temperatures.
2. Pour all the resin into a container containing all the granular compound and mix thoroughly for two (2) minutes with a flat paddle.
3. Immediately after mixing, slowly pour the mixture down one side of the socket until the socket basket is full.
4. Check for leakage at nose of socket, add putty if required.



STEP 9 - CURING

1. **WIRELOCK®** will gel in approximately 15 minutes, in a temperature range 65 degrees F to 75 degrees F.
2. The socket must remain undisturbed in the vertical position for an additional ten (10) minutes after gel is complete.
3. The socket will be ready for service 60 minutes after gelling.
4. Never heat sockets to accelerate gel or curing.



STEP 10 - RE-LUBRICATION

Re-lubricate wire rope as required.

STEP 11 - PROOF LOADING

Whenever possible, the assembly should be proof loaded. All slings with poured sockets, in accordance with ASME B30.9, shall be Proof Loaded.

ALTERNATE SEIZING AND BROOMING METHOD

Reference the **WIRELOCK® TECHNICAL DATA MANUAL** from Crosby for an alternative socketing method.

APPENDIX I. THREE WIRE ROPE SYSTEM WITH ADDITIONAL FOURTH WIRE ROPE RETROFIT MANUAL

Retrofit Manual

Low Tension 3 Wire Rope System → High Tension 4 Wire Rope System

Table of Contents

Converting Low Tension 3 Wire Rope System to a 4-Wire Rope High Tension System

Materials and Parts Required

1) Two-FHWA accepted high tension wire rope terminals (for 4 wire rope systems).
2) Four-wire rope splice connections (per splice location).
    a) Field swage terminations (see Installing a Turnbuckle with Field Swage Terminations).
    b) Epoxy socket terminations (see Splicing a Wire Rope with Epoxy Socket Terminations).
3) Four-wire rope turnbuckle connections (per turnbuckle location).
    a) Field swage terminations (see Installing a Turnbuckle with Field Swage Terminations).
    b) Epoxy Socket terminations (see Installing a Turnbuckle with Epoxy Socket Terminations).
4) Eight-wire rope terminations.
    a) Field swage terminations (see Installation of Field Applied Swage Termination).
    b) Epoxy socket terminations (see Installation of Epoxy Socket Termination).
5) 3x7 stranded wire rope prestreched or non-prestretched.
6) Materials required to install fourth cable.
    a) Powered drill with 3/8-inch steel bit.
    b) J-bolts (1 per length of need post).
7) Calibrated tension meter.
8) Method of determining the ambient temperature (thermometer).

Procedure

1) Remove low tension terminals as shown in Figure 1.

    NOTE: First, verify all cable heights, then mark and drill holes, as shown in Appendix A, sheets 1 and 7.

    a) Release tension in system.

    b) Cut wire rope near the end of length of need (LON)/beginning of low tension terminal.

    c) Remove all structures above ground that were components of the low tension terminal, and consider removing all structures below ground that were components of the low tension terminal.
2) Existing low tension systems may be spliced together to form longer systems (see Figure 1 and 2 and “Splicing a Wire Rope with Epoxy Socket Terminations” or “Splicing a Wire Rope with Field Applied Swage” for instructions). The new systems must maintain a maximum spacing of turnbuckles listed below.
    a) 750 ft for non-prestretched wire rope.
    b) 1000 ft for prestretched wire rope.
3) Install a FHWA accepted high tension terminal at each end of the system as shown in Figure 2. Lists of accepted systems are available at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/.
4) Install fourth wire rope as described in “Installing Fourth Wire Rope on an Existing Low Tension Length of Need Post.”

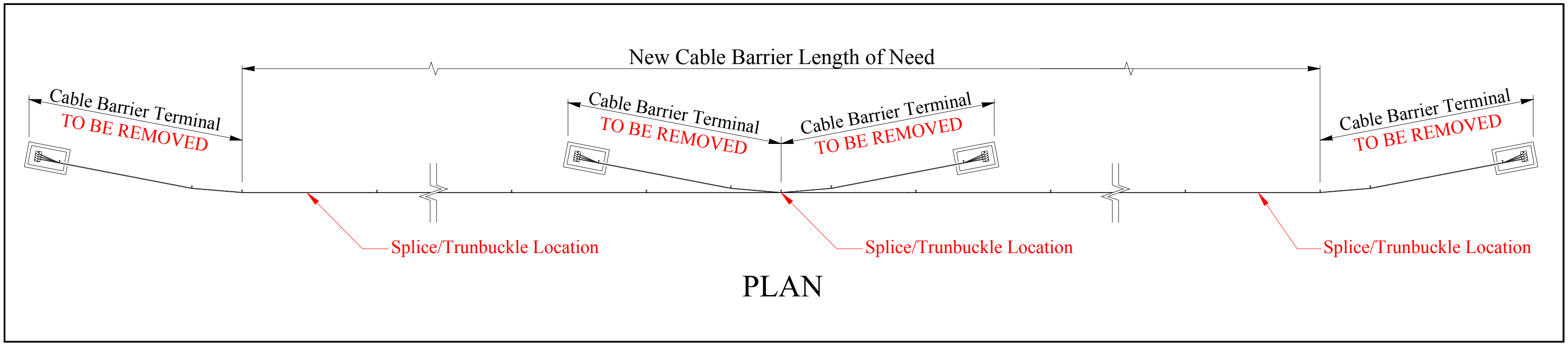


Figure 1. Drawing Indicating Portions of Barrier to be Removed or Replaced.

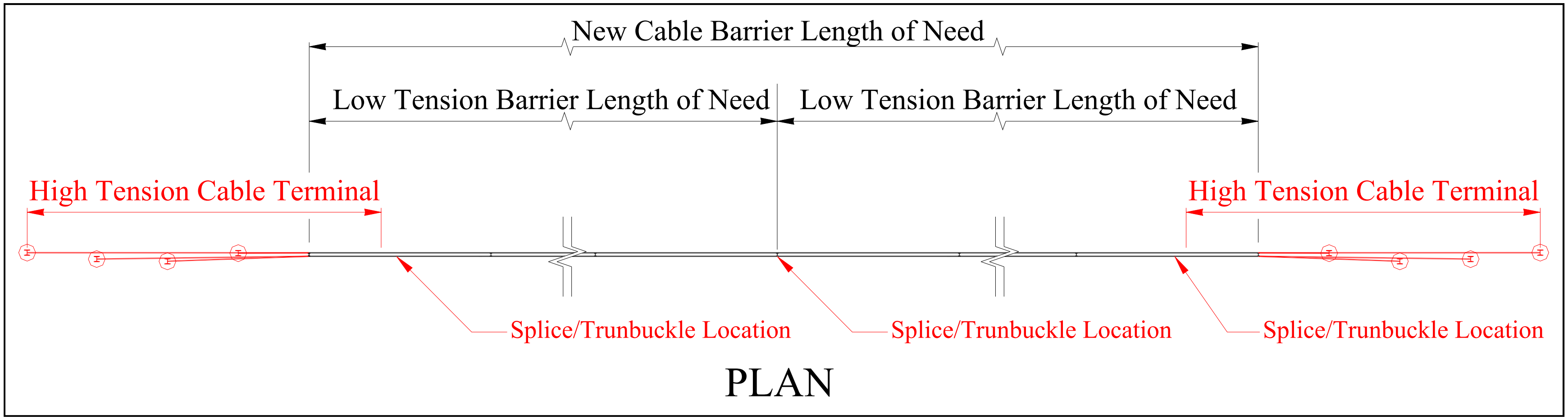


Figure 2. Drawing Showing New Terminal Installation Locations.

5) Install turnbuckles on each of the four wire ropes at the mid-length of the cumulative system. Turnbuckles shall be installed no more than 1000 ft apart for prestretched wire rope (750 ft for non-prestretched wire rope). A splice connection may be used at all other locations. At each end of the cumulative system a new strand of wire rope will be connected to the existing system that will be long enough to be terminated at the end of the newly installed terminal. Special care is to be taken to provide the same length-of-need as previously provided by the low tension system. A detailed drawing of retrofitted high tension system can be found in Appendix A.
6) Install the newly attached wire ropes at the appropriate wire rope heights described in Appendix A.
7) Terminate each of the four wire ropes at the appropriate terminal locations.
8) The turnbuckles installed in previous steps will be utilized to tension the wire ropes to correct levels. An ambient temperature reading will be taken at the installation site. Using this value a correct target tension value will be determined using chart in Appendix B.

Installing Fourth Wire Rope on an Existing Low Tension Length of Need Post

Materials and Parts Required

1) Tape measure.
2) Powered drill.
3) 3/8-inch metal drill bit.
4) J-bolt.
5) 3x7 stranded wire rope prestreched or non-prestretched.

Procedure

1) Field drill new 3/8-inch hole in length of need (LON) post 20 inches from the top of the post as shown in Figure 3.
2) The hole will be drilled only through one flange (field side of the post or opposite side of third wire rope as shown in Figure 4).
3) Attach 3x7 wire rope to LON post using standard a J-bolt with the tail of the bolt facing upward as shown in Figure 4.
4) Verify that height of fourth wire rope is 13½ inches.

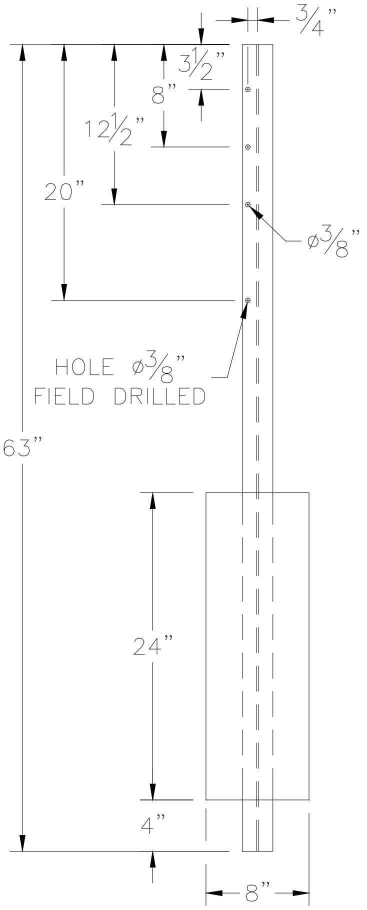


Figure 3. Length of Need Post Details.

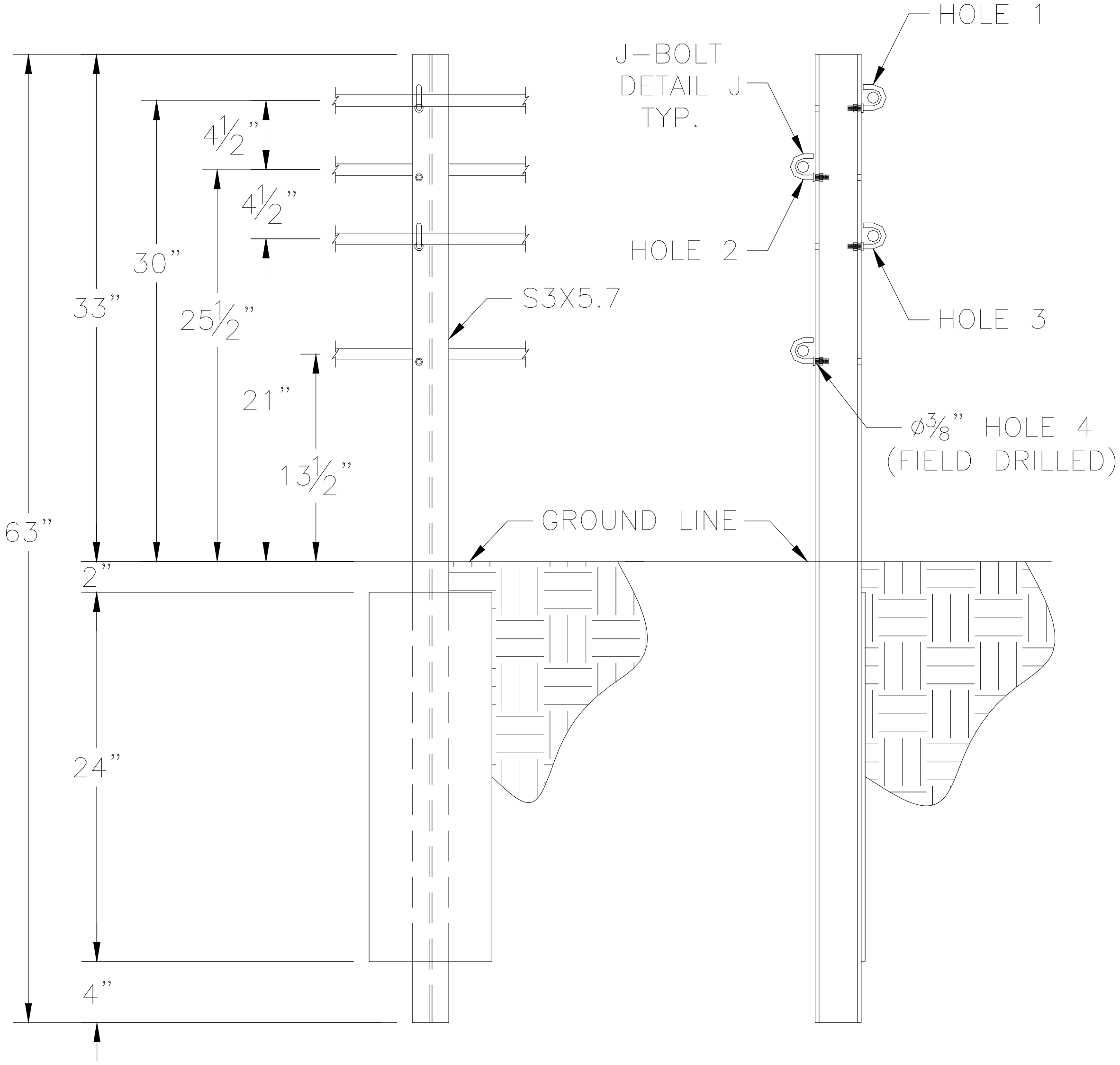


Figure 4. Wire Rope Mounting Locations.

Splicing a Wire Rope with Field Applied Swage

See “Installing a Turnbuckle with Field Swage Terminations”

Installing a Turnbuckle with Field Swage Terminations

Materials

1) One 5873G wire rope fitting with left-hand threads.
2) One 5874G wire rope fitting with right-hand threads.
3) One 5826G 1-inch wire rope turnbuckle.

Procedure

1) Install a 5873G wire rope fitting with left-hand threads on one of the two wire rope ends that will be joined together using a turnbuckle (see Installation of Field Applied Swage Termination).
2) Install a 5874G wire rope fitting with right hand threads on the opposing end not utilized in step 1 (see Installation of Field Applied Swage Termination).
3) Use a 5826G 1-inch wire rope turnbuckle to connect the two fittings installed in steps 1 and 2.
4) See Figure 5 for an assembled view of the turnbuckle with field applied terminations.

Figure 5. Image of Turnbuckle with Field Applied Terminations Installed.

Installation of Field Applied Swage Termination

Materials and Parts Required

1) Power supply/hydraulic motor.
2) 5875B swaging machine for wire rope fittings (available from Trinity Industries).
3) Field swage termination.
    a) 5873G wire rope fitting with left-hand threads.
    b) 5874G wire rope fitting with right-hand threads.
4) Measuring tape.
5) Marking pen.

Procedure

1) Cut wire rope to correct length.
2) Mark wire rope for correct embedment depth from cut end (5¼ inches for Trinity Highway Products, LLC part numbered 5873G and 5874G), as shown in Figure 6.

Figure 6. Image of Marking of Wire Rope.

3) Insert swage termination (5873G or 5874G) into swaging machine (5875B) and secure with at least two nuts as shown in Figure 7.

Figure 7. Image of Installation of Field Swage Termination in Swaging Machine.

4) Insert the marked wire rope end into the open end of field swage termination. Verify that when the wire rope is fully inserted the mark previously placed on the wire rope is inside or flush with the end of the swage termination. **WARNING: discard any swage terminations that do not allow for proper embedment of the wire rope. A shallow embedment depth may lead to a premature failure of the termination.** See Figure 8 for an example of a properly embedded wire rope. Notice the mark is flush with the end of the termination.

Figure 8. Image of a Properly Embedded Wire Rope Ready for Swaging.

5) Next, apply moderate force to compression dies to cause them to engage the swage once the swaging process has begun. During the swaging process maintain a moderate force on the wire rope forcing it into the termination ensuring the wire rope is fully embedded during the swaging process. See Figure 9 for proper location to apply force to the compression dies. Always keep extremities away from the throat between compression dies and the gears on the underside of the swaging machine. These parts can do severe bodily harm if extremities get caught during the swaging process.

Figure 9. Image of a Proper Hand Placement during Wire Rope Swaging Process.

6) While maintaining force discussed in step 5, turn on hydraulic pump so that the hydraulic cylinder will pull the swage termination through the throat between the compression dies. Once the compression dies have engaged the swage termination, as shown in Figure 10, remove your hand from the compression dies to prevent bodily injury.

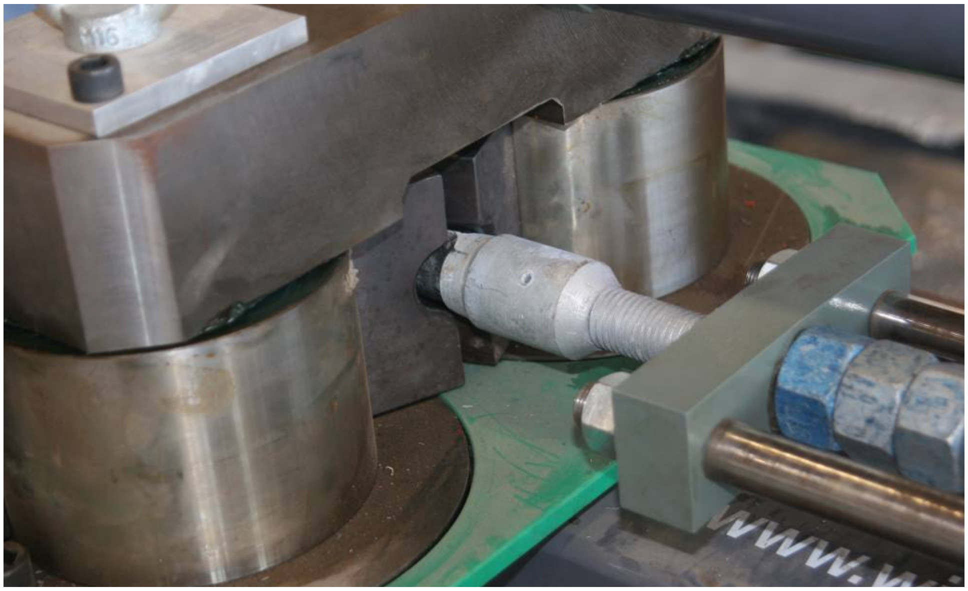


Figure 10. Image Showing Initial Engagement of Compression Dies.

7) Allow the cylinder to pull the swage termination completely through the compression dies. The compression dies should disengage from the termination automatically once the fitting is fully swaged.
8) Remove the termination from the swaging machine.
9) The swaged termination should look similar to the one displayed in Figure 11. Check to see that you can no longer see the marking on the wire rope. If you can still see the marking on the wire rope, cut the wire rope just past the end of the termination and start over with a new termination. Discard the improperly swaged termination because it may have a reduced load capacity.

Figure 11. Image of a Properly Swaged Termination

Splicing a Wire Rope with Epoxy Socket Terminations

Materials and Parts Required

1) One G-417 ¾-inch closed spelter socket.
2) One G-416 ¾-inch open spelter socket.
3) Two W416-7 Crosby 100cc wirelock socket compound.

Procedure

1) Install the G-417 ¾-inch closed spelter socket on one of the two ends of wire rope being spliced (see Installation of Epoxy Socket Termination).
2) Install the G-416 ¾-inch open spelter socket on the opposing end of wire rope being spliced (see Installation of Epoxy Socket Termination).
3) Splice the wire rope using the pin incorporated in the open spelter socket design. Figure 12 is a drawing of a splice connection using an epoxy spelter socket termination.

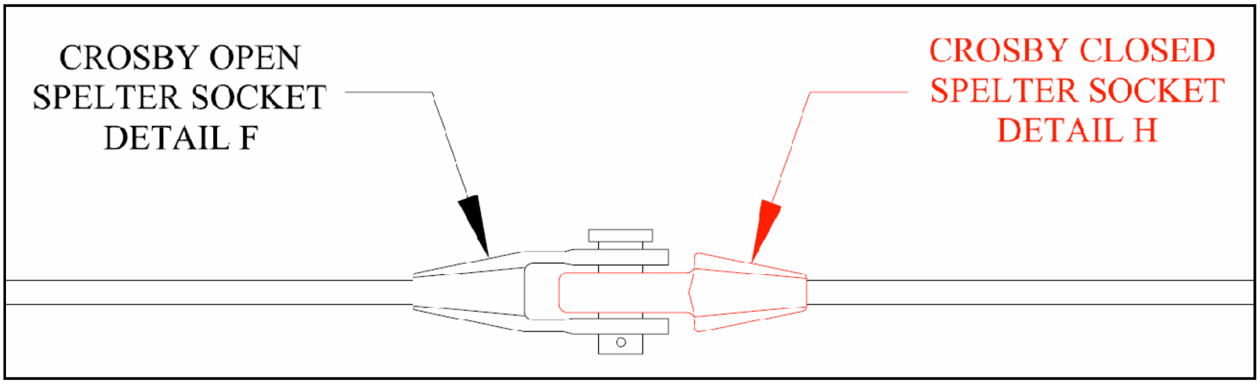


Figure 12. Drawing Showing Epoxy Spelter Socket Termination Splice Detail.

Installing a Turnbuckle with Epoxy Socket Terminations

Materials and Parts Required

1) Two G-416 ¾-inch open spelter sockets.
2) Two W416-7 Crosby 100cc wirelock socket compound.
3) One HG-226 Crosby eye and eye 1x12 turnbuckle.

Procedure

1) Install a G-416 ¾-inch open spelter socket on both ends of wire rope that will be spliced using a turnbuckle (see Installation of Epoxy Socket Termination).
2) Connect both open spelter sockets to the eye and eye turnbuckle using the pin incorporated in their design.
3) Final product should look similar to Figure 13.

Figure 13. Image of Turnbuckle with Epoxy Socket Terminations Installed.

Terminating a Wire Rope with Epoxy Socket Terminations

Recommend use of field swage termination pending small car testing with the epoxy socket connection.

Materials and Parts Required

1) One G-416 ¾-inch open spelter socket.
2) One W416-7 Crosby 100cc wirelock socket compound.
3) One G-291 ¾-inch × 8-inch regular nut eye bolt.
4) Two ¾-inch nuts.

Procedure

1) Install a G-416 ¾-inch open spelter socket on the end of the wire rope that will be terminated (see Installation of Epoxy Socket Termination).
2) Attach a G-291 ¾-inch × 8-inch regular nut eye bolt using the pin incorporated in the design of the open spelter socket.
3) All G-291 eyebolts will utilize a double nut configuration when terminating a wire rope end.
4) Figure 14 is an example of how to correctly terminate a wire rope with an epoxy socket termination.

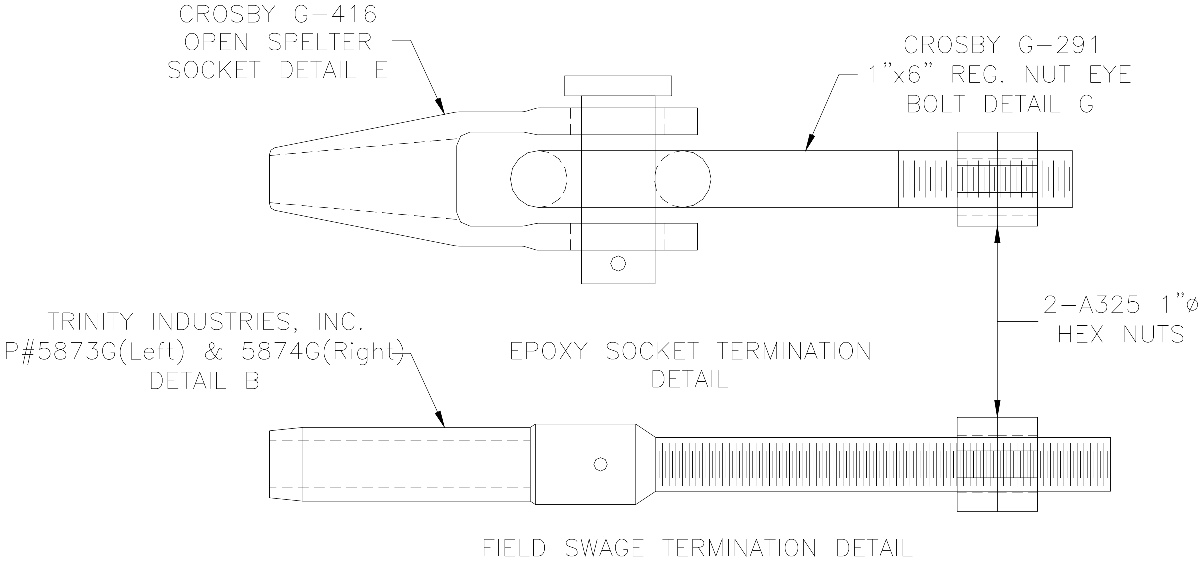


Figure 14. Image of Properly Terminated Epoxy Socket Termination

Installation of Epoxy Socket Termination

Materials and Parts Required

1) G-417/G-416 Crosby ¾-inch closed/open eye epoxy spelter socket
2) W416-7 Crosby 100cc wirelock socket compound
3) Booster packs for temperatures between 48 and 27 deg F.
4) Banding wire
5) Silicone putty or plasticine
6) Stand to hold socket and wire rope

Procedure

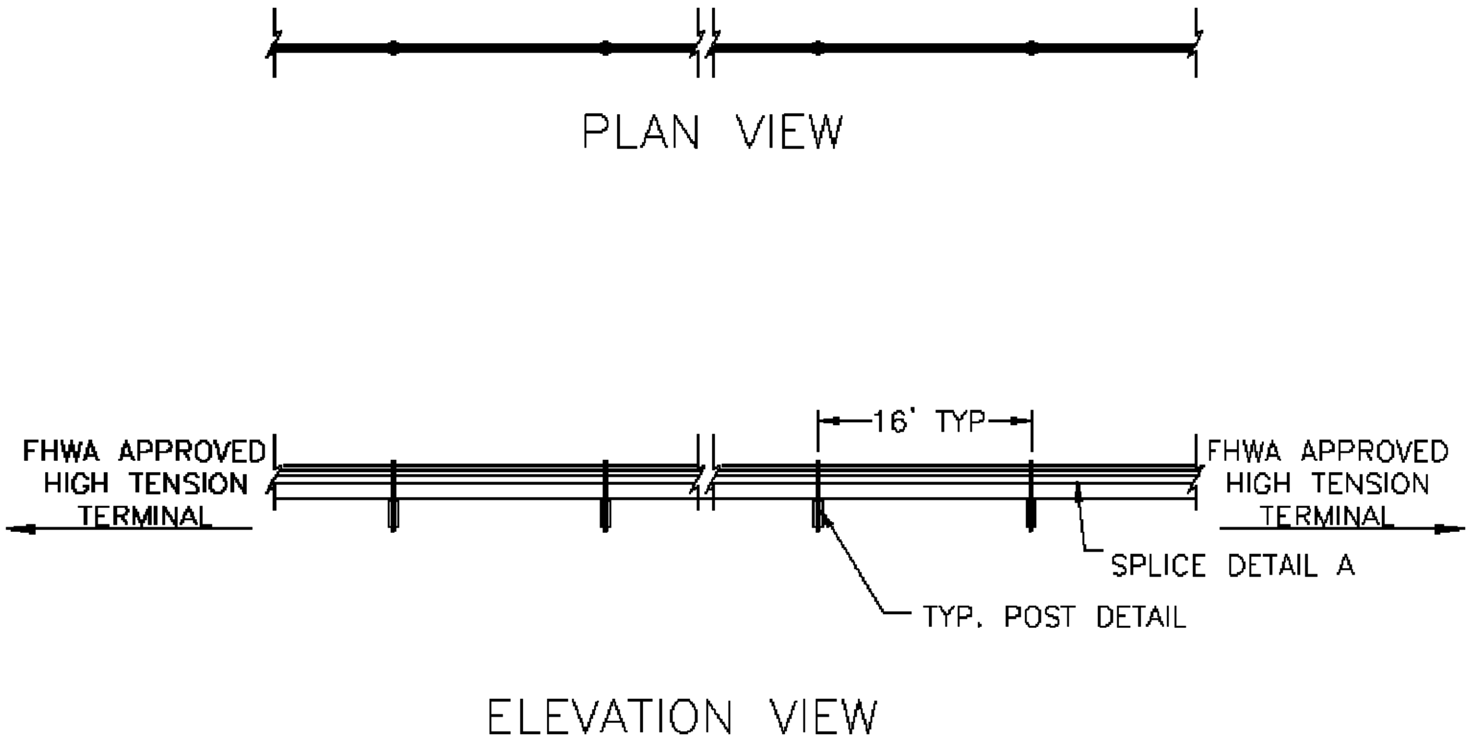
1) Please refer to Appendix C for Instructions provided by Crosby for preparing and curing of epoxy sockets.
2) Preparation time for the wire rope will vary based on skill level of installer
3) Gel time for the epoxy is approximately 15 minutes in a temp range of 65 to 75 deg F.
4) The Epoxy socket **MUST REMAIN UPRIGHT** for 10 minutes after gelling has occurred. This is a total of 25 minutes for a temperature range of 65 to 75 deg F. It is suggested to use a stand similar to the one shown in Figure 15 to hold the socket upright during the initial curing process.

Figure 15. Suggested Method of Supporting Termination During Initial Curing Process.

5) The Epoxy socket will be ready for service 60 minutes after gelling is complete. This is a total of 75 minutes for a temperature range of 65 to 75 deg F.

6) The socket should **NEVER** be submitted to loading until the socket is fully cured (75 minutes). **NEVER** heat the socket or wirelock in an attempt to speed up the curing process.

Appendix A: Detailed Drawings of Retrofitted High Tension



NOTE: -TURNBUCKLES MAX SPACING
1000FT FOR PRESTRETCHED WIRE ROPE
750FT FOR NON PRESTRETCHED WIRE ROPE

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

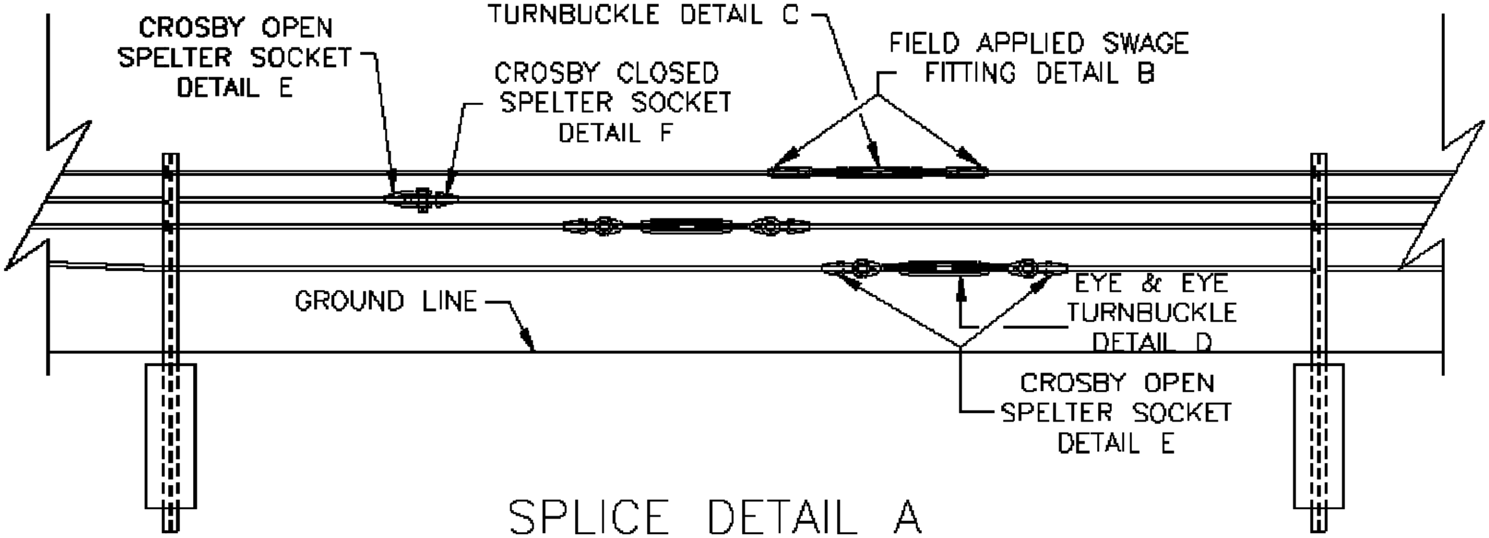
Project No	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
1 of 7

APPROVED:
Dusty Arrington 2009-10-23

Aug 18, 2010 - 9.25am



SPLICE DETAIL A

The Texas A&M University System

REVISIONS			
NO	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5			

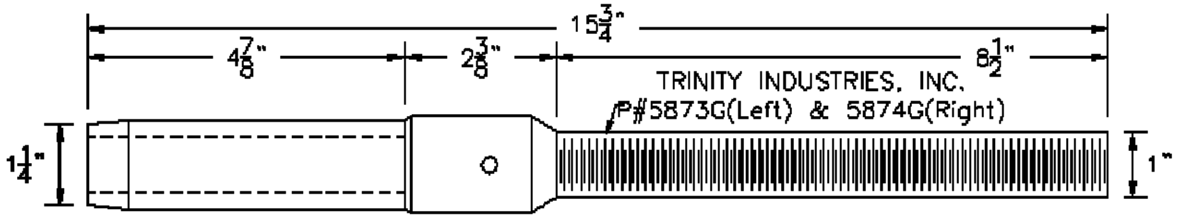
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

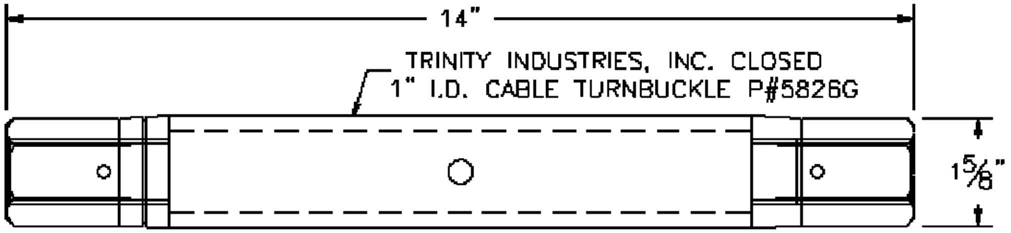
4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
2 of 7

Aug 18, 2010 - 9:30am



FIELD APPLIED SWAGE FITTING
DETAIL B



TURNBUCKLE DETAIL C

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

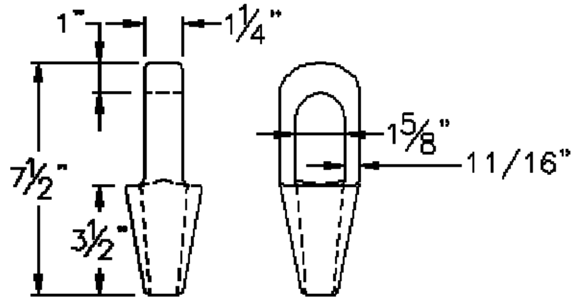
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

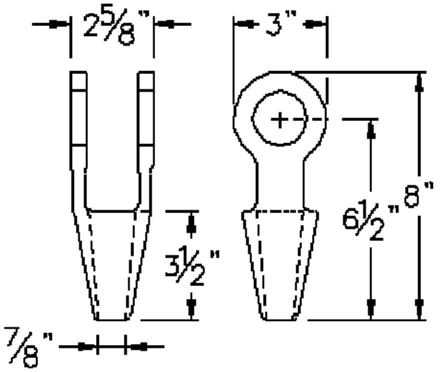
4CABLE LOW TENSION BARRIER SYSTEM RETROFIT

Sheet No. 3 of 7

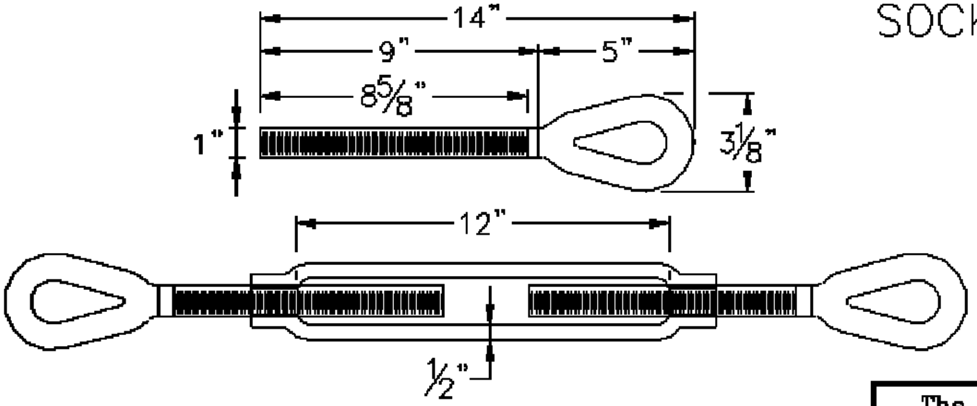
Aug 18, 2010 - 9:29am



CROSBY G-417 ¾"
CLOSED SPELTER
SOCKET DETAIL F



CROSBY G-416 ¾"
OPEN SPELTER
SOCKET DETAIL E



CROSBY HG-226 1"X12"
EYE & EYE TURNBUCKLE
DETAIL D

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-29	RSP	
2			
3			
4.			
6.			

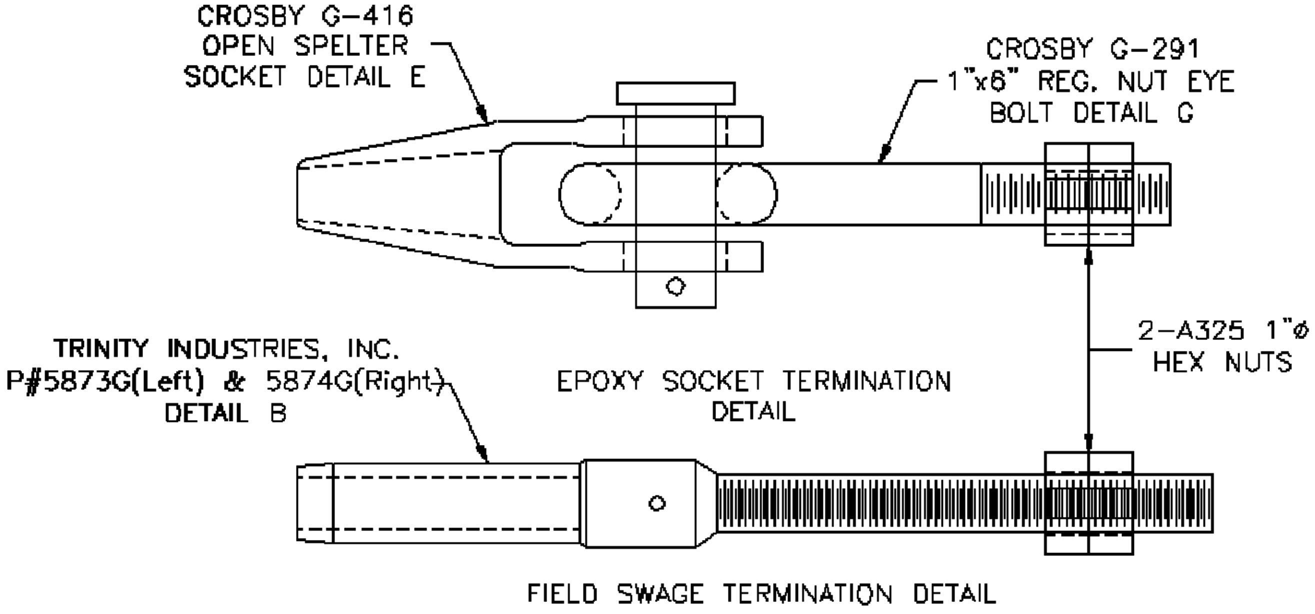
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
4 of 7

Aug 18, 2010 - 9:31pm



CABLE TERMINATION DETAILS

The Texas A&M University System

REVISIONS

NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

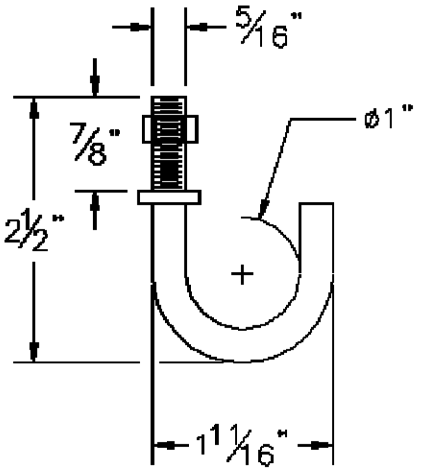
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

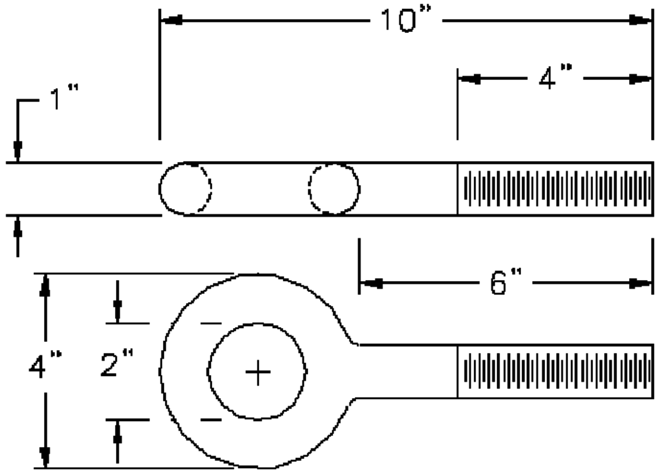
4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
5 of 7

Aug 16, 2010 – 9:32am



J-BOLT
DETAIL J



CROSBY G-291 1"x6" REG.
NUT EYE BOLT DETAIL G

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5			

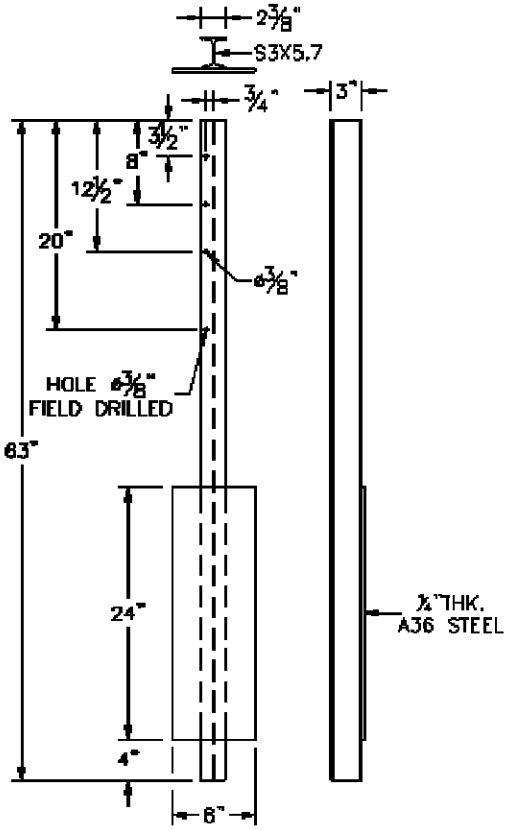
TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

Project No	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

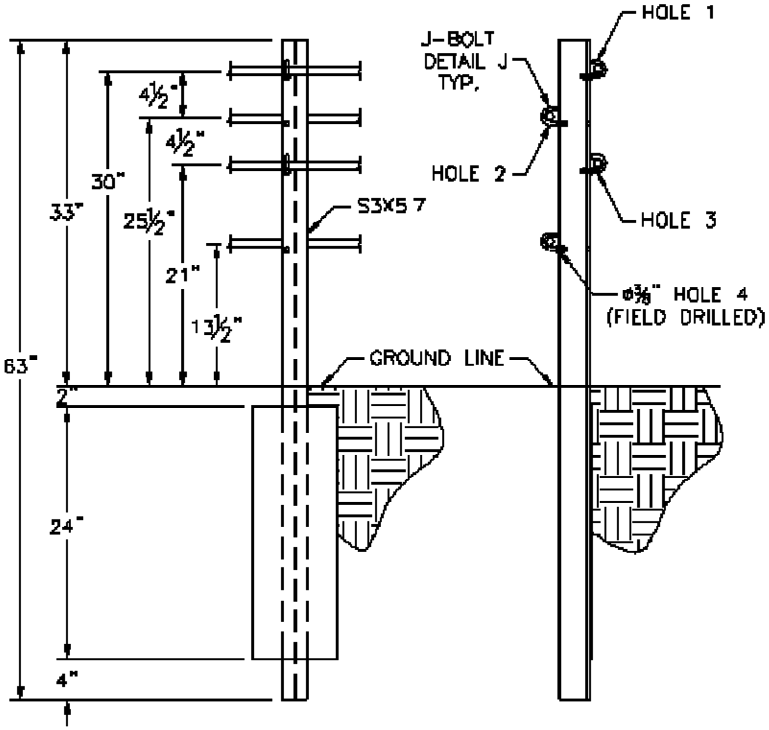
4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

Sheet No.
6 of 7

Aug 18, 2010 – 9:33am



TYP. POST DETAIL



LENGTH OF NEED POSTS
CABLE HEIGHTS

The Texas A&M University System

REVISIONS			
NO.	DATE	BY	CHK.
1.	09-10-23	RSP	
2.			
3.			
4.			
5.			

TEXAS TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS 77843

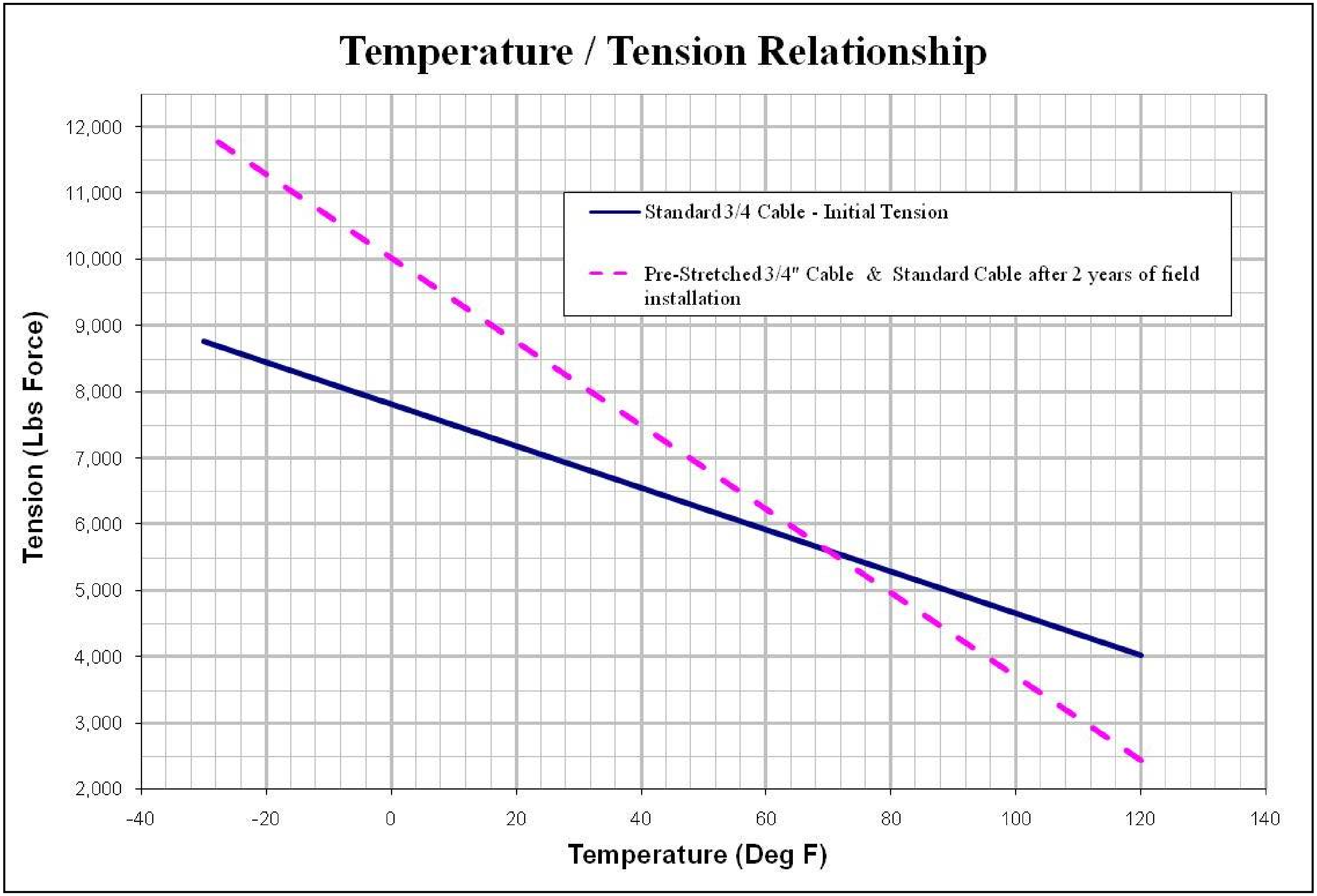
Project No.	Date	Drawn By	Scale
405160-11	2009-10-09	RSP	

4CABLE LOW TENSION
BARRIER SYSTEM RETROFIT

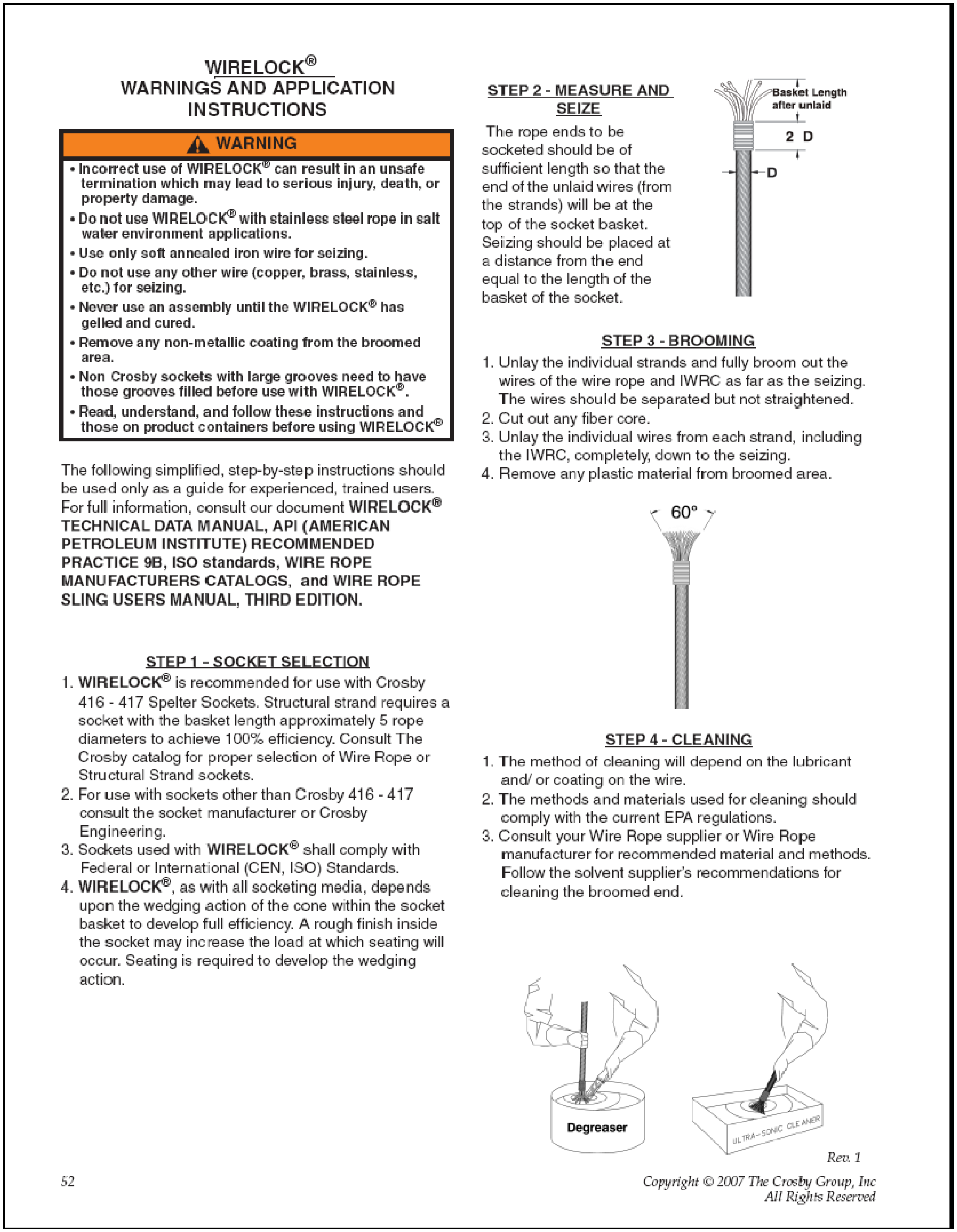
Sheet No.
7 of 7

Aug 18, 2010 – 9.35am

Appendix B: Tension/Temperature Relationship



Appendix C: Manufacture Supplied Installation Instructions (10)



WIRELOCK®
WARNINGS AND APPLICATION INSTRUCTIONS

⚠ WARNING

- **Incorrect use of WIRELOCK® can result in an unsafe termination which may lead to serious injury, death, or property damage.**
- **Do not use WIRELOCK® with stainless steel rope in salt water environment applications.**
- **Use only soft annealed iron wire for seizing.**
- **Do not use any other wire (copper, brass, stainless, etc.) for seizing.**
- **Never use an assembly until the WIRELOCK® has gelled and cured.**
- **Remove any non-metallic coating from the broomed area.**
- **Non Crosby sockets with large grooves need to have those grooves filled before use with WIRELOCK®.**
- **Read, understand, and follow these instructions and those on product containers before using WIRELOCK®**

The following simplified, step-by-step instructions should be used only as a guide for experienced, trained users. For full information, consult our document **WIRELOCK® TECHNICAL DATA MANUAL, API (AMERICAN PETROLEUM INSTITUTE) RECOMMENDED PRACTICE 9B, ISO standards, WIRE ROPE MANUFACTURERS CATALOGS, and WIRE ROPE SLING USERS MANUAL, THIRD EDITION.**

STEP 1 - SOCKET SELECTION

1. **WIRELOCK®** is recommended for use with Crosby 416 - 417 Spelter Sockets. Structural strand requires a socket with the basket length approximately 5 rope diameters to achieve 100% efficiency. Consult The Crosby catalog for proper selection of Wire Rope or Structural Strand sockets.
2. For use with sockets other than Crosby 416 - 417 consult the socket manufacturer or Crosby Engineering.
3. Sockets used with **WIRELOCK®** shall comply with Federal or International (CEN, ISO) Standards.
4. **WIRELOCK®**, as with all socketing media, depends upon the wedging action of the cone within the socket basket to develop full efficiency. A rough finish inside the socket may increase the load at which seating will occur. Seating is required to develop the wedging action.

STEP 2 - MEASURE AND SEIZE

The rope ends to be socketed should be of sufficient length so that the end of the unlaid wires (from the strands) will be at the top of the socket basket. Seizing should be placed at a distance from the end equal to the length of the basket of the socket.

STEP 3 - BROOMING

1. Unlay the individual strands and fully broom out the wires of the wire rope and IWRC as far as the seizing. The wires should be separated but not straightened.
2. Cut out any fiber core.
3. Unlay the individual wires from each strand, including the IWRC, completely, down to the seizing.
4. Remove any plastic material from broomed area.

STEP 4 - CLEANING

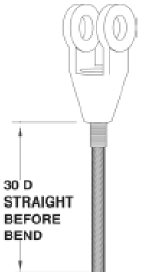
1. The method of cleaning will depend on the lubricant and/ or coating on the wire.
2. The methods and materials used for cleaning should comply with the current EPA regulations.
3. Consult your Wire Rope supplier or Wire Rope manufacturer for recommended material and methods. Follow the solvent supplier's recommendations for cleaning the broomed end.

Rev. 1

52

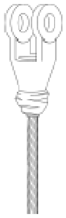
STEP 5 - POSITIONING OF SOCKET

1. Position socket over the broom until it reaches the seizing on the wire rope. The wires should be LEVEL with the top of the socket basket.
2. Clamp rope and socket vertically ensuring alignment of their axes.
3. **CAUTION: DO NOT USE OVERSIZED SOCKETS FOR WIRE ROPE.**



STEP 6 - SEAL SOCKET

Seal the base of the socket with putty or plasticine to prevent leakage of the **WIRELOCK®**.



STEP 7 - WIRELOCK® KITS

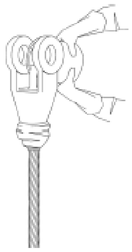
1. **WIRELOCK®** kits are pre-measured and consist of two (2) containers - one (1) with resin and one (1) with granular compound.
2. Use the complete kit - **NEVER MIX LESS THAN THE TOTAL CONTENTS OF BOTH CONTAINERS.**
3. Each kit has a shelf life clearly marked on each container and this must be observed. **NEVER USE OUT OF DATE KITS.**

⚠ CAUTION

- **WIRELOCK® resin, in liquid state, is flammable.**
- **Chemicals used in this product can give off toxic fumes and can burn eyes and skin.**
- **Never use out-of-date material.**
- **Use only in well-ventilated work areas.**
- **Never breathe fumes directly or for extended time.**
- **Always wear safety glasses to protect eyes.**
- **Always wear gloves to protect hands.**
- **Avoid direct contact with skin anywhere.**

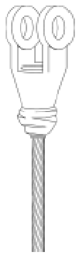
STEP 8 - MIXING AND POURING

1. Mix and pour **WIRELOCK®** within the temperature range of 48 degrees to 110 degrees F. Booster kits are available for reduced temperatures.
2. Pour all the resin into a container containing all the granular compound and mix thoroughly for two (2) minutes with a flat paddle.
3. Immediately after mixing, slowly pour the mixture down one side of the socket until the socket basket is full.
4. Check for leakage at nose of socket, add putty if required.



STEP 9 - CURING

1. **WIRELOCK®** will gel in approximately 15 minutes, in a temperature range 65 degrees F to 75 degrees F.
2. The socket must remain undisturbed in the vertical position for an additional ten (10) minutes after gel is complete.
3. The socket will be ready for service 60 minutes after gelling.
4. Never heat sockets to accelerate gel or curing.



STEP 10 - RE-LUBRICATION

Re-lubricate wire rope as required.

STEP 11 - PROOF LOADING

Whenever possible, the assembly should be proof loaded. All slings with poured sockets, in accordance with ASME B30.9, shall be Proof Loaded.

ALTERNATE SEIZING AND BROOMING METHOD

Reference the **WIRELOCK® TECHNICAL DATA MANUAL** from Crosby for an alternative socketing method.