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DOS K12/ASTM M50 TESTING AND EVALUATION OF THE UNIVERSAL SAFETY RESPONSE 14 FT GRAB-300 BARRIER NET

by

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DISCLAIMER

KEY WORDS

Anti-ram; perimeter; crash testing; barriers; gates; bollards; walls; fences; homeland security.

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16. Abstract

The objective of this test is to determine if the GRAB-300 14-ft (4.3 m) barrier net is capable of arresting a 6810 kg (15,000 lb) truck traveling at 80 km/h (50 mi/h) based on Condition Designation K12 as stated in *ST-STD-02.01, Revision A* and according to Condition Designation M50 of *ASTM 2656-07*. Both condition designations require the GRAB-300 14-ft (4.3 m) barrier net to withstand kinetic energy of 1,695,000 J (1,250,000 ft-lb).

This report presents the construction details of the GRAB-300 14-ft (4.3 m) barrier net, details of the vehicle used in the test performed, details of the test, and the assessment of the test results. The cargo bed penetrated 1.4 m (4.6 ft) beyond the inside edge of the barrier.

ST-STD-02.01, Revision A performance criteria limits penetration of the leading edge of the cargo bed to 1 m (3.3 ft) beyond the pre-impact, inside edge of the barrier. According to the results of the full-scale crash test, the GRAB-300 14-ft (4.3 m) barrier net does not meet the requirements for Condition Designation K12 in accordance March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*.

ASTM 2656-07 provides a range of vehicle test designations and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. According to *ASTM 2656-07*, the GRAB-300 14-ft (4.3 m) barrier net meets Condition Designation/Penetration Rating M50/P2, which allows penetration of 1.01 m to 7 m (3.31 to 23.0 ft).

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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)

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INTRODUCTION

PROBLEM

In an effort to assess the performance of anti-terrorist protection barriers, the United States Department of State, Bureau of Diplomatic Security, Physical Security Division (DS/PSP/PSD) developed guidelines to evaluate the performance of perimeter barriers/gates. The March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*, is the current version used to evaluate the performance of an anti-terrorist protection barrier.[(1)] According to this standard, performance of an anti-terrorist protection barrier is evaluated and assessed according to its effectiveness in arresting attacking vehicles, and not necessarily for economics, aesthetics, operational cycle time, special maintenance needs, or climate and environment effects. The GRAB-300 14-ft (4.3 m) barrier net evaluated herein was designed by Universal Safety Response, Inc. The intended function of this design is to provide road closure capable of arresting an attacking vehicle.

BACKGROUND

The procedures set out in *SD-STD-02.01, Revision A* are intended to ensure that perimeter barriers/gates provide a specified level of vehicle impact resistance as recommended by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division. The assessment criteria are based on the capability of the barrier/gate to arrest the vehicle such that it does not penetrate or vault over the system. Three levels of performance are defined based on the amount of vehicular impact kinetic energy the barrier/gate is capable of arresting. *SD-STD-02.01, Revision A* limits the penetration of the leading edge of the cargo bed to one meter (3.3 ft) beyond the pre-impact, inside edge of the barrier. If the barrier meets this requirement, a pass rating will be assigned at the appropriate speed designation by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division.

However, the previous penetration levels detailed in the April 1985 *SD-STD-02.01 Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates* are still being accepted by branches of the armed forces for use at facilities where adequate distance permits additional penetration past the barrier.[(2)] Therefore, in August 2007, the American Standards for Testing Materials (ASTM) International developed and published *ASTM Designation: F2656-07, Standard Test Method for Vehicle Crash Testing of Perimeter Barriers*.[(3)] This test method provides a range of vehicle impact conditions, test designations, and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. This new test method will soon be adopted as the official standard for testing of perimeter barriers.

The test reported herein was performed and evaluated in accordance with March 2003 standard, *SD-STD-02.01, Revision A* and *ATSM 2656-07*.

OBJECTIVES/SCOPE OF RESEARCH

The objective of this test is to determine if the GRAB-300 14-ft (4.3 m) barrier net is capable of arresting a 6810 kg (15,000 lb) truck traveling at 80 km/h (50 mi/h) based on Condition Designation K12 as stated in *ST-STD-02.01, Revision A* and according to Condition Designation M50 of *ASTM 2656-07*. Both condition designations require the GRAB-300 14-ft (4.3 m) barrier net to withstand kinetic energy of 1,695,000 J (1,250,000 ft-lb).

This report presents the construction details of the GRAB-300 14-ft (4.3 m) barrier net, details of the vehicle used in the test, details of the test performed, and the assessment of the test results.

TECHNICAL DISCUSSION

TEST PARAMETERS

Test Facility

The test facilities at the Texas Transportation Institute's Proving Ground consist of an 809-hectare (2000-acre) complex of research and training facilities situated 16 km (10 mi) 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 evaluation of roadside safety hardware and perimeter security barriers/gates. The site selected for placing of the GRAB-300 14-ft (4.3 m) barrier net was on the edge of a wide out-of-service apron. The apron consists of an unreinforced jointed concrete pavement in 3.8 m x 4.6 m (12.5 ft x 15 ft) blocks nominally 203-305 mm (8-12 inches) deep. The apron is over 50 years old and the joints have some displacement, but are otherwise flat and level.

Test Article – Design and Construction

Universal Safety Response, Inc. (USR) GRAB-100 K12-14 ft (4.3 m) multilane road closure system is a deployable gate/net system. The road closure system tested herein consists of a net, anchor stanchions and proprietary hydraulic shock absorbing pistons. The width of the net for this test was 14 ft (4.3 m). The net was anchored on each end by a separate anchor stanchion and foundation. The net was manufactured by Holloway Houston, Inc. and has upper and lower horizontal 1-1/2 inch (38 mm) diameter wire ropes with swaged eye end connections. Vertical 3/4-inch (19 mm) diameter wire ropes are attached to the main horizontal ropes and the middle horizontal 3/4-inch (19 mm) diameter wire rope. This middle horizontal rope terminates at the last vertical rope on each end of the net.

The net is deployed by an electric motor attached to a secondary post system located on each end of the net. These posts in the lifting base installation were 6 inches x 6 inches x 3/8 inch thick (152 mm x 152 mm x 9.5 mm thick). The net is attached to these secondary posts using 5/16-inch (8 mm) diameter cables with turn buckles and eye-bolts to allow for tensioning of the net between the deployment posts. Details of the net system are shown in 1 through 9.

Swage fittings connect the net to the stanchion sleeves. The sleeves are made of 12-inch (305 mm) diameter Schedule 100 pipe. The pipe sleeves were manufactured from ASTM A106 material. Four 1-inch (25 mm) thick sleeve rings were welded to each pipe ring. These rings are welded to a net anchor bracket The net anchor bracket consists of two 1-1/4-inch (32 mm) thick shear plates welded to a 1-1/4-inch (32 mm) thick anchor plate. Cap plates with a thickness of 1/2-inch (13 mm) were welded to the top and bottom sides of the anchor brackets. Details of the pipe sleeves are provided in figures 2 and 3.

A steel anchor stanchion assembly was used to anchor the stanchion sleeves to a concrete foundation. For this test, the distance between the stanchion centerlines was approximately 20 ft-6 inches (6.2 m). The steel anchor stanchion assembly consisted of a 10-inch (254 mm) diameter Schedule 160 pipe welded to a TS16x8x1/2 (TS406x203x13) structural tube. The 10-inch (254 mm) diameter pipe was manufactured from ASTM A106 material. The structural tube was manufactured from A500 Grade B material. A 3-inch (76 mm) thick rib plate was welded inside the full length of the stanchion pipe. Steel plate, 1 inch (25 mm) thick, was welded to the sides of the structural tube for added strength. The width of the 1-inch (25 mm) plate on the top and bottom sides was 24 inches (610 mm). Steel stiffeners with a thickness of 3/4-inch (19 mm) were welded between the top and bottom plates and to the added side plates. The length of the added steel plates was 58 inches. The length of the TS16x8x1/2 (TS406x203x13) tube was 89 inches (2261 mm). All steel plates were manufactured from ASTM A36 Material. Details of the steel anchor stanchion assembly are provided in figures 4 and 6 through 9.

Each steel anchor stanchion was anchored to a 12 ft x 12 ft x 18 inch thick (3.7 m x 3.7 m x 457 mm thick) concrete foundation. Reinforcement in the foundation consisted of #5 (#16) reinforcing steel at 6 inches (152 mm) on center each way in two mats of reinforcing steel (top and bottom mats) with the exception of the longitudinal reinforcing steel immediately beneath the steel anchor stanchion. Number 5 (#16) stirrups were constructed above and below the steel anchor assembly and were located on 6 inch (152 mm) centers. These stirrups helped to anchor the steel anchor assembly in the concrete foundation. Considering the deployed state of the net and pistons from the impact of the vehicle, the foundations and steel anchor stanchion assemblies were oriented 15 degrees from the direction of travel of the vehicle. The compressive strength of the foundation concrete the day the test was performed was 4084 psi 28.2 MPa.

An 18-inch concrete apron was constructed to connect the 12 ft x 12 ft (3.7 m x 3.7 m) concrete foundation to the smaller 5 ft x 5 ft x 12 inch (1.5 m x 1.5 m x 305 mm) footing used to support the net lifting base installation. Reinforcement in the apron consisted of #5 (#16) bars 10 inches (254 mm) on center. One single mat of reinforcing steel was used to construct the apron. Number 5 (#16) dowels, 4 ft (1.2 m) in length, were drilled and anchored in the existing foundations using Hilti HIT HY 150 Epoxy Anchoring System. These dowels were anchored 10 inches (254 mm) into in the existing foundation concrete. The compressive strength of the apron concrete the day the test was performed was 4679 psi (32.2 MPa). Details of the system are provided in figures 1 through 9, and photographs of the completed installation are shown in figure 10.

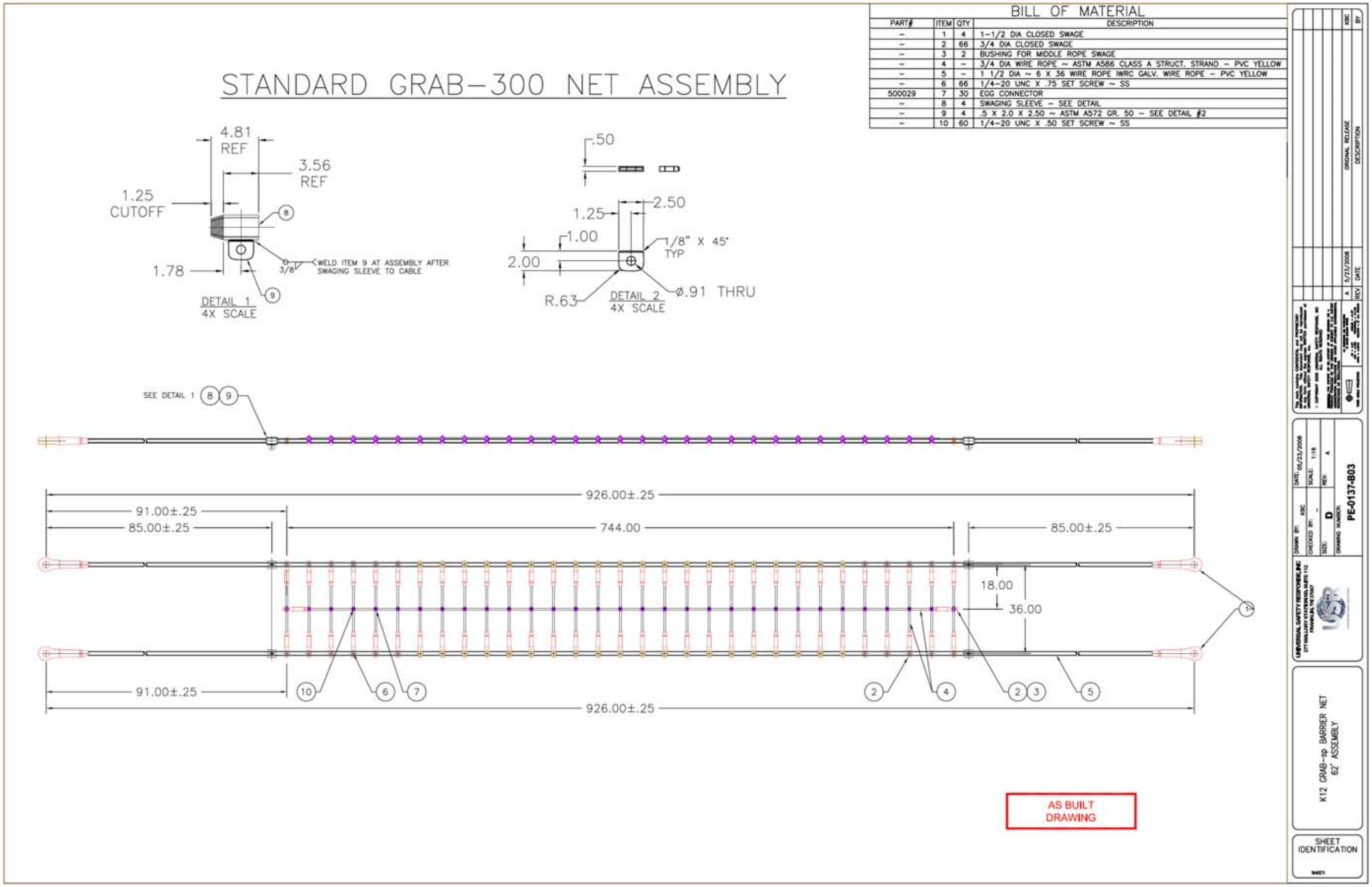


Figure 1. Details of the GRAB-300 14-ft barrier net -- assembly.

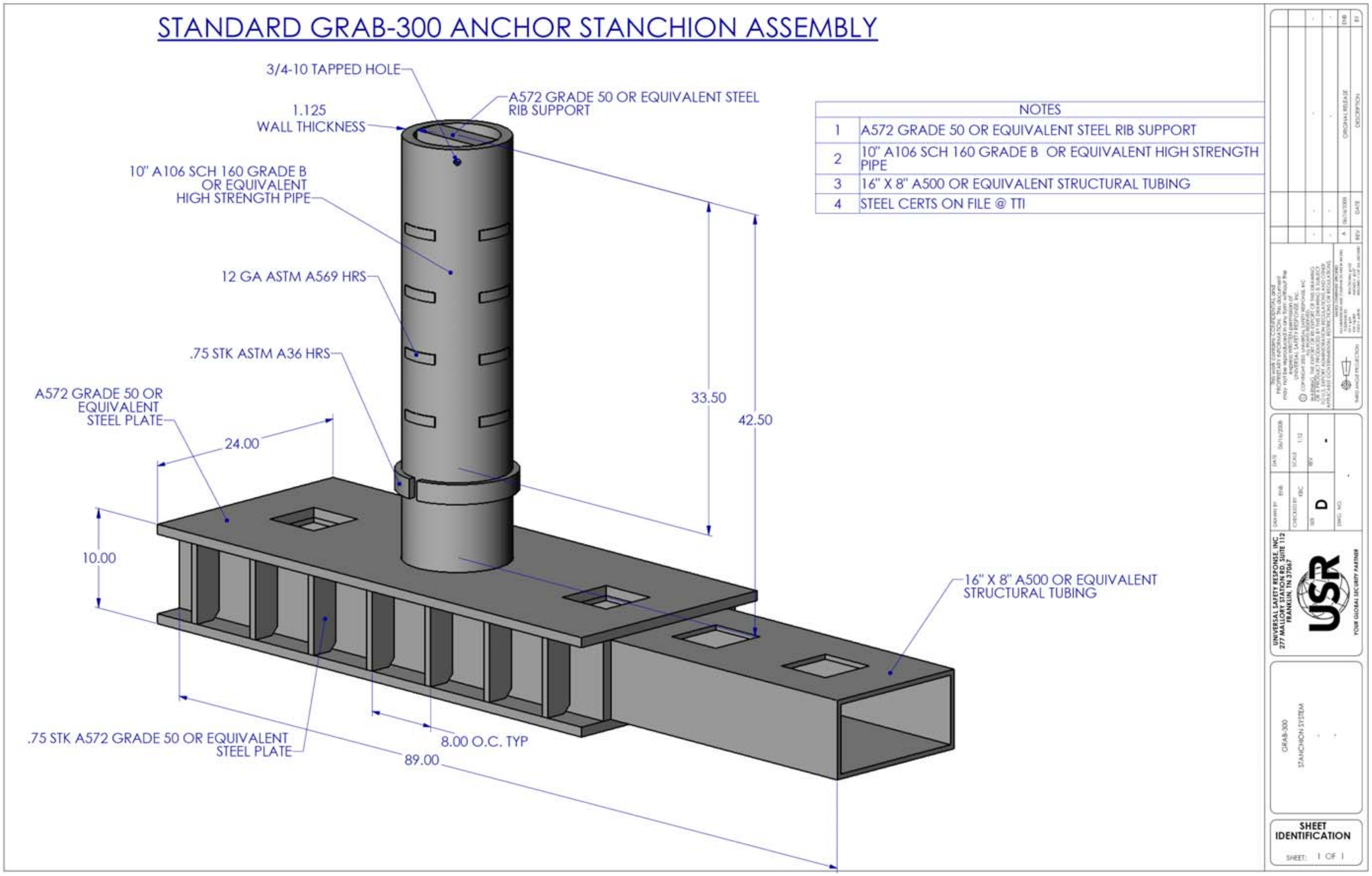


Figure 2. Details of the GRAB-300 14-ft barrier net – stanchion system.

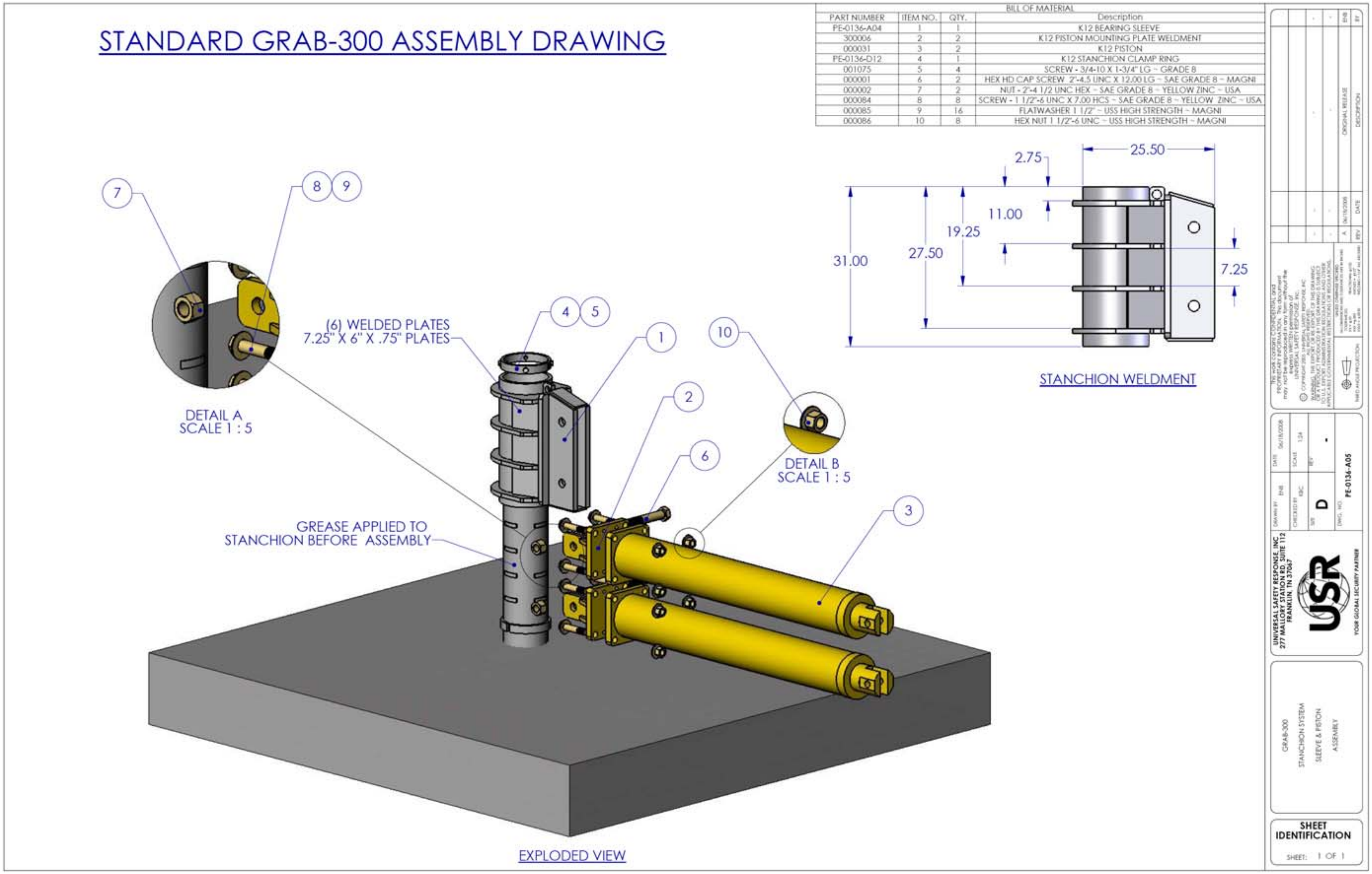


Figure 3. Details of the GRAB-300 14-ft barrier net – stanchion system sleeve and piston assembly.

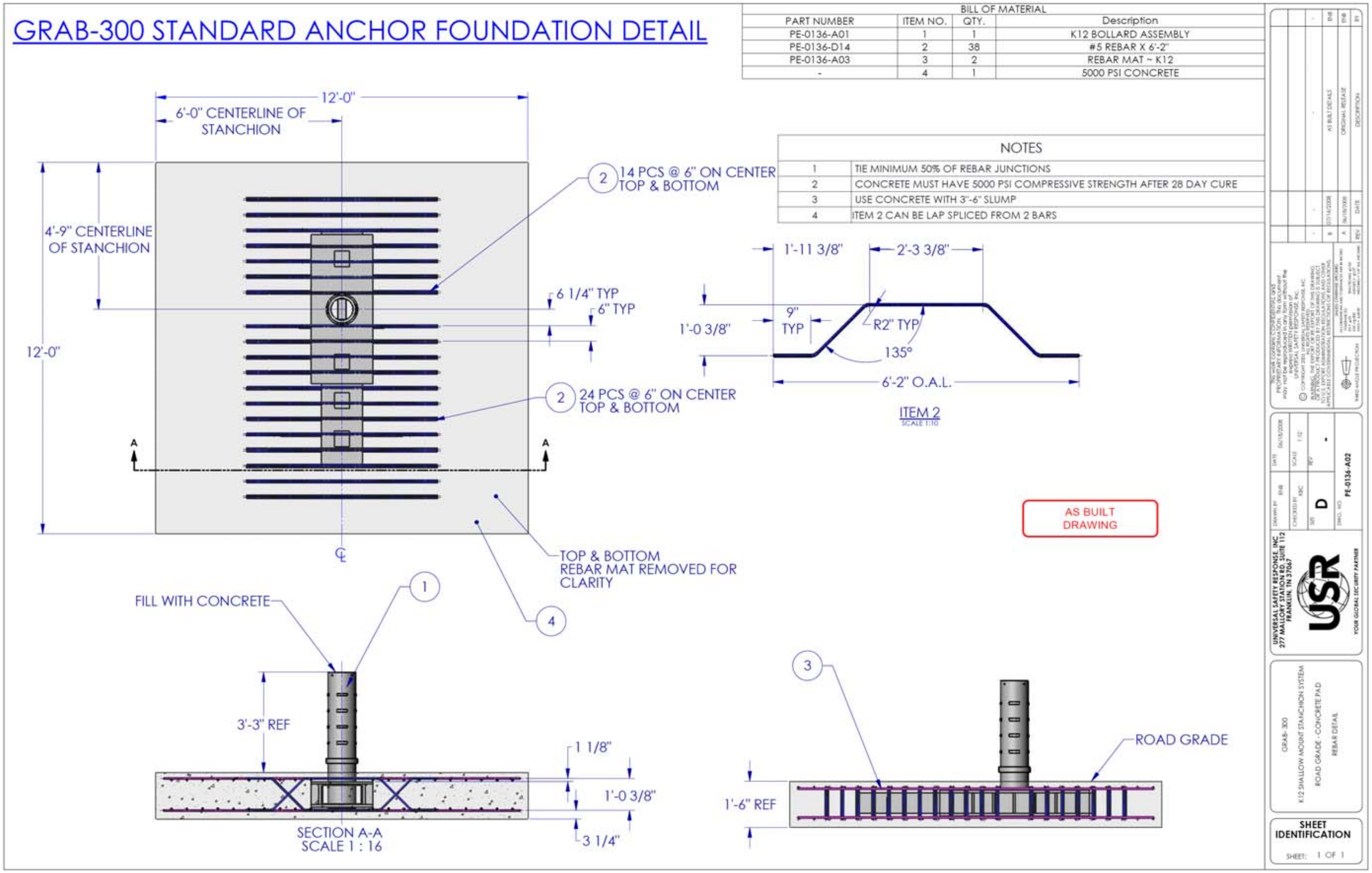


Figure 4. Details of the GRAB-300 14-ft barrier net – standard anchor foundation.

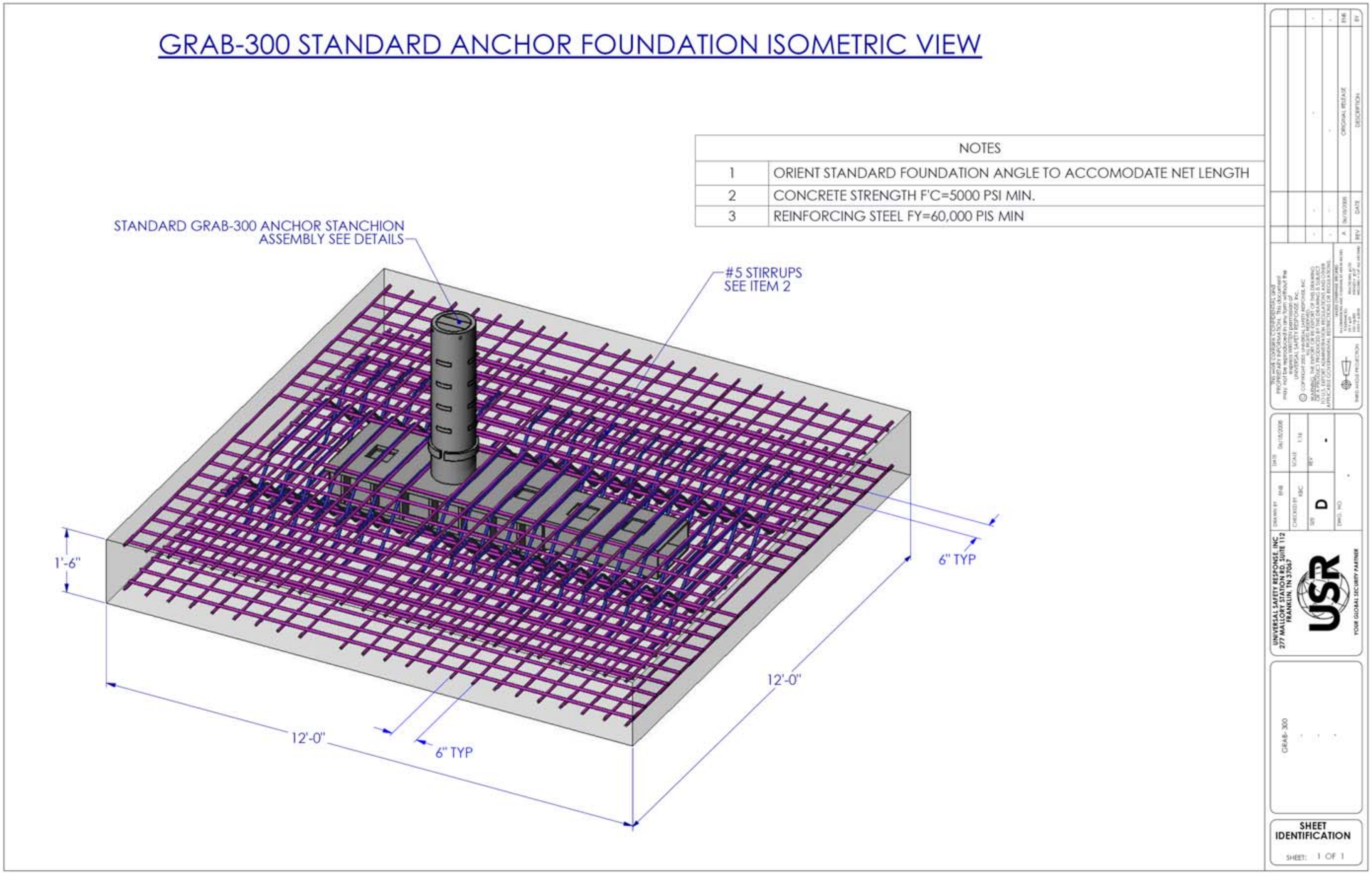


Figure 5. Details of the GRAB-300 14-ft barrier net – concrete pad rebar detail.

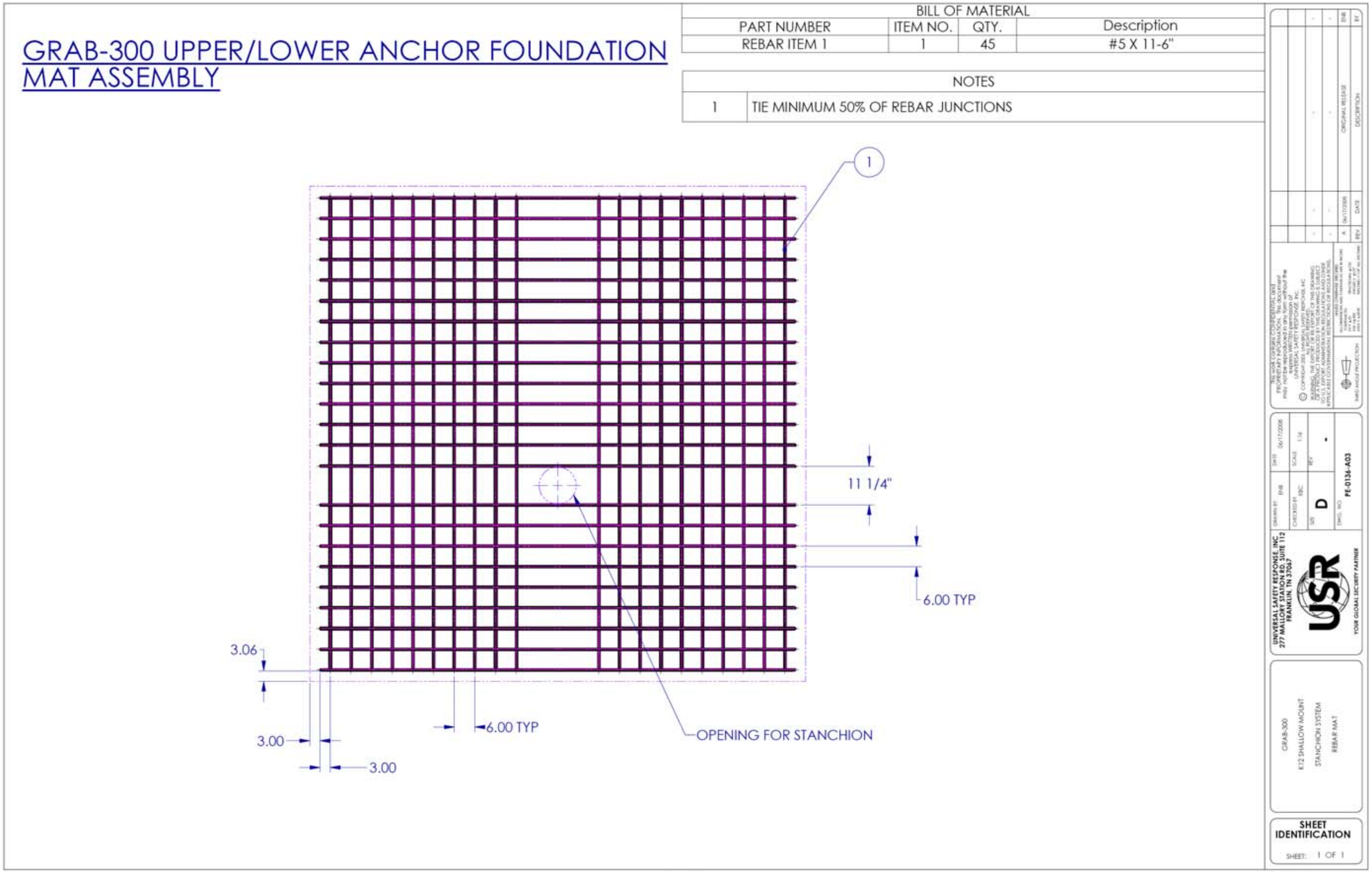


Figure 6. Details of the GRAB-300 14-ft barrier net – stanchion system rebar mat.

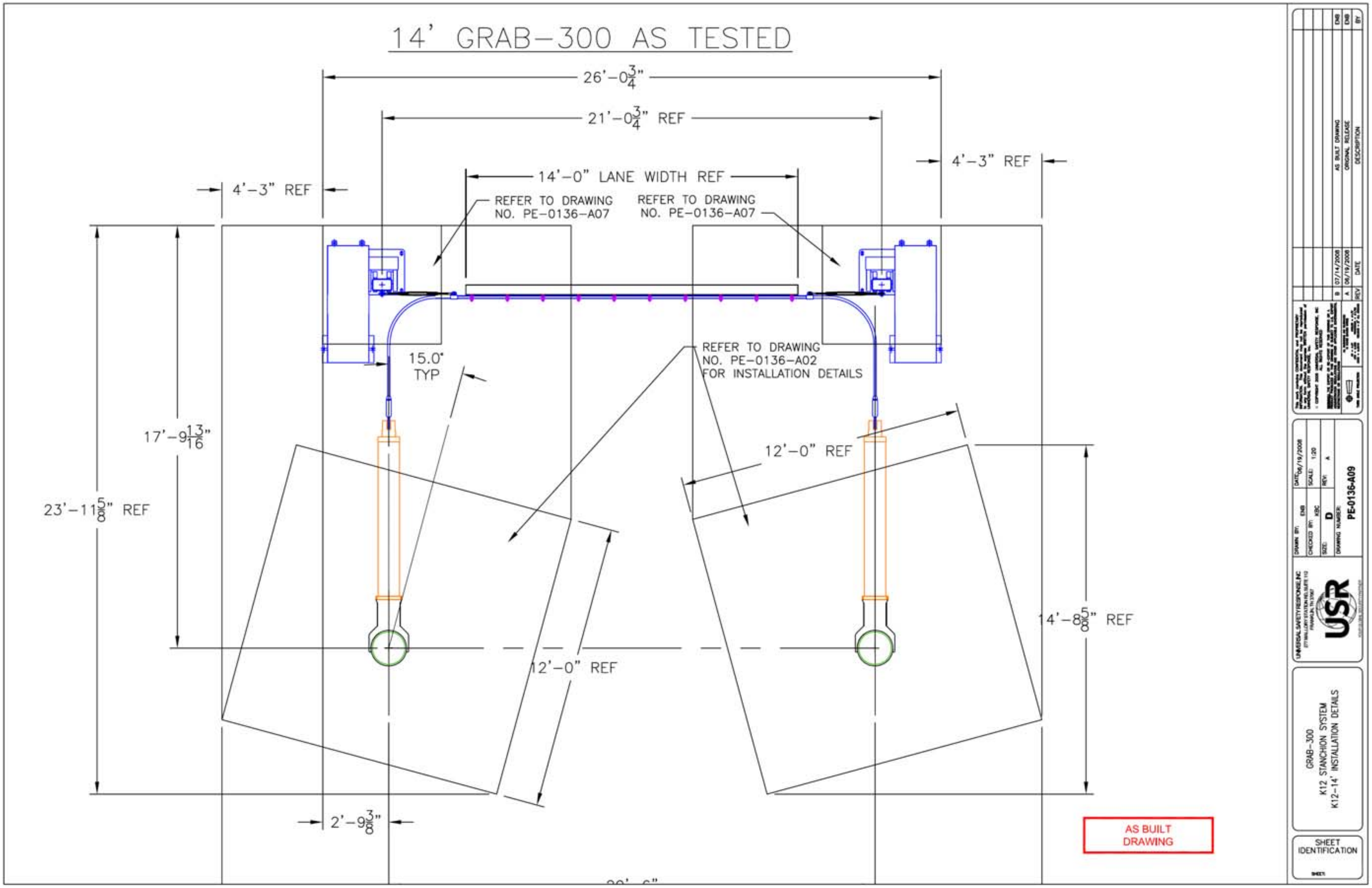


Figure 7. Details of the GRAB-300 14-ft barrier net – stanchion system installation details.

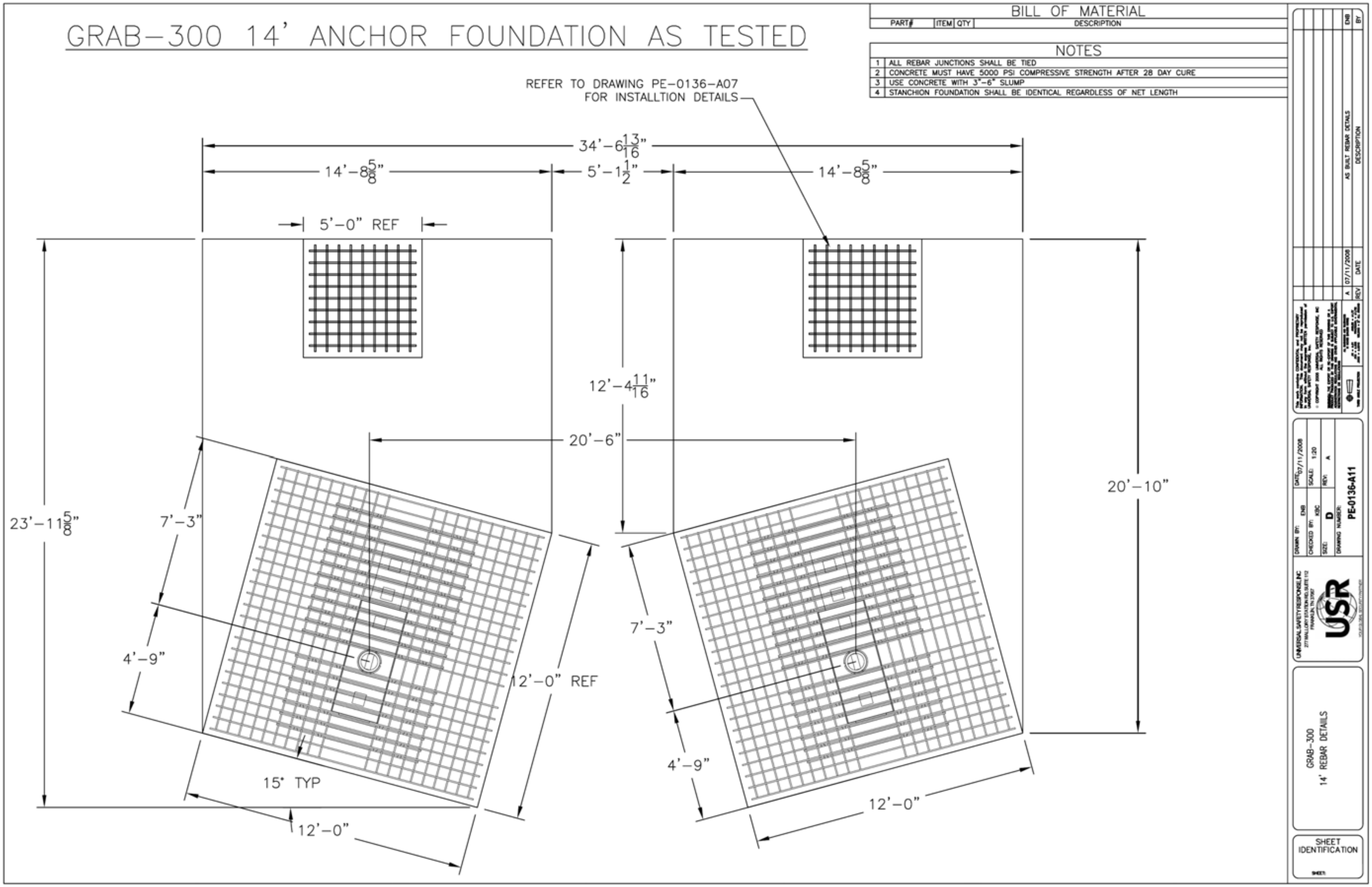


Figure 8. Details of the GRAB-300 14-ft barrier net – anchor foundation.

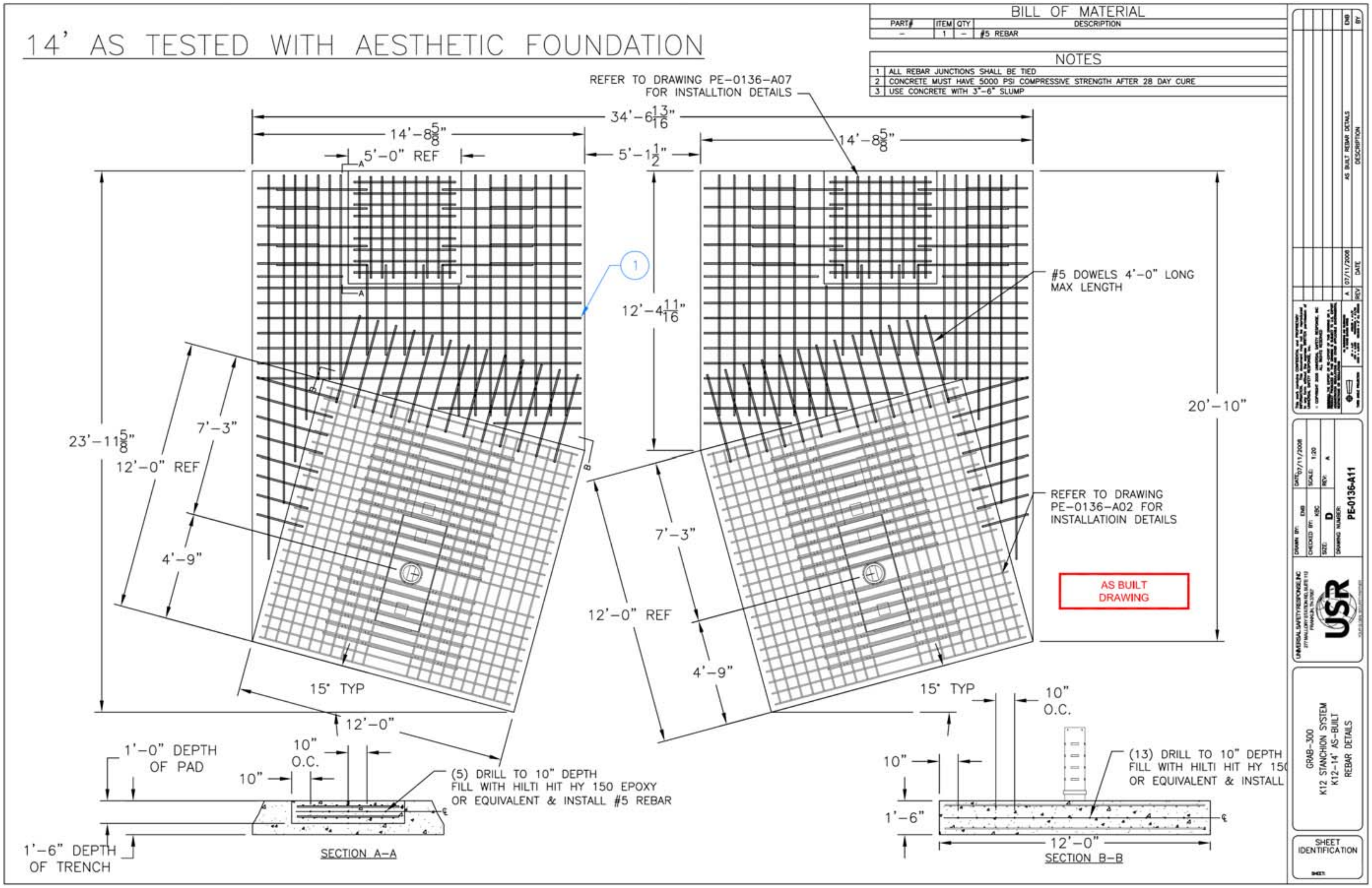


Figure 9. Details of the GRAB-300 14-ft barrier net – stanchion system rebar details.

Figure 10. GRAB-300 14-ft barrier net prior to testing.

Test Conditions and Evaluation Criteria

According to *SD-STD-02.01, Revision A*, the GRAB-300 14-ft (4.3 m) barrier net can be rated according to one of three designated condition levels as shown in Table 1. The test conditions are intended to ensure that perimeter barriers and gates will provide a specified level of vehicle impact resistance. Actual vehicle speed must be within a permissible range to receive the condition designation. *ST-STD-02.01, Revision A* performance criteria limits penetration of the leading edge of the cargo bed to 1 m beyond the pre-impact, inside edge of the barrier. If the barrier meets this requirement, a pass rating will be assigned at the appropriate speed designation by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division.

Table 1. Impact Condition Designations according to *SD-STD-02.01, Revision A*.*

Nominal Impact Speed	Permissible Impact Speed Range	Kinetic Energy	Designation
80 kph 50 mph	75.0-above kph 47.0-56.9 mph	1,695,000 J 1,250,000 ft-lb	K12
65 kph 40 mph	60.1-75.0 kph 38.0-46.9 mph	1,085,000 J 800,000 ft-lb	K8
50 kph 30 mph	45.0-60.0 kph 28.0-37.9 mph	610,000 J 450,000 ft-lb	K4

* Taken directly from Table 1 of *SD-STD-02.01, Revision A.*

The levels of kinetic energy that a barrier shall withstand according to *ASTM F2656-07* are shown in Table 2. Again, the test conditions are intended to ensure that perimeter barriers and gates will provide a specified level of vehicle impact resistance. Actual vehicle speed must be within a permissible range to receive the specific condition designation. The test speed associated with each test vehicle and condition designation is shown in the last column of table 2 taken from *ASTM F2657-07.*

The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. Test vehicle dynamic penetration is referenced to each vehicle as follows: The base of the “A” pillar for the small passenger car (C); the front leading lower edge of the pickup truck bed (P); the leading lower edge of the cargo bed on the medium duty truck (M); and the leading lower vertical edge of the cargo bed on the heavy goods vehicle (H). Penetration ratings according to *ASTM F2656-07* are shown in table 3.

Table 2. Impact Condition Designations according to *ASTM 2656-07*.

Test Vehicle/Minimum Test Inertial Vehicle, kg(lbm)	*Nominal Minimum Test Velocity km/h(mph)*	*Permissible Speed Range, km/h (mph)*	*Kinetic Energy, KJ (ft-kips)*	*Condition Designation*
Small passenger car (C) 1100 (2430)	*65 (40) 80 (50) 100 (60)*	*60.1-75.0 (38.0-46.9) 75.1-90.0 (47.0-56.9) 90.1-above (57.0-above)*	*179 (131) 271 (205) 424 (295)*	*C40 C50 C60*
Pickup truck (P) 2300 (5070)	*65 (40) 80 (50) 100 (60)*	*60.1-75.0 (38.0-46.9) 75.1-90.0 (47.0-56.9) 90.1-above (57.0-above)*	*375 (273) 568 (426) 887 (613)*	*PU40 PU50 PU60*
Medium-duty truck (M) 6800(15000)	*50 (30) 65 (40) 80 (50)*	*45.0-60.0 (28.0-37.9) 60.1-75.0 (38.0-46.9) 75.1-above (47.0-above)*	*656 (451) 1110 (802) 1680 (1250)*	*M30 M40 M50*
Heavy goods vehicle (H) 29500(65000)	*50 (30) 65 (40) 80 (50)*	*45.0-60.0 (28.0-37.9) 60.1-75.0 (38.0-46.9) 75.1-above (47.0-above)*	*2850 (1950) 4810 (3470) 7280 (5430)*	*H30 H40 H50*

Table 3. Penetration Ratings according to *ASTM F2656-07*.

Penetration Designation	*Dynamic Penetration Rating*
P1	*≤ 1 m (3.3 ft)*
P2	*1.01 m to 7 m (3.31 to 23.0 ft)*
P3	*7.01 m to 30 m (23.1 to 98.4 ft)*
P4	*30 m (98 ft) or greater*

The test reported herein was performed in accordance with March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates* and also in accordance with *ASTM 2656-07*. Appendix A presents brief descriptions of these procedures.

The test vehicle specified was a medium duty truck with diesel engine, tested at a gross vehicle weight of 6800 kg (15,000 lb) ±90 kg (200 lb), which satisfies both standards.

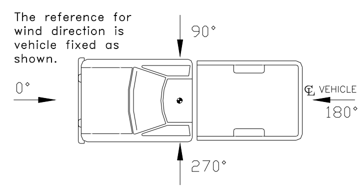
CRASH TEST 400001-USR14 (*SD-STD-02.01* K12 / *ASTM 2656-07* M50)

Test Vehicle

A 1999 NaviStar 4700 single-unit flatbed truck, shown in figures 11 and 12, was used for the crash test. Test inertia weight of the vehicle was 6872 kg (15,150 lb). The height to the lower edge of the vehicle front bumper was 51 cm (20.25 inches), and the height to the upper edge of the front bumper was 80 cm (31.5 inches). Figure 18 in appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The crash test was performed the morning of July 3, 2008. A total of 0.8 inch of rainfall was recorded during the four days prior to the test. Moisture content of the crushed limestone base material in which the test article was installed was 7.9 percent. Weather conditions at the time of testing were: Wind Speed: 3 km/h (2 mi/h); Wind Direction: 200 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 29 ºC (85 ºF); Relative Humidity: 65 percent.



Impact Description

The 1999 NaviStar 4700 single-unit flatbed truck, traveling at an impact speed of 80.6 km/h (50.1 mi/h), impacted the GRAB-300 14-ft (4.3 m) barrier net at an impact angle of 89.1 degrees. The centerline of the vehicle was aligned with the centerline of the barrier net. At approximately 0.059 s after impact, the piston of the left side shock absorber began to pull out of its housing, and at 0.069 s, the right side began to pull out. Also at 0.069 s, the barrier net began to crush the front of the truck. The end of the shock absorber on the left side contacted the rear of the vehicle at 0.196 s, and the right side contacted the rear of the truck at 0.209 s. At 0.292 s, the vehicle reached maximum penetration into the net (1.59 (5.2 ft)), and at 0.319 s, the vehicle began to rebound. The rear of the vehicle reached maximum pitch height at 0.0687 s, and the vehicle came to rest at 1.068 s. At rest, the vehicle was 0.10 m (0.3 ft) beyond the inside of the barrier on the left side, and 0.02 m (0.07 ft) forward of the inside of the barrier on the right side. Appendix C, figure 19, show sequential photographs of the test period.

Figure 11. Vehicle/installation geometrics for test 400001-USR14.

Figure 12. Vehicle before test 400001-USR14.

Damage to Test Article

Damage to the GRAB-300 14-ft (4.3 m) barrier net is shown in figure 13 and 14. The left side shock absorber pulled out a maximum of 1.56 m (5.1 ft), and the right side 1.59 (5.2 ft) at approximately 0.292 s after impact. The barrier net remained on the vehicle as it rebounded and came to rest 0.10 m (0.3 ft) beyond the inside of the barrier on the left side, and 0.02 m (0.07 ft) forward of the inside of the barrier on the right side.

Vehicle Damage

Damage to the 1999 NaviStar 4700 single-unit flatbed truck is shown in figure 15. The front tire and rim were pushed into the fuel tank on the right causing an indentation in the fuel tank. Both front tires were deflated. The left front spring mount broke, and the windshield popped out. Also damaged were the front bumper, hood, radiator, radiator support, fan and water pump, and the lower part of the cab. Maximum exterior crush to the vehicle was 8 inches (203 mm). Photographs of the interior of the vehicle are shown in figure 16.

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk for informational purposes only. In the longitudinal direction, the occupant impact velocity was 11.0 m/s (36.1 ft/s) at 0.187 s, the highest 0.010-s occupant ridedown acceleration was -24.0 g's from 0.190 to 0.200 s, and the maximum 0.050-s average acceleration was -16.9 g's between 0.175 and 0.225 s. In the lateral direction, the occupant impact velocity was 0.1 m/s (0.3 ft/s) at 0.187 s, the highest 0.010-s occupant ridedown acceleration was 6.4 g's from 0.191 to 0.201 s, and the maximum 0.050-s average was 1.9 g's between 0.255 and 0.305 s. These data and other pertinent information from the test are summarized in figure 17. Vehicle accelerations versus time traces are presented in appendix D, figures 20 through 25.

Figure 13. Vehicle/barrier after test 400001-USR14.

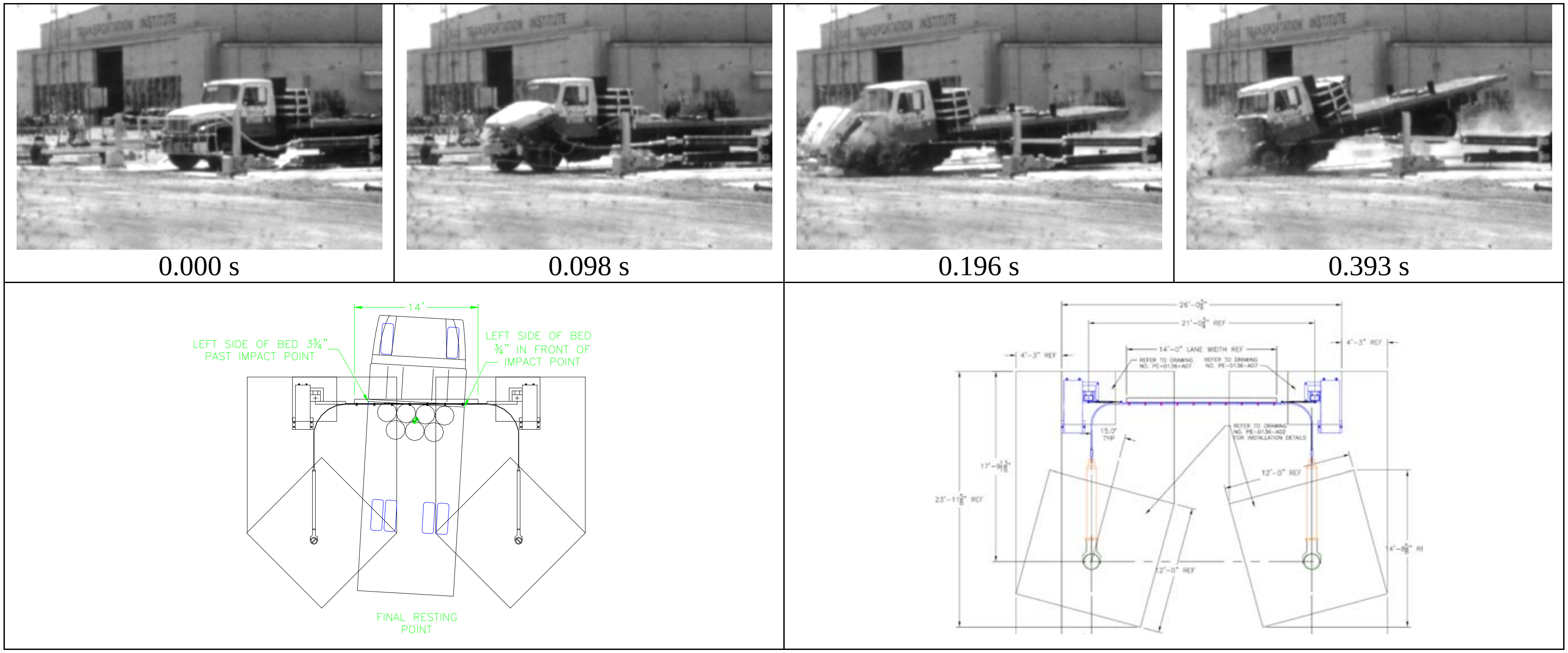
Figure 14. Installation after test 400001-USR14.

Figure 15. Vehicle after test 400001-USR14.

Before test

After test

Figure 16. Interior of vehicle for test 400001-USR14.



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 400001-USR14
- Date 2008-07-03

Test Article
- Type .... Security Barrier
- Name .... GRAB-300 14-ft barrier net
- Installation Length (m) .... 4.3 (14 ft)
- Material or Key Elements .... Barrier net, anchor stanchions and proprietary hydraulic shock absorbing pistons

Soil/Foundation Type .... Concrete footing in crushed limestone, Damp @ 7.9%

Test Vehicle
- Type .... Production
- Designation .... K12 / M50
- Model .... 1999 NaviStar 4700
- Mass (kg) single-unit flatbed truck
  - Curb .... 5924 (13,060 lb)
  - Test Inertial .... 6872 (15,150 lb)

Impact Conditions
- Speed (km/h) .... 80.6 (50.1 mi/h)
- Angle (deg) 89.1

Exit Conditions
- Speed (km/h) .... Stopped
- Angle (deg) 85.2

Occupant Risk Values
- Impact Velocity (m/s)
  - Longitudinal .... 11.0 (36.1 ft/s)
  - Lateral .... 0.1 (0.3 ft/s)
- Ridedown Accelerations (g's)
  - Longitudinal .... -24.0
  - Lateral 6.4
- Max. 0.050-s Average (g's)
  - Longitudinal .... -16.9
  - Lateral 1.9
  - Vertical .... -4.8

Penetration of Cargo Bed (m)
- Distance Beyond Inside
  - Edge of Barrier (m) .... 1.40 (4.6 ft)

Figure 17. Summary of results for test K12 / M50 on GRAB-300 14-ft barrier net.

SUMMARY AND CONCLUSIONS

ASSESSMENT OF TEST RESULTS

The acceptable range for impact speed for this Condition Designation K12 / M50 test was 75.0 km/h (50.0 mi/h) or above, and the actual impact speed was 80.6 km/h (50.1 mi/h). The 1999 NaviStar 4700 single-unit flatbed truck impacted the barrier at 89.1 degrees, with the centerline of the vehicle aligned with the centerline of the GRAB-300 14-ft (4.3 m) barrier net. The GRAB-300 14-ft (4.3 m) barrier net brought the vehicle to a complete stop. The cargo remained onboard the vehicle; however, the hood of the vehicle and parts of the barrier were thrown beyond the inside edge of the barrier. The front of the cargo bed penetrated beyond the inside edge of the barrier a distance of 1.4 m (4.6 ft).

CONCLUSIONS

As stated above, the cargo bed penetrated 1.4 m (4.6 ft) beyond the inside edge of the barrier.

ST-STD-02.01, Revision A performance criteria limits penetration of the leading edge of the cargo bed to 1 m (3.3 ft) beyond the pre-impact, inside edge of the barrier. According to the results of the full-scale crash test, the GRAB-300 14-ft (4.3 m) barrier net does not meet the requirements for Condition Designation K12 in accordance March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*.

ASTM 2656-07 provides a range of vehicle test designations and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. According to *ASTM 2656-07*, the GRAB-300 14-ft (4.3 m) barrier net meets Condition Designation/Penetration Rating M50/P2, which allows penetration of 1.01 m to 7 m (3.31 to 23.0 ft).

REFERENCES

1. "Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates," *SD-STD-02.01, Revision A*, Physical Security Division, United States Department of State, Washington, D.C., March 2003.

2. "Specification for Vehicle Crash Test of Perimeter Barriers and Gates," *SD-STD-02.01,* Physical Security Division, United States Department of State, Washington, D.C., April 1985.

3. "Standard Test Method for Vehicle Crash Testing of Perimeter Barriers," *ASTM Designation: F2656-07*, American Standards for Testing Materials International, West Conshohocken, PA, August 2007.

4. 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.

APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were in accordance with guidelines presented in *SD-STD-2.01, Revision A.* Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicle was instrumented with 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 are transmitted to a base station by means of an 8-channel, proportional-bandwidth, Inter-Range Instrumentation Group (IRIG), FM/FM telemetry link for digital recording. 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 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-millisecond (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.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

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

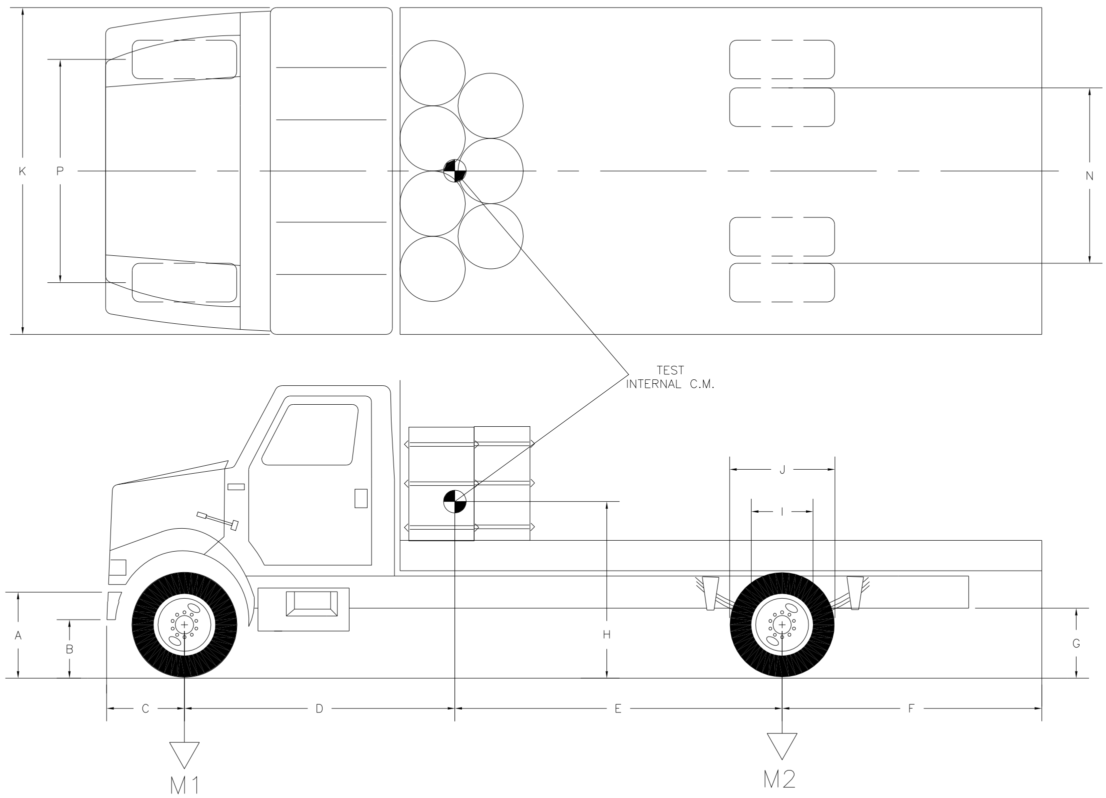
APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Vehicle Measurements for State Department Testing

DATE: 2008-07-03 TEST NO.: 400001-USR14 VIN NO.: 1HTSCABNXXH672564

YEAR: 1999 MAKE: NaviStar MODEL: 4700

TIRE SIZE: 275/80R22.5 ODOMETER: 171752



GEOMETRY (inches)

A	31.5	B	20.25	C	30.5	D	98.2	E	107.3	F	92.0	G	29.0
H		I	23.5	J	39.5	K	94.5	L	80.5	N	73.0		

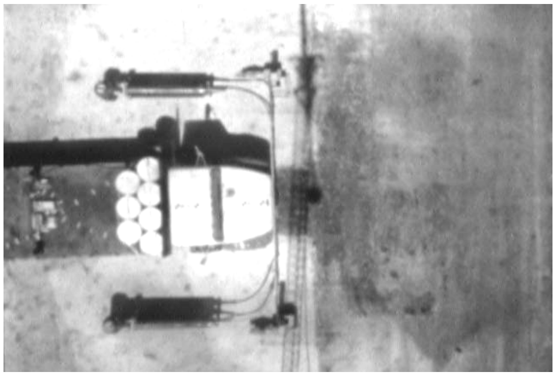
MASS DISTRIBUTION (lb)

LF	4120	RF	3770	LR	3670	RR	3590

MASS (lb)	CURB	TEST INERTIAL
M_1	6770	7890
M_2	6290	7260
M_{Total}	13,060	15,150

Figure 18. Vehicle properties for test 400001-USR14.

APPENDIX C. SEQUENTIAL PHOTOGRAPHS



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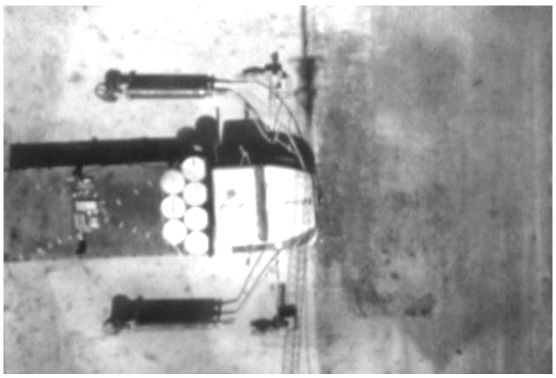

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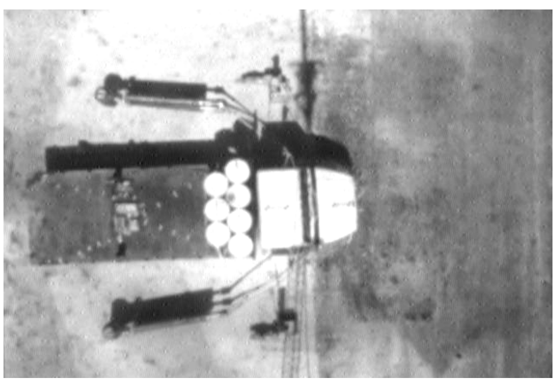

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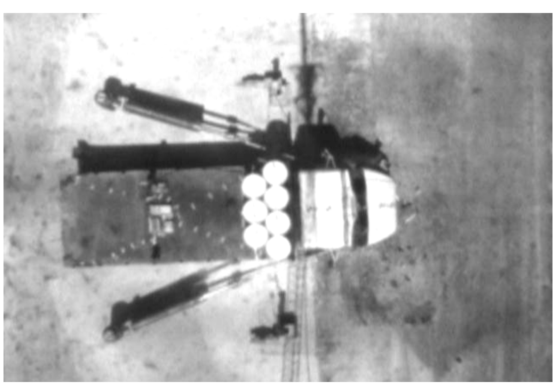

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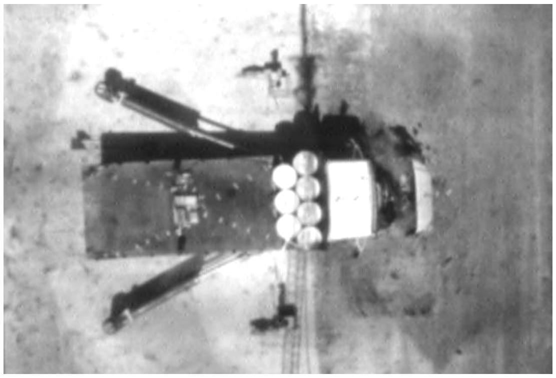
Figure 19. Sequential photographs for test 400001-USR14 (overhead and frontal views).



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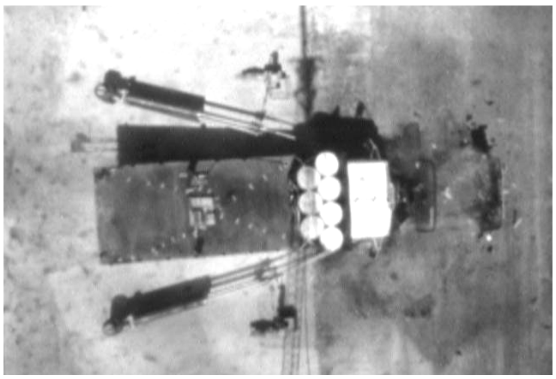

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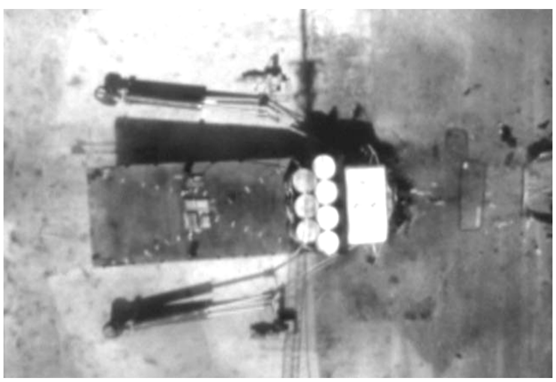

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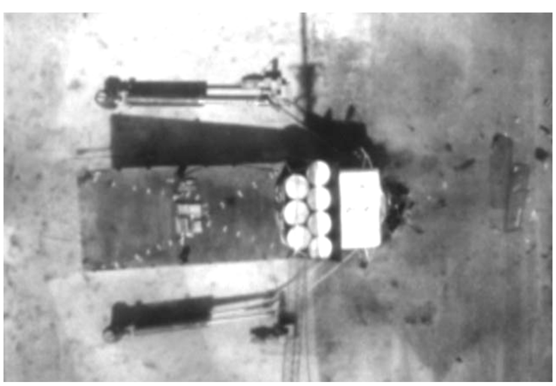

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Figure 19. Sequential photographs for test 400001-USR14
(overhead and frontal views) (continued).

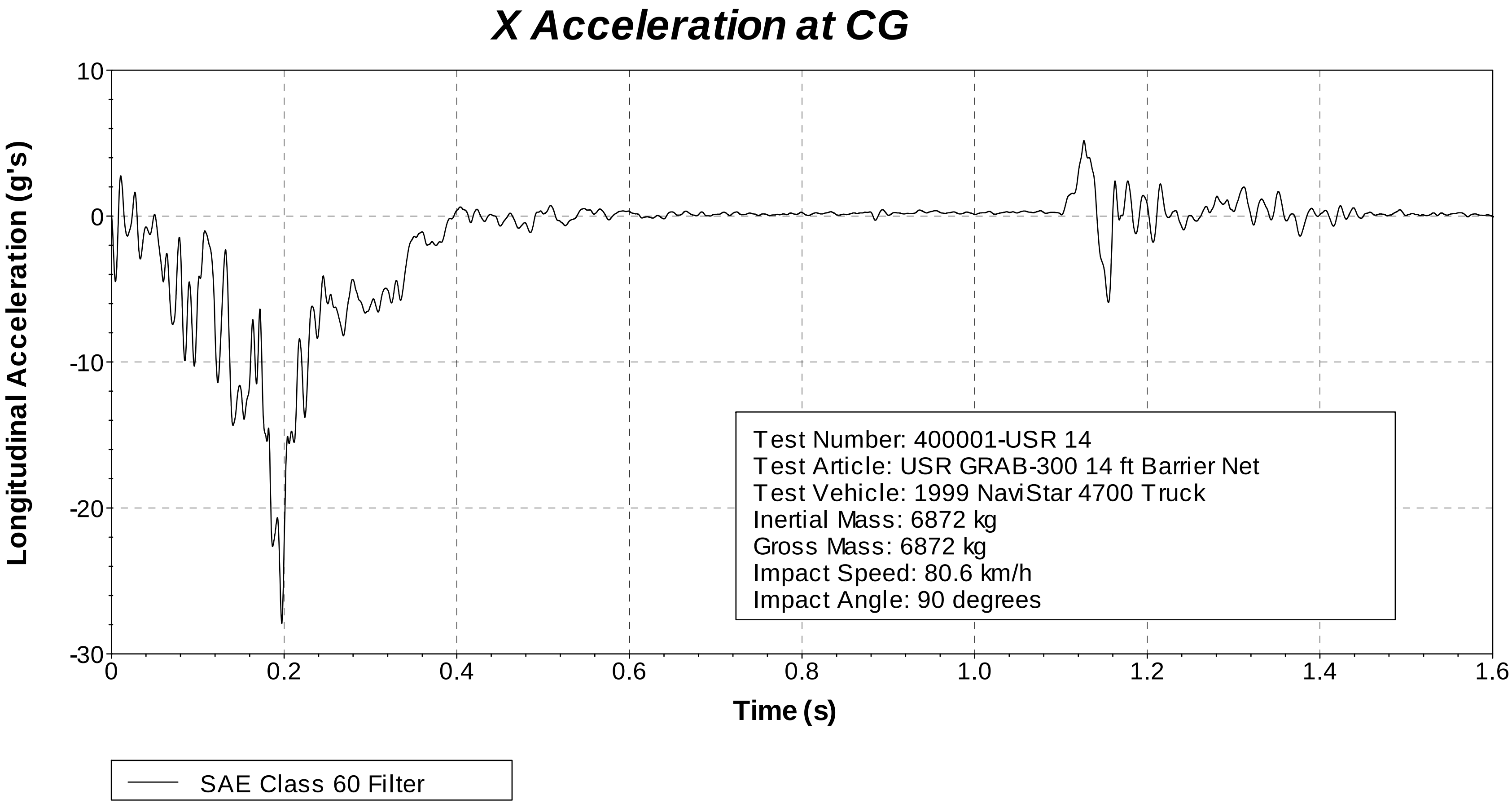

Figure 20. Vehicle longitudinal accelerometer trace for test 400001-USR14 (accelerometer located at center of gravity).

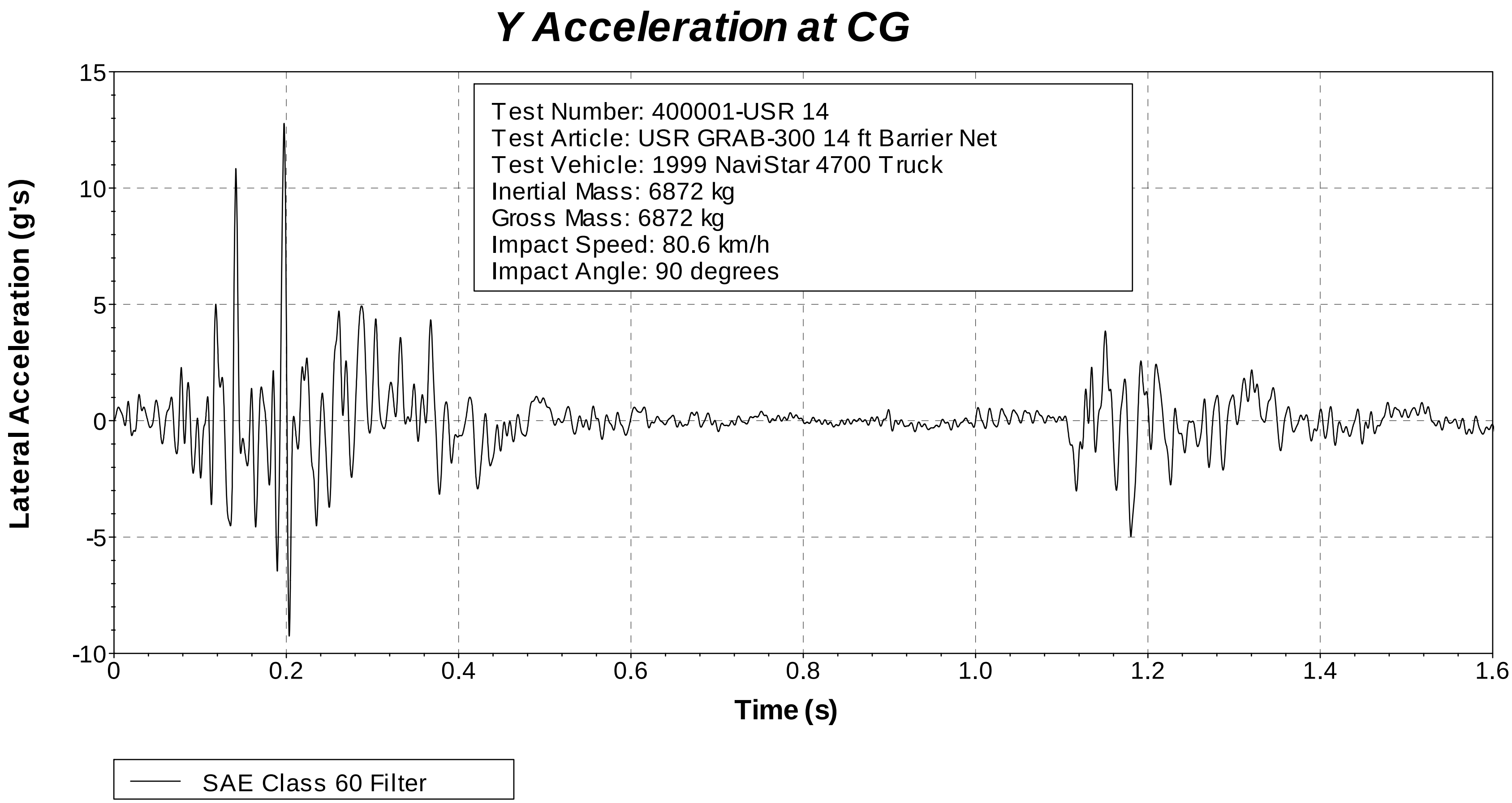

Figure 21. Vehicle lateral accelerometer trace for test 400001-USR14
(accelerometer located at center of gravity).

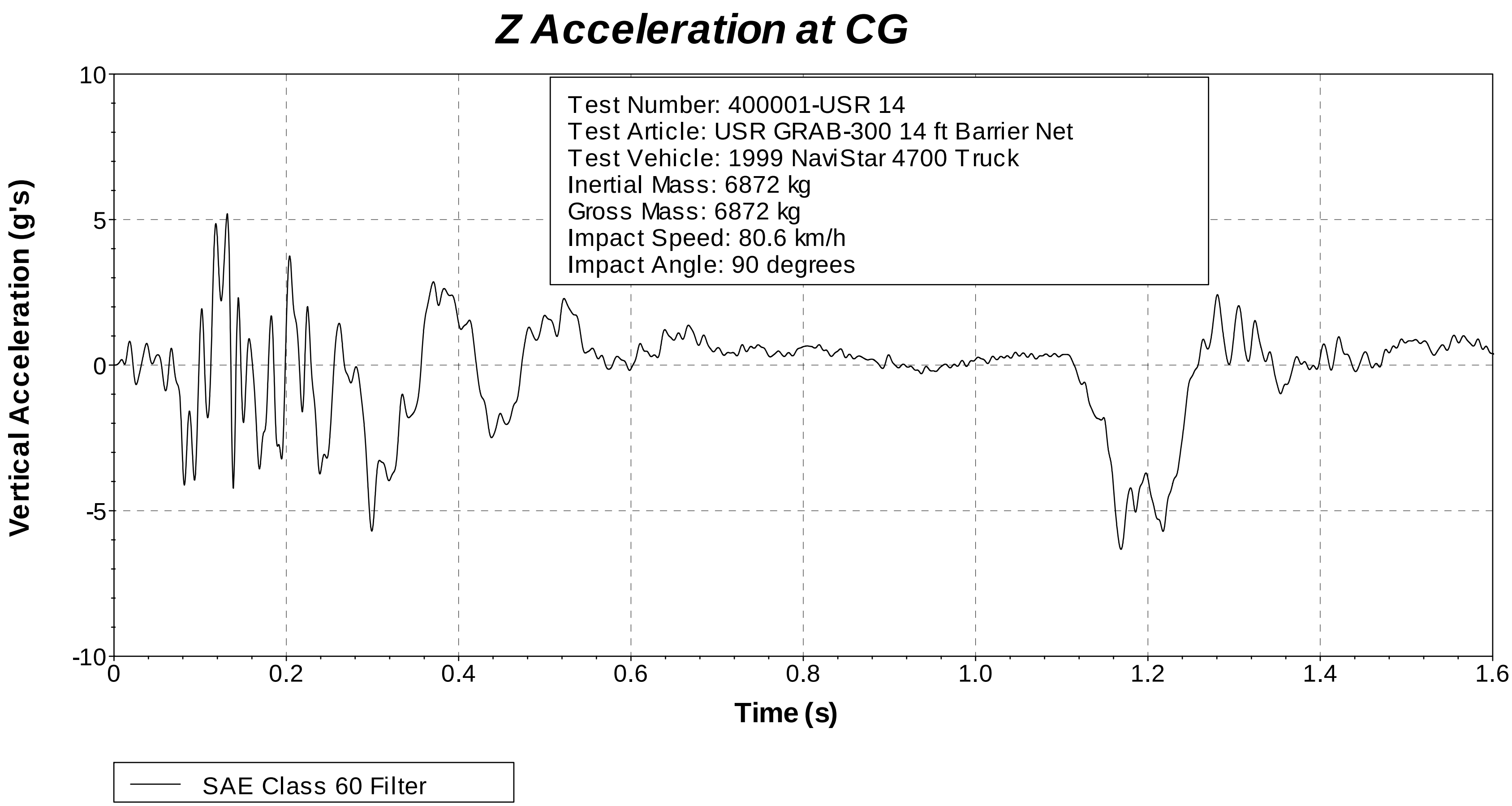

Figure 22. Vehicle vertical accelerometer trace for test 400001-USR14
(accelerometer located at center of gravity).

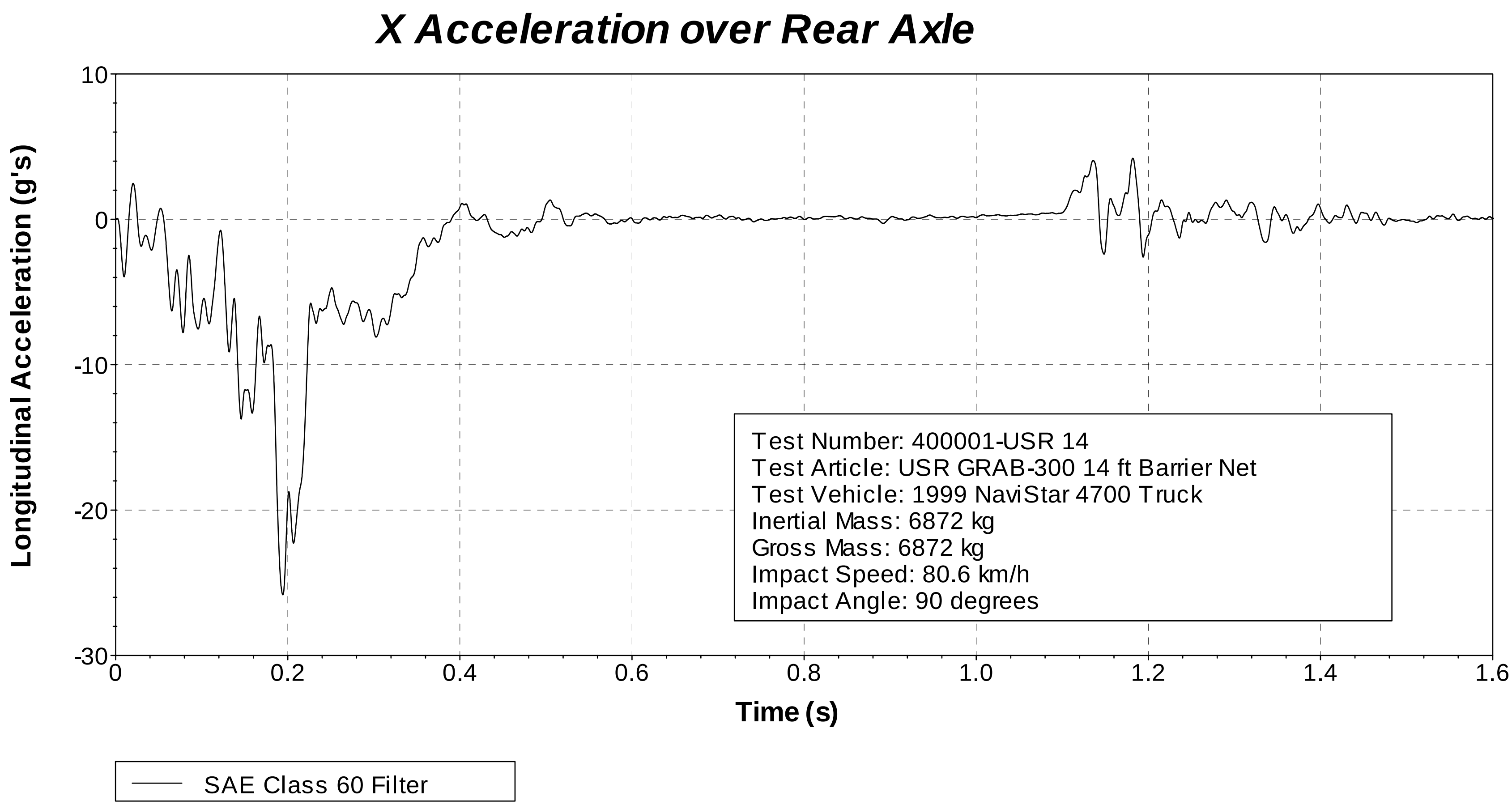

Figure 23. Vehicle longitudinal accelerometer trace for test 400001-USR14 (accelerometer located over rear axle).

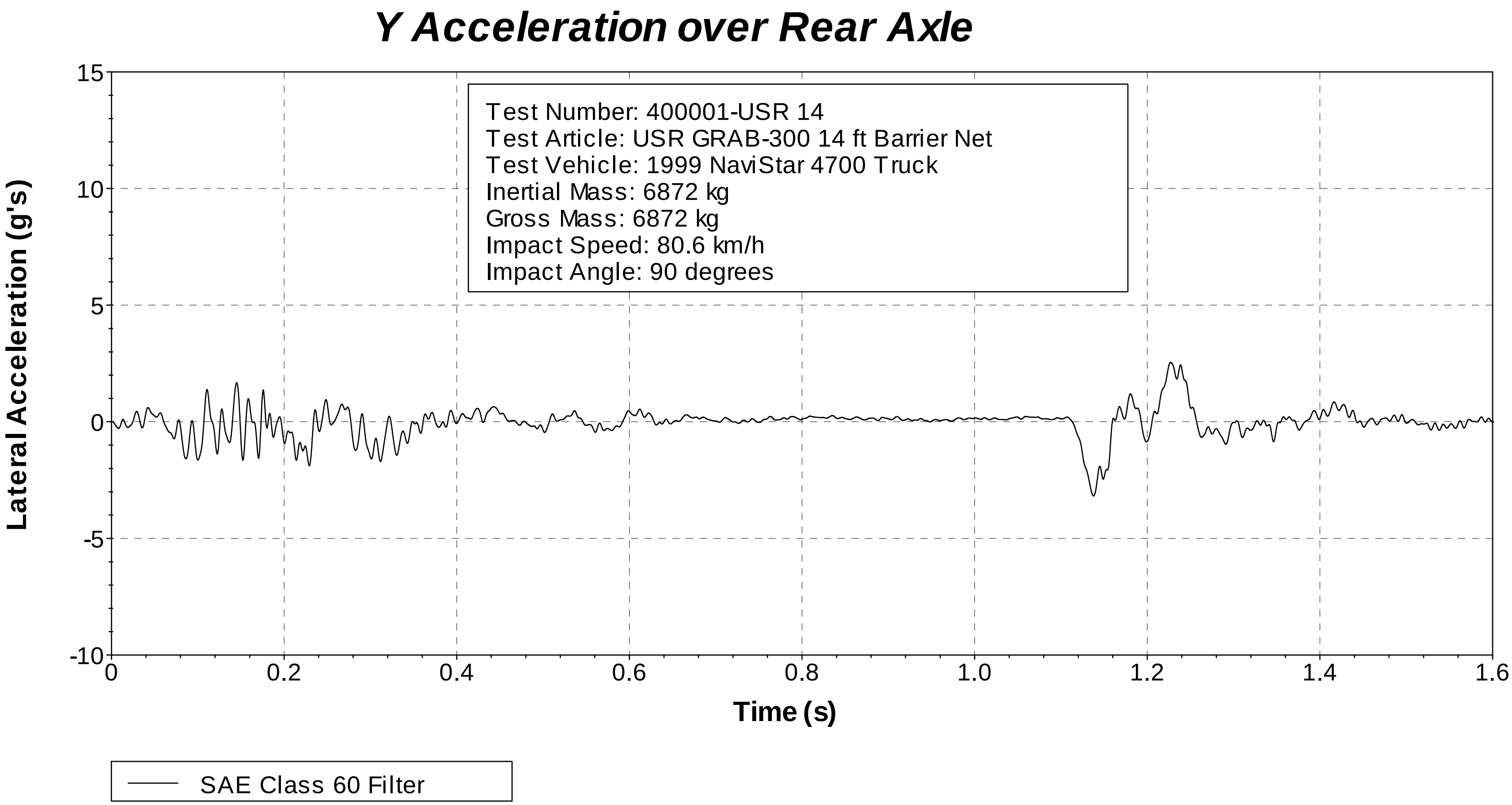

Figure 24. Vehicle lateral accelerometer trace for test 400001-USR14 (accelerometer located over rear axle).

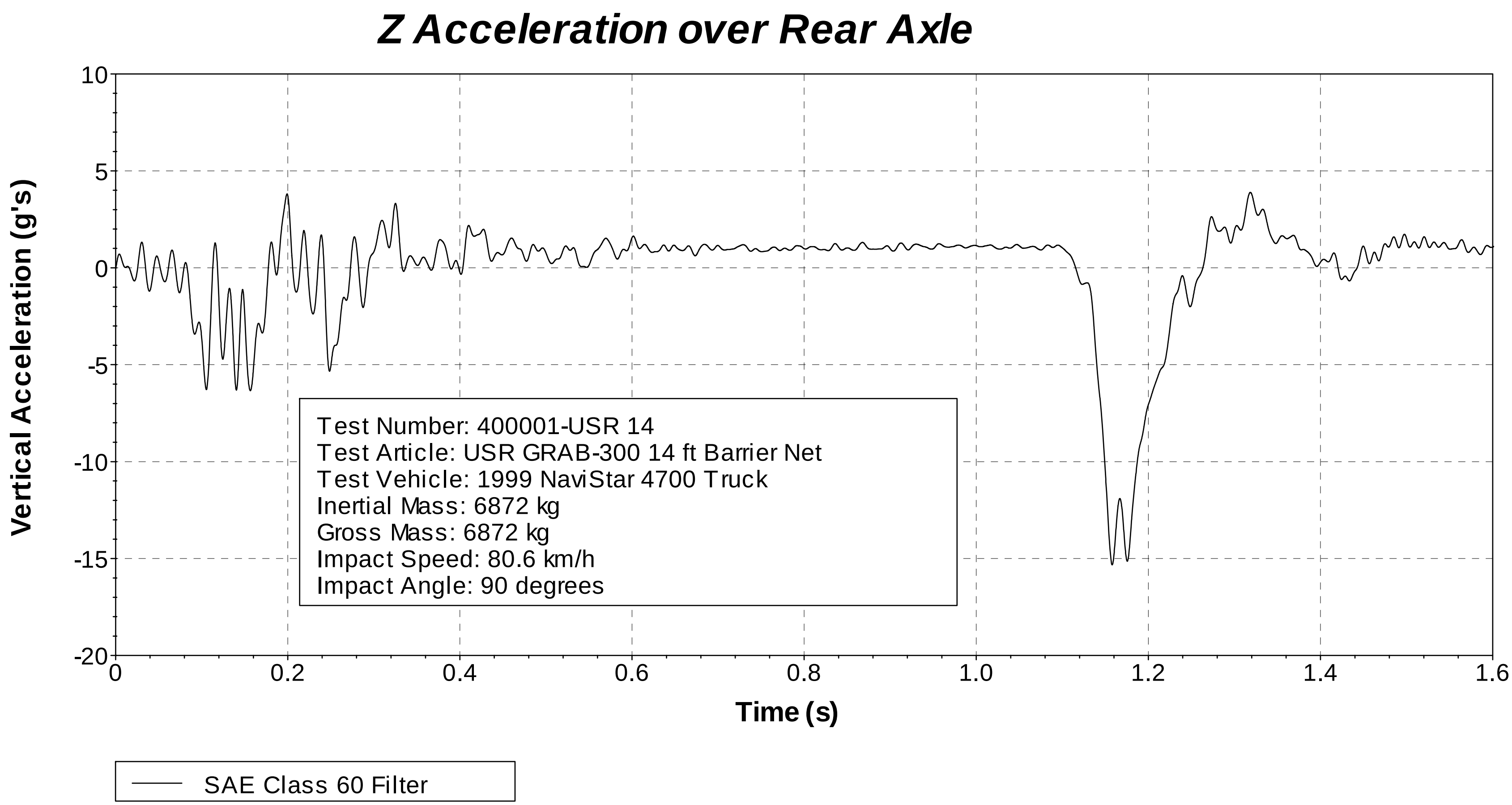

Figure 25. Vehicle vertical accelerometer trace for test 400001-USR14 (accelerometer located over rear axle).

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DOS K12/ASTM M50 TESTING AND EVALUATION OF THE UNIVERSAL SAFETY RESPONSE 62 FT GRAB-300 BARRIER NET

by

William F. Williams, P.E.
Assistant Research Engineer

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Research Engineer

and

Wanda L. Menges
Research Specialist

Contract No.: P2008400
Project/Test No.: 400001-USR13
Test Date: 2008-07-02

Sponsored by
UNIVERSAL SAFETY RESPONSE, INC.

August 2008

TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS 77843

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KEY WORDS

Anti-ram; perimeter; crash testing; barriers; gates; bollards; walls; fences; homeland security.

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15. Supplementary Notes
Research Study Title: Crash Testing of USR 62-ft GRAB-SP Barrier Net
Name of Contacting Representative: Matthew Gelfand

16. Abstract

The objective of this test is to determine if the GRAB-300 62-ft (19 m) barrier net is capable of arresting a 6810 kg (15,000 lb) truck traveling at 80 km/h (50 mi/h) based on Condition Designation K12 as stated in *ST-STD-02.01, Revision A* and according to Condition Designation M50 of *ASTM 2656-07*. Both condition designations require the GRAB-300 62-ft (19 m) barrier net to withstand kinetic energy of 1,695,000 J (1,250,000 ft-lb).

This report presents the construction details of the GRAB-300 62-ft (19 m) barrier net, details of the vehicle used in the test, details of the test, and the assessment of the test results. The cargo bed penetrated 6.4 m (20.9 ft) beyond the inside edge of the barrier net.

ST-STD-02.01, Revision A performance criteria limits penetration of the leading edge of the cargo bed to 1 m (3.3 ft) beyond the pre-impact, inside edge of the barrier. According to the results of the full-scale crash test, the GRAB-300 62-ft (19 m) barrier net does not meet the requirements for Condition Designation K12 in accordance March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*.

ASTM 2656-07 provides a range of vehicle test designations and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. According to *ASTM 2656-07*, the GRAB-300 62-ft (19 m) barrier net meets Condition Designation/Penetration Rating M50/P2, which allows penetration of 1.01 m to 7 m (3.31 to 23.0 ft).

17. Key Words	18. Distribution Statement
anti-ram; perimeter; crash testing; barriers; gates; bollards; walls; fences; homeland security	Copyrighted. Not to be copied or reprinted without consent from Universal Safety Response, Inc.

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Unclassified	Unclassified	50	

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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)

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INTRODUCTION

PROBLEM

In an effort to assess the performance of anti-terrorist protection barriers, the United States Department of State, Bureau of Diplomatic Security, Physical Security Division (DS/PSP/PSD) developed guidelines to evaluate the performance of perimeter barriers/gates. The March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*, is the current version used to evaluate the performance of an anti-terrorist protection barrier.(1) According to this standard, performance of an anti-terrorist protection barrier is evaluated and assessed according to its effectiveness in arresting attacking vehicles, and not necessarily for economics, aesthetics, operational cycle time, special maintenance needs, or climate and environment effects. The GRAB-300 62-ft (19 m) barrier net evaluated herein was designed by Universal Safety Response, Inc. The intended function of this design is to provide road closure capable of arresting an attacking vehicle.

BACKGROUND

The procedures set out in *SD-STD-02.01, Revision A* are intended to ensure that perimeter barriers/gates provide a specified level of vehicle impact resistance as recommended by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division. The assessment criteria are based on the capability of the barrier/gate to arrest the vehicle such that it does not penetrate or vault over the system. Three levels of performance are defined based on the amount of vehicular impact kinetic energy the barrier/gate is capable of arresting. *SD-STD-02.01, Revision A* limits the penetration of the leading edge of the cargo bed to one meter (3.3 ft) beyond the pre-impact, inside edge of the barrier. If the barrier meets this requirement, a pass rating will be assigned at the appropriate speed designation by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division.

However, the previous penetration levels detailed in the April 1985 *SD-STD-02.01 Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates* are still being accepted by branches of the armed forces for use at facilities where adequate distance permits additional penetration past the barrier.(2) Therefore, in August 2007, the American Standards for Testing Materials (ASTM) International developed and published *ASTM Designation: F2656-07, Standard Test Method for Vehicle Crash Testing of Perimeter Barriers*.(3) This test method provides a range of vehicle impact conditions, test designations, and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. This new test method will soon be adopted as the official standard for testing of perimeter barriers.

The test reported herein was performed and evaluated in accordance with March 2003 standard, *SD-STD-02.01, Revision A* and *ATSM 2656-07*.

OBJECTIVES/SCOPE OF RESEARCH

The objective of this test is to determine if the GRAB-300 62-ft (19 m) barrier net is capable of arresting a 6810 kg (15,000 lb) truck traveling at 80 km/h (50 mi/h) based on Condition Designation K12 as stated in *ST-STD-02.01, Revision A* and according to Condition Designation M50 of *ASTM 2656-07*. Both condition designations require the GRAB-300 62-ft (19 m) barrier net to withstand kinetic energy of 1,695,000 J (1,250,000 ft-lb).

This report presents the construction details of the GRAB-300 62-ft (19 m) barrier net, details of the vehicle used in the test, details of the test, and the assessment of the test results.

TECHNICAL DISCUSSION

TEST PARAMETERS

Test Facility

The test facilities at the Texas Transportation Institute's Proving Ground consist of an 809-hectare (2000-acre) complex of research and training facilities situated 16 km (10 mi) 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 evaluation of roadside safety hardware and perimeter security barriers/gates. The site selected for placing of the GRAB-300 62-ft barrier net was on the edge of a wide out-of-service apron. The apron consists of an unreinforced jointed concrete pavement in 3.8 m x 4.6 m (12.5 ft x 15 ft) blocks nominally 203-305 mm (8-12 inches) deep. The apron is over 50 years old and the joints have some displacement, but are otherwise flat and level.

Test Article – Design and Construction

Universal Safety Response, Inc. (USR) GRAB-100 K12-62-ft (19 m) multilane road closure system is a deployable gate/net system. The road closure system tested herein consists of a net, anchor stanchions and proprietary hydraulic shock absorbing pistons. The width of the net for this test was 62 ft (18.9 m). The net was anchored on each end by a separate anchor stanchion and foundation. The net was manufactured by Holloway Houston, Inc. and has upper and lower horizontal 1-1/2 inch (38 mm) diameter wire ropes with swaged eye end connections. Vertical 3/4-inch (19 mm) diameter wire ropes are attached to the main horizontal ropes and the middle horizontal 3/4-inch (19 mm) diameter wire rope. This middle rope terminates at the end vertical rope.

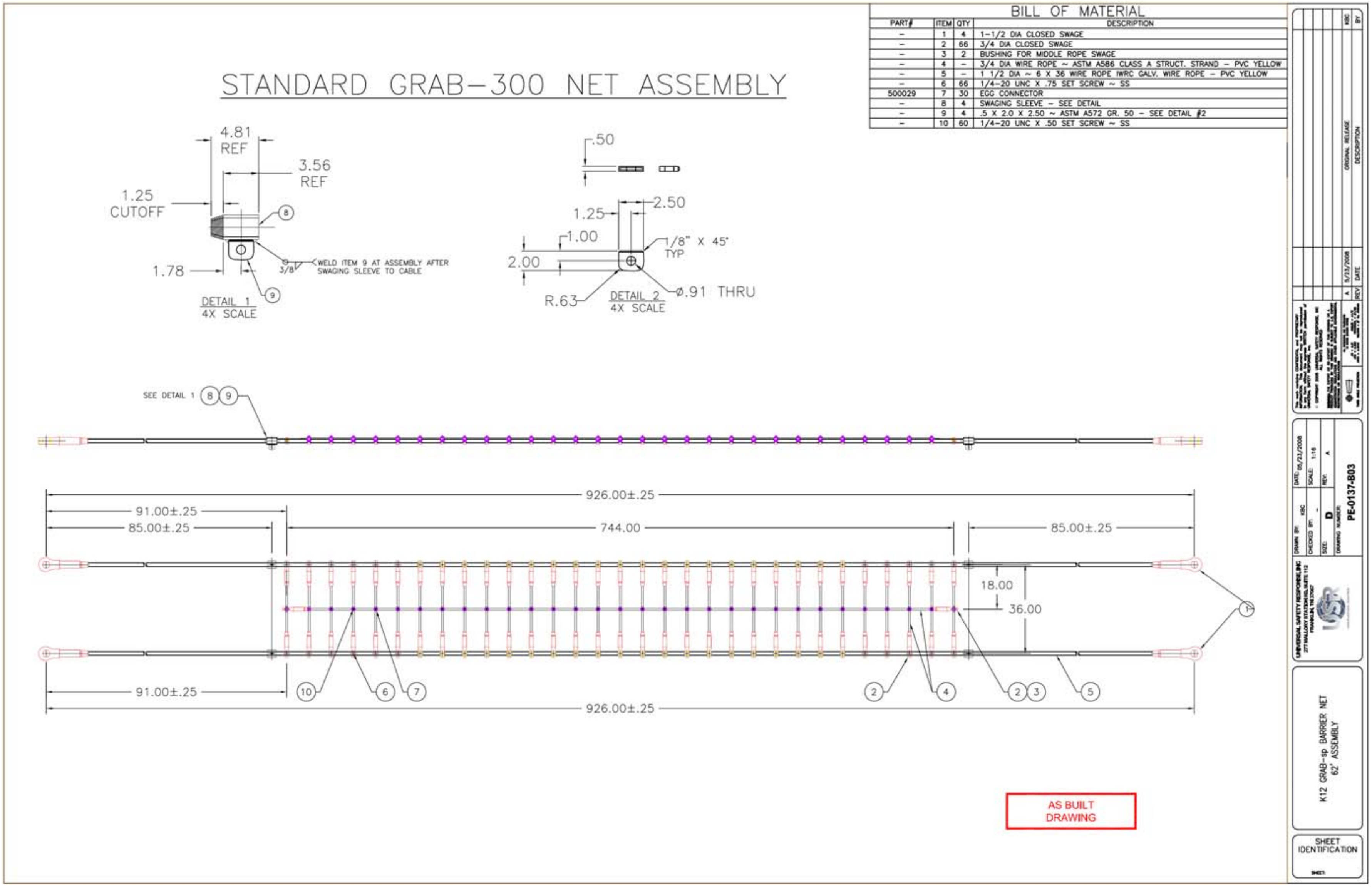
The net is deployed by an electric motor attached to a secondary post system located on each end of the net. The posts in the lifting base installation were 6 inches x 6 inches x 3/8 inches thick (152 mm x 152 mm x 9.5 mm thick). The net is attached to these secondary posts using 5/16-inch (8 mm) diameter cables with turn buckles and eye-bolts that allow for tensioning of the net between the deployment posts. Details of the net system are shown in figures 1 through 9.

Swage fittings connect the net to the stanchion sleeves. The sleeves are made of 12-inch (305 mm) diameter Schedule 100 pipe. The pipe sleeves were manufactured from ASTM A106 material. Four 1-inch (25 mm) thick sleeve rings were welded to each pipe ring. These ring are welded to a net anchor bracket. The net anchor bracket consists of two 1-1/4-inch (32 mm) thick shear plates welded to 1-1/4-inch (32 mm) thick anchor plate. Cap plates with a thickness of 1/2-inch (13 mm) were welded to the top and bottom sides of the anchor brackets. Details of the pipe sleeves are provided in figures 2 and 3.

A steel anchor stanchion assembly was used to anchor the stanchion sleeves to a concrete foundation. For this test, the distance between the stanchion centerlines was approximately 68 ft-8 inches (20.9 m). The steel anchor stanchion assembly consisted of a 10-inch (254 mm) diameter Schedule 160 pipe welded to a TS16x8x1/2 (TS406x203x13) structural tube. The 10-inch (254 mm) diameter pipe was manufactured from ASTM A106 material. The structural tube was manufactured from A500 Grade B material. A 3-inch (76 mm) thick rib plate was welded inside the full length of the stanchion pipe. Steel plate, 1 inch (25 mm) thick, was welded to the sides of the structural tube for added strength. The width of the 1-inch (25 mm) plate on the top and bottom sides was 24 inches (610 mm). Steel stiffeners with a thickness of 3/4-inch (19 mm) were welded between the top and bottom plates and to the side plates. The lengths of the added steel plates were 58 inches (1473 mm). The length of the TS16x8x1/2 (TS406x203x13) tube was 89 inches (2261 mm). All steel plates were manufactured from ASTM A36 Material. Details of the steel anchor stanchion assembly are provided in figure 4 and 6 through 9.

Each steel anchor stanchion was anchored to a 12 ft x 12 ft x 18 inches thick (3.7 m x 3.7 m x 203 inches thick) concrete foundation. Reinforcement in the foundation consisted of #5 (#16) reinforcing steel at 6 inches (152 mm) on centers each way in two mats of reinforcing steel (top and bottom) with the exception of the longitudinal reinforcing steel immediately beneath the steel anchor stanchion. Number 5 (#16) stirrups were constructed above and below the steel anchor assembly and were located on 6 inches (152 mm) on centers. These stirrups helped to anchor the steel anchor assembly in the concrete foundation. Considering the deployed state of the net and pistons from the impact of the vehicle, the foundations and steel anchor stanchion assemblies were oriented 40 degrees from the direction of travel of the vehicle. The compressive strength of the foundation concrete the day the test was performed was 4761 psi (32.8 MPa).

An 18-inch (457 mm) concrete apron was constructed to connect the 12 ft x 12 ft (3.7 m x 3.7 m) concrete foundation to the smaller 5 ft x 5 ft x 12 inches (1.5 m x 1.5 m x 305 mm) footing used to support the net lifting base installation. Reinforcement in the apron consisted of #5 (#16) bars at 10 inches (254 mm) on center. One single mat of reinforcing steel was used to construct the apron. Number 5 (#16) dowels, 4 ft in length were drilled and anchored in the existing foundations using the Hilti HIT HY 150 epoxy anchoring system. These dowels were anchored 10 inches (254 mm) into in the existing foundation concrete. The compressive strength of the apron concrete the day the test was performed was 3260 psi (22.5 MPa). Details of the system are provided in figures 1 through 9, and photographs of the completed installation are shown in figure 10.



BILL OF MATERIAL

PART#	ITEM	QTY	DESCRIPTION
–	1	4	1-1/2 DIA CLOSED SWAGE
–	2	66	3/4 DIA CLOSED SWAGE
–	3	2	BUSHING FOR MIDDLE ROPE SWAGE
–	4	–	3/4 DIA WIRE ROPE ~ ASTM A586 CLASS A STRUCT. STRAND – PVC YELLOW
–	5	–	1 1/2 DIA ~ 6 X 36 WIRE ROPE IWRC GALV. WIRE ROPE – PVC YELLOW
–	6	66	1/4-20 UNC X .75 SET SCREW ~ SS
500029	7	30	EGG CONNECTOR
–	8	4	SWAGING SLEEVE – SEE DETAIL
–	9	4	.5 X 2.0 X 2.50 ~ ASTM A572 GR. 50 – SEE DETAIL #2
–	10	60	1/4-20 UNC X .50 SET SCREW ~ SS

Figure 1. Details of the GRAB-300 62-ft barrier net -- assembly.

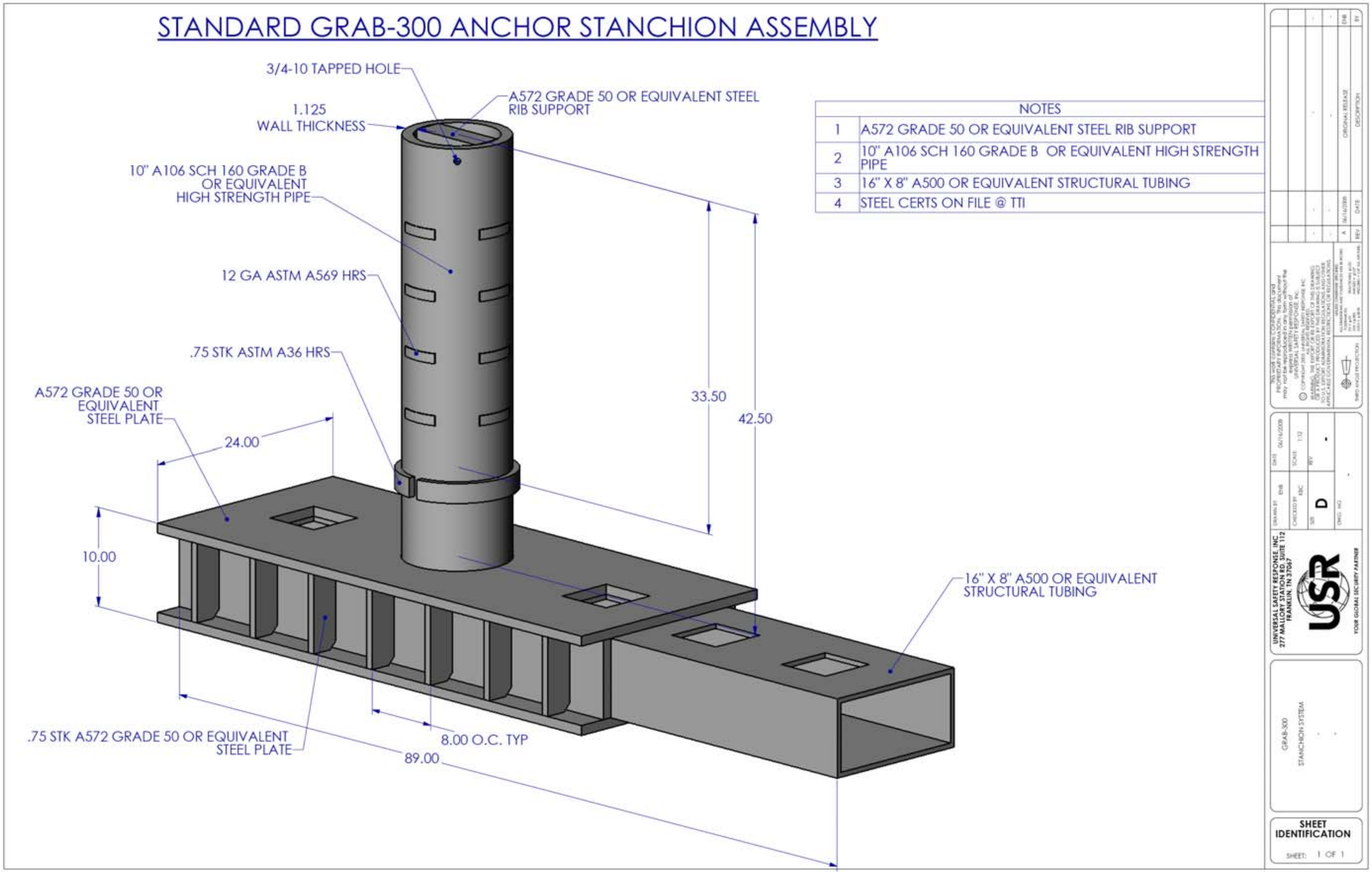
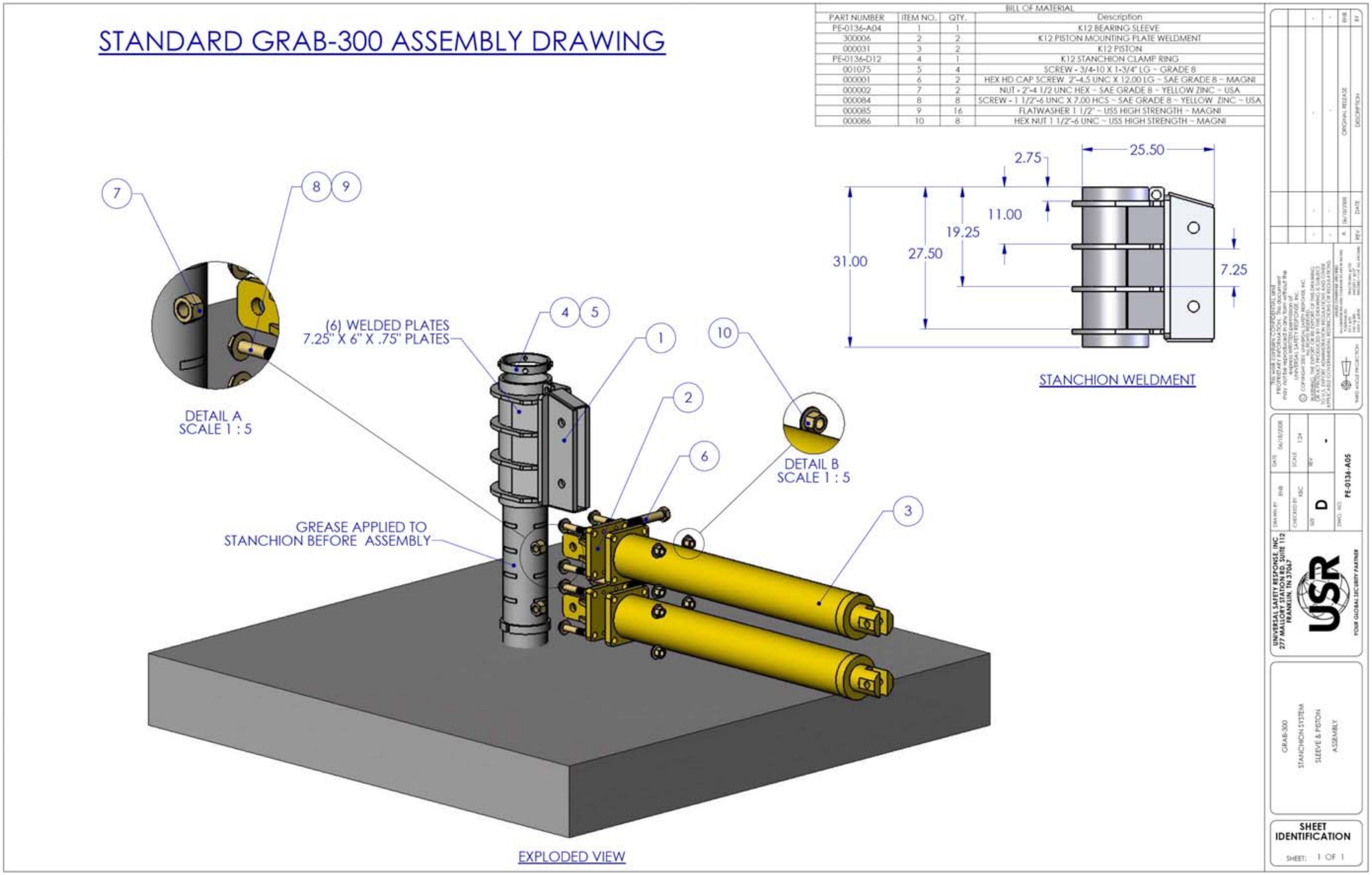


Figure 2. Details of the GRAB-300 62-ft barrier net – stanchion system.



BILL OF MATERIAL			
PART NUMBER	ITEM NO.	QTY.	Description
PE-0136-A04	1	1	K12 BEARING SLEEVE
300006	2	2	K12 PISTON MOUNTING PLATE WELDMENT
000031	3	2	K12 PISTON
PE-0136-D12	4	1	K12 STANCHION CLAMP RING
001075	5	4	SCREW - 3/4-10 X 1-3/4" LG ~ GRADE 8
000001	6	2	HEX HD CAP SCREW 2"-4.5 UNC X 12.00 LG ~ SAE GRADE 8 ~ MAGNI
000002	7	2	NUT - 2"-4 1/2 UNC HEX ~ SAE GRADE 8 ~ YELLOW ZINC ~ USA
000084	8	8	SCREW - 1 1/2"-6 UNC X 7.00 HCS ~ SAE GRADE 8 ~ YELLOW ZINC ~ USA
000085	9	16	FLATWASHER 1 1/2" ~ USS HIGH STRENGTH ~ MAGNI
000086	10	8	HEX NUT 1 1/2"-6 UNC ~ USS HIGH STRENGTH ~ MAGNI

Figure 3. Details of the GRAB-300 62-ft barrier net – stanchion system sleeve and piston assembly.

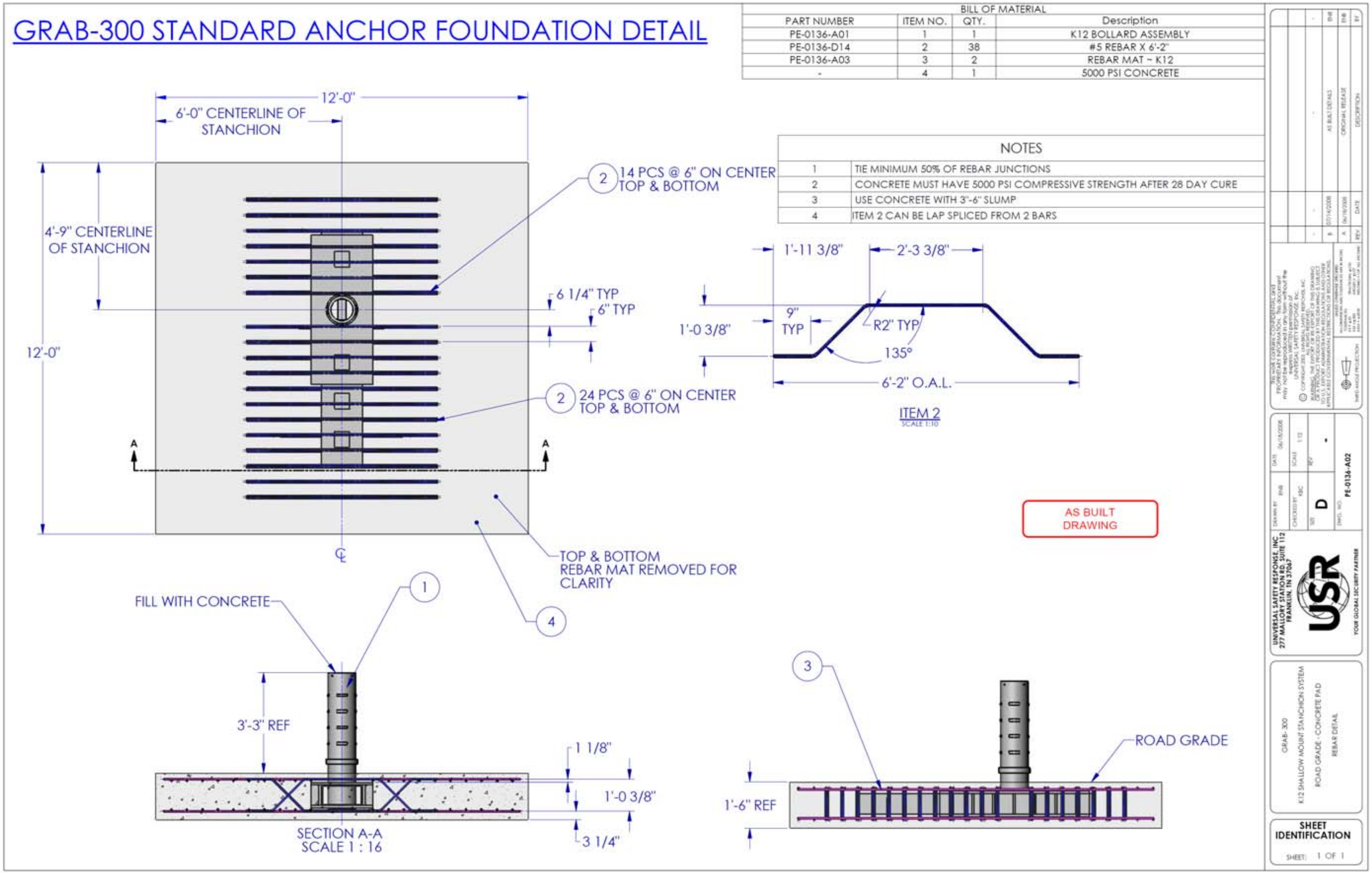


Figure 4. Details of the GRAB-300 62-ft barrier net – standard anchor foundation.

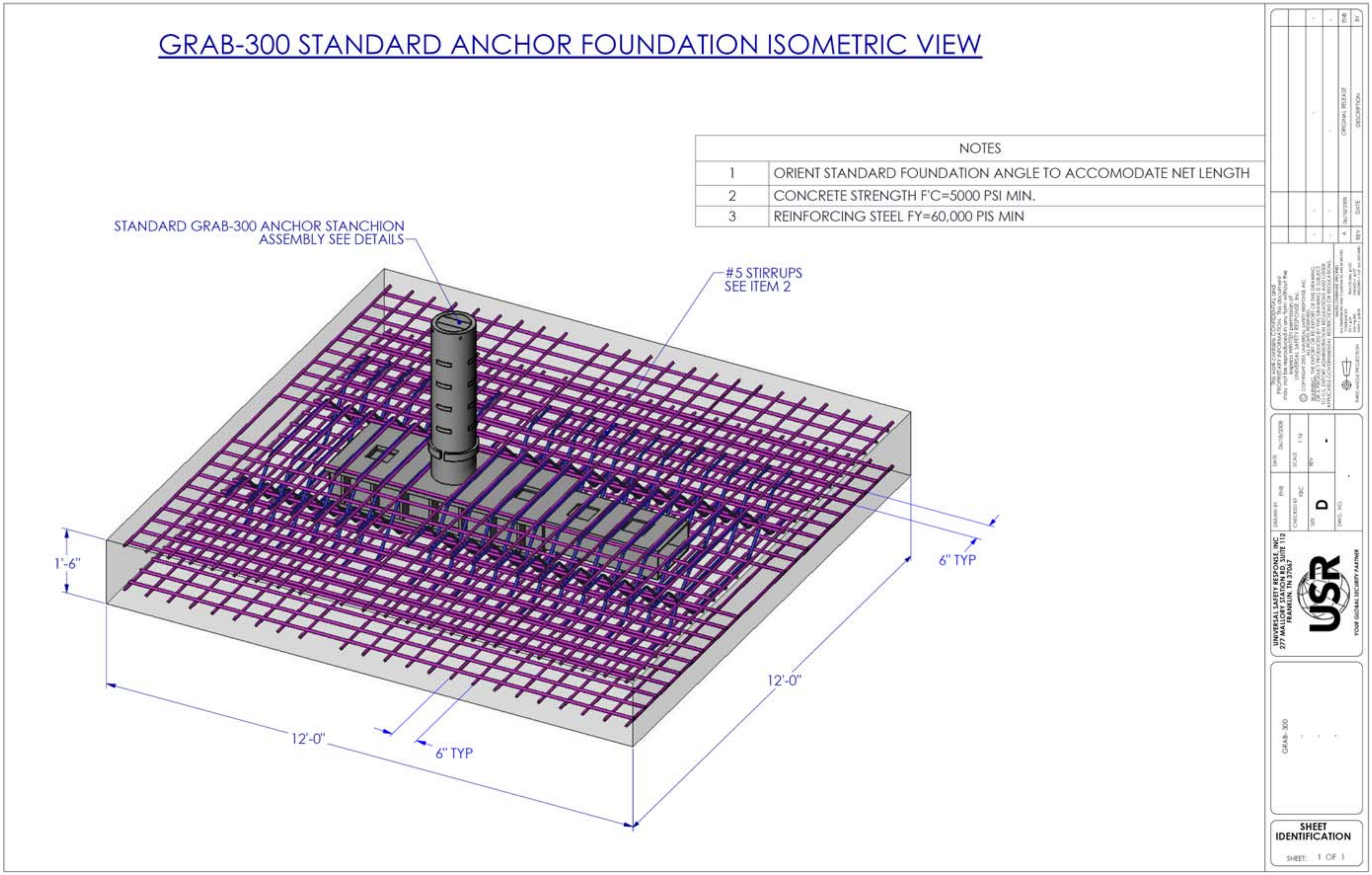


Figure 5. Details of the GRAB-300 62-ft barrier net – concrete pad rebar detail.

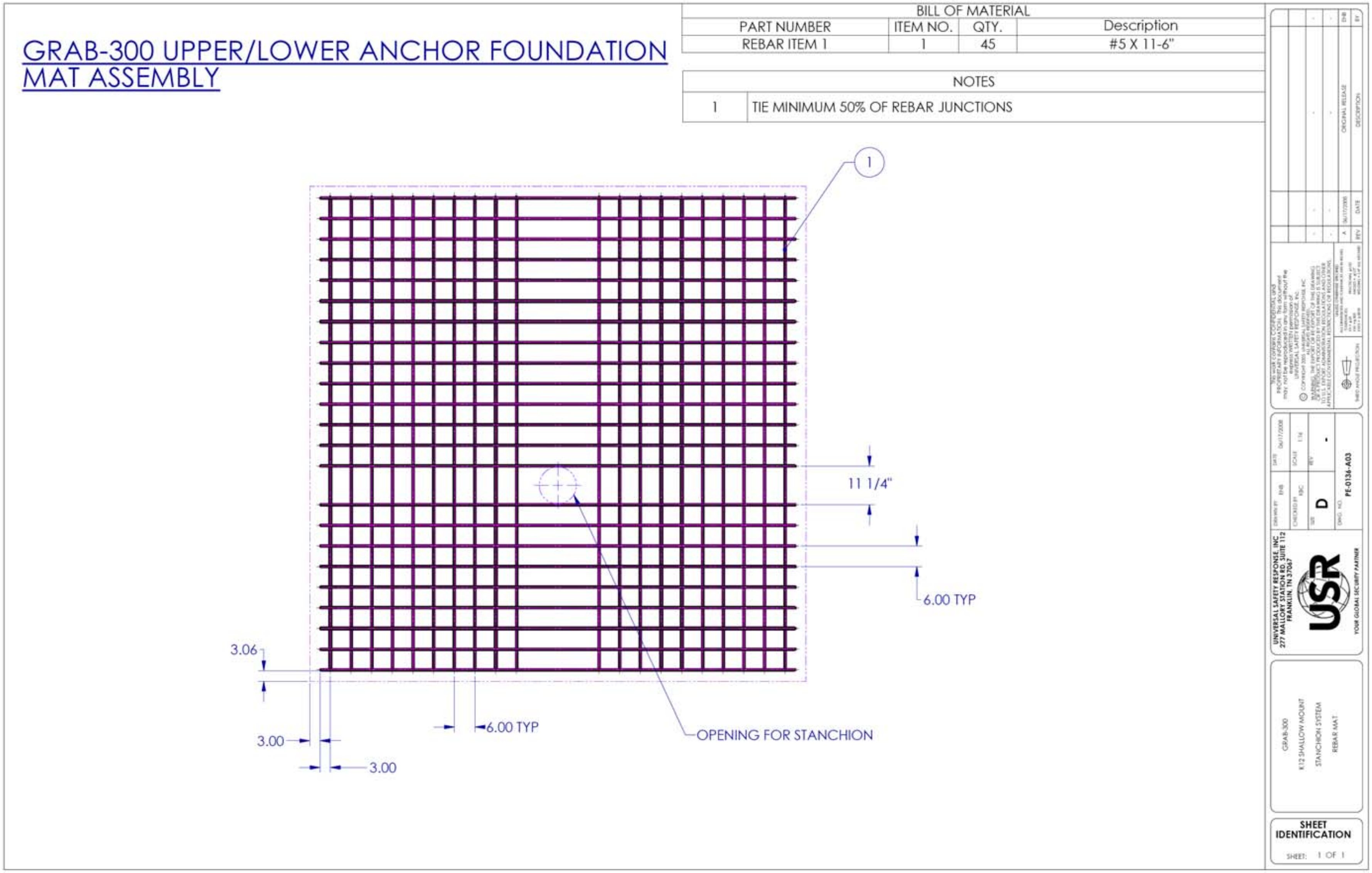


Figure 6. Details of the GRAB-300 62-ft barrier net – stanchion system rebar mat.

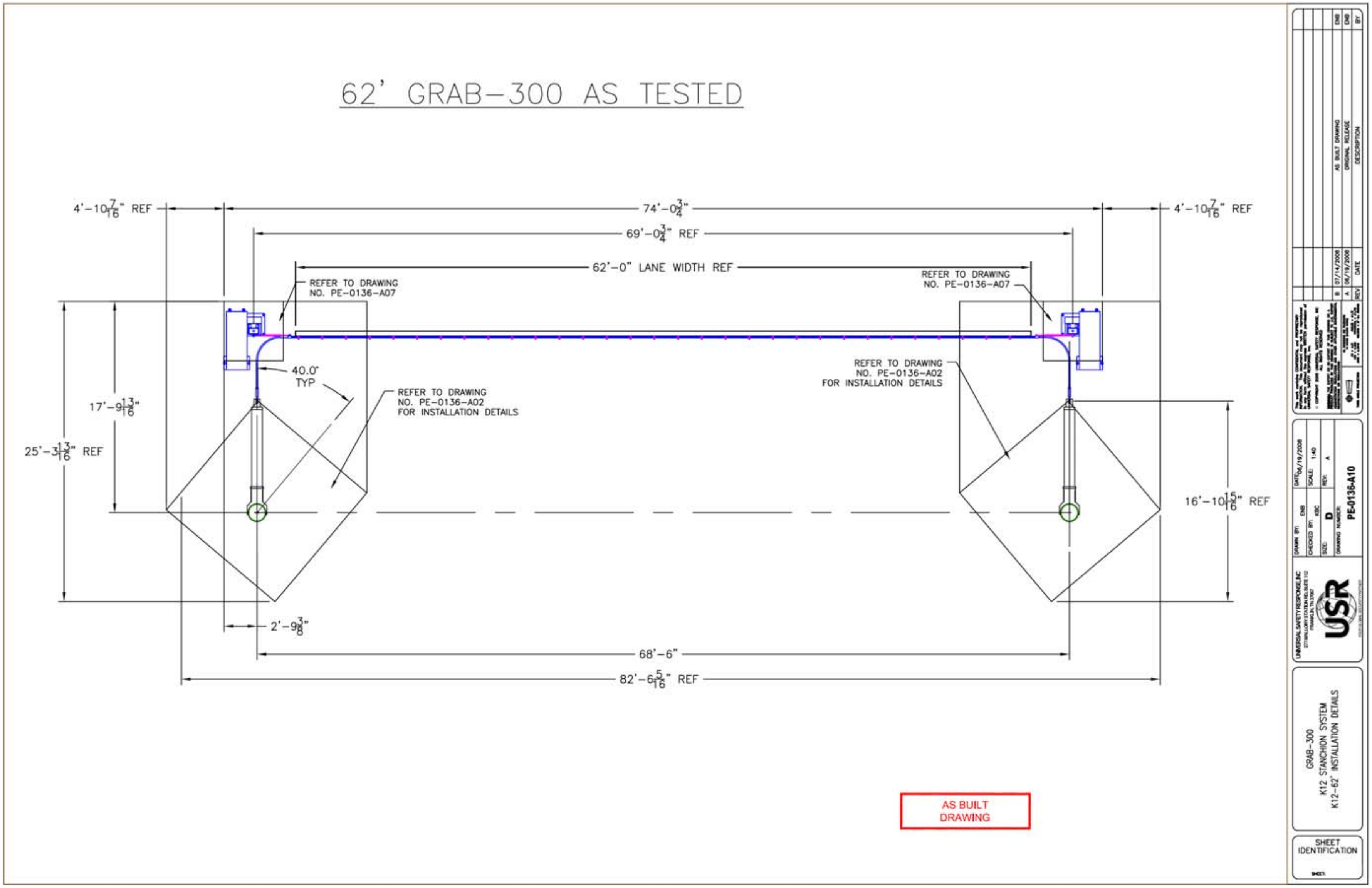


Figure 7. Details of the GRAB-300 62-ft barrier net – stanchion system installation details.

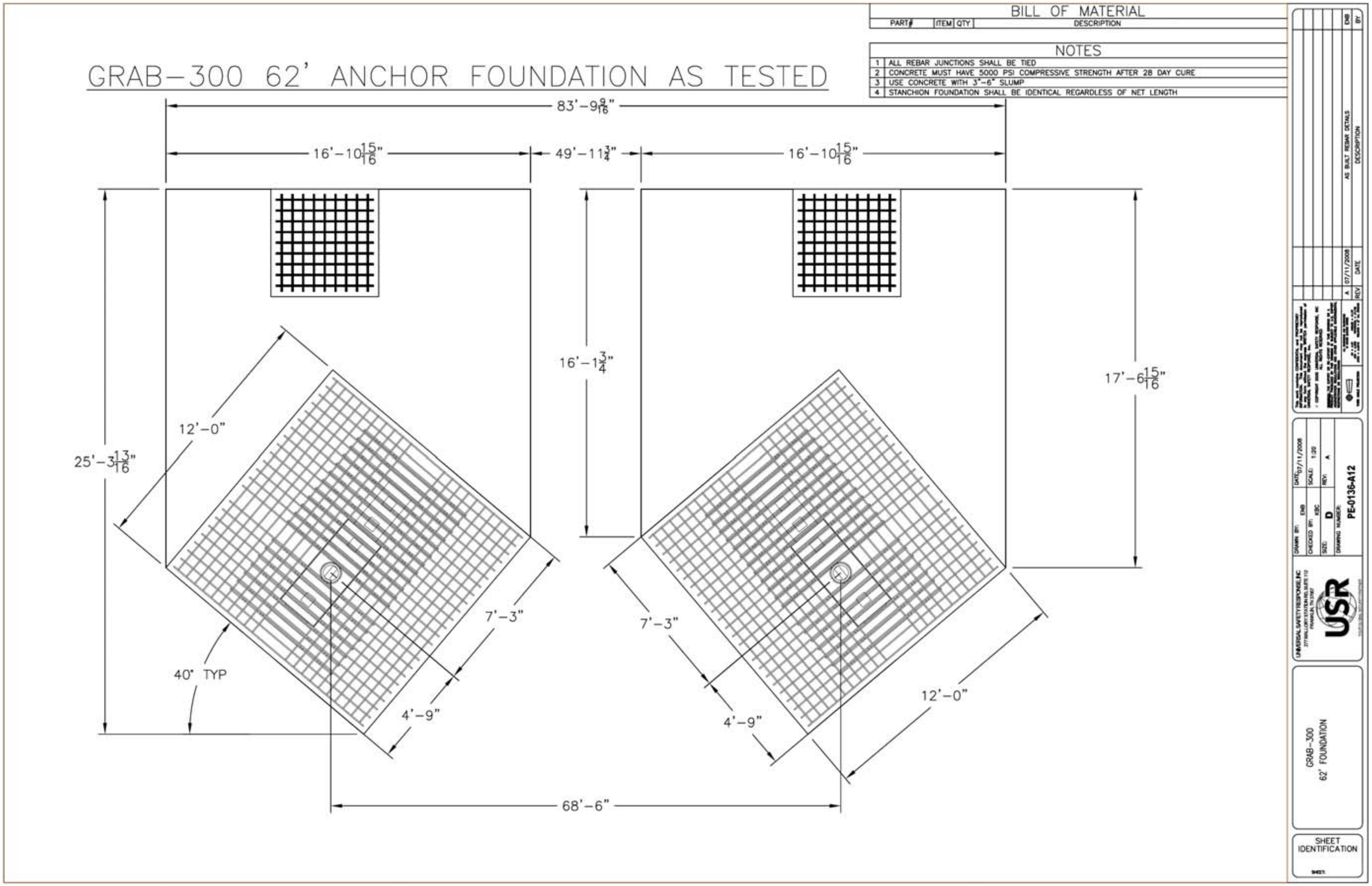


Figure 8. Details of the GRAB-300 62-ft barrier net – anchor foundation.

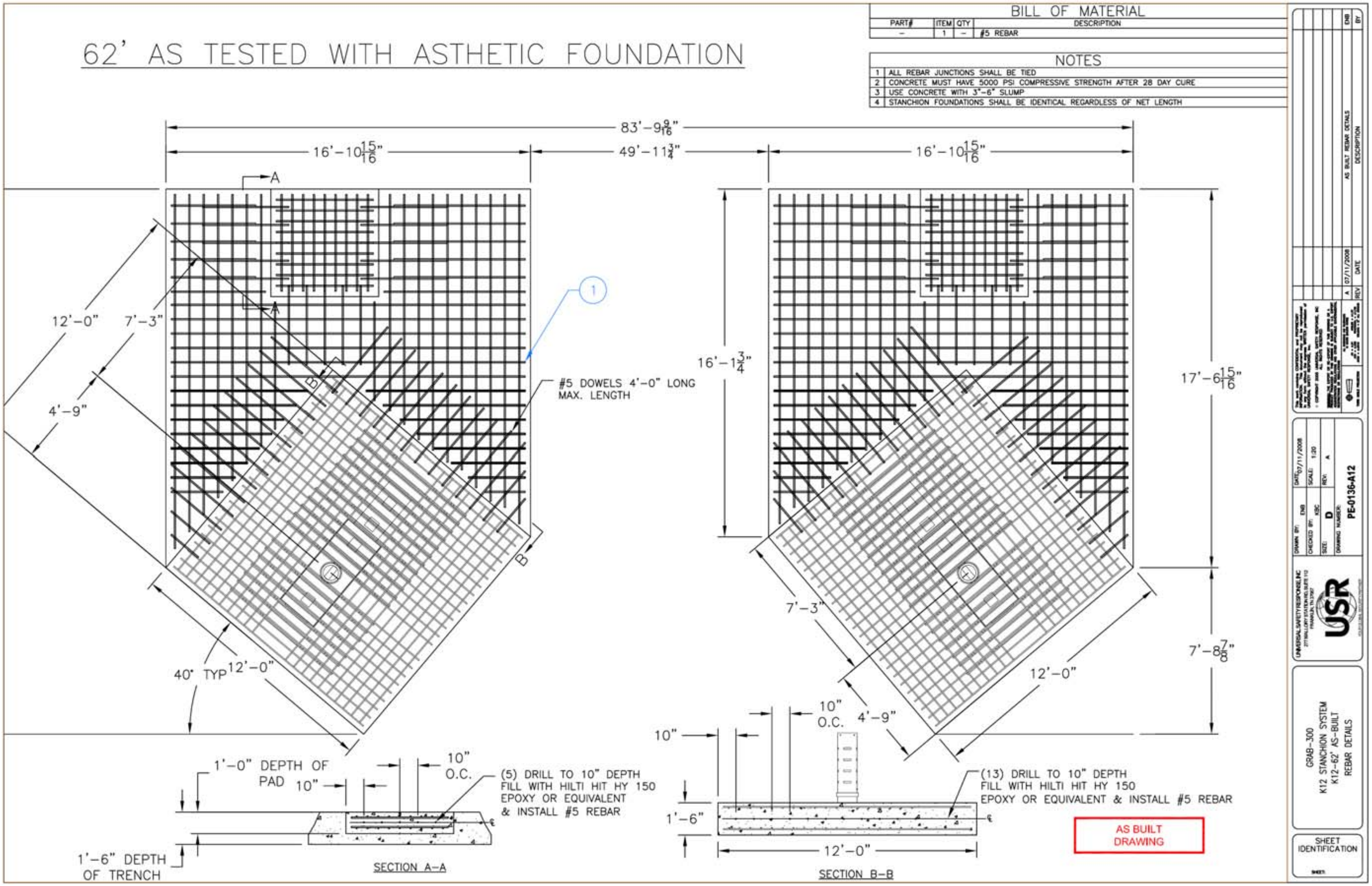


Figure 9. Details of the GRAB-300 62-ft barrier net – stanchion system rebar details..

Figure 10. GRAB-300 62-ft barrier net prior to testing.

Test Conditions and Evaluation Criteria

According to *SD-STD-02.01, Revision A*, the GRAB-300 62-ft barrier net can be rated according to one of three designated condition levels as shown in Table 1. The test conditions are intended to ensure that perimeter barriers and gates will provide a specified level of vehicle impact resistance. Actual vehicle speed must be within a permissible range to receive the condition designation. *ST-STD-02.01, Revision A* performance criteria limits penetration of the leading edge of the cargo bed to 1 m beyond the pre-impact, inside edge of the barrier. If the barrier meets this requirement, a pass rating will be assigned at the appropriate speed designation by the United States Department of State, Bureau of Diplomatic Security, Physical Security Division.

Table 1. Impact Condition Designations according to *SD-STD-02.01, Revision A*.*

Nominal Impact Speed	***Permissible Impact Speed Range***	***Kinetic Energy***	***Designation***
80 kph *50 mph*	*75.0-above kph* *47.0-56.9 mph*	*1,695,000 J* *1,250,000 ft-lb*	*K12*
65 kph *40 mph*	*60.1-75.0 kph* *38.0-46.9 mph*	*1,085,000 J* *800,000 ft-lb*	*K8*
50 kph *30 mph*	*45.0-60.0 kph* *28.0-37.9 mph*	*610,000 J* *450,000 ft-lb*	*K4*

* Taken directly from Table 1 of *SD-STD-02.01, Revision A.*

The levels of kinetic energy that a barrier shall withstand according to *ASTM F2656-07* are shown in Table 2. Again, the test conditions are intended to ensure that perimeter barriers and gates will provide a specified level of vehicle impact resistance. Actual vehicle speed must be within a permissible range to receive the specific condition designation. The condition designations, shown in the last column of table 2, taken from *ASTM F2657-07,* are defined by the vehicle type and impact speed.

The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. Test vehicle dynamic penetration is referenced to each vehicle as follows: The base of the "A" pillar for the small passenger car (C); the front leading lower edge of the pickup truck bed (P); the leading lower edge of the cargo bed on the medium duty truck (M); and the leading lower vertical edge of the cargo bed on the heavy goods vehicle (H). Penetration ratings according to *ASTM F2656-07* are shown in table 3.

Table 2. Impact Condition Designations according to *ASTM 2656-07*.

Test Vehicle/Minimum Test Inertial Vehicle, kg(lbm)	*Nominal Minimum Test Velocity km/h(mph)*	*Permissible Speed Range, km/h (mph)*	*Kinetic Energy, KJ (ft-kips)*	*Condition Designation*
Small passenger car (C) 1100 (2430)	*65 (40)* *80 (50)* *100 (60)*	*60.1-75.0 (38.0-46.9)* *75.1-90.0 (47.0-56.9)* *90.1-above (57.0-above)*	*179 (131)* *271 (205)* *424 (295)*	*C40* *C50* *C60*
Pickup truck (P) 2300 (5070)	*65 (40)* *80 (50)* *100 (60)*	*60.1-75.0 (38.0-46.9)* *75.1-90.0 (47.0-56.9)* *90.1-above (57.0-above)*	*375 (273)* *568 (426)* *887 (613)*	*PU40* *PU50* *PU60*
Medium-duty truck (M) 6800(15000)	*50 (30)* *65 (40)* *80 (50)*	*45.0-60.0 (28.0-37.9)* *60.1-75.0 (38.0-46.9)* *75.1-above (47.0-above)*	*656 (451)* *1110 (802)* *1680 (1250)*	*M30* *M40* *M50*
Heavy goods vehicle (H) 29500(65000)	*50 (30)* *65 (40)* *80 (50)*	*45.0-60.0 (28.0-37.9)* *60.1-75.0 (38.0-46.9)* *75.1-above (47.0-above)*	*2850 (1950)* *4810 (3470)* *7280 (5430)*	*H30* *H40* *H50*

Table 3. Penetration Ratings according to *ASTM F2656-07*.

Penetration Designation	*Dynamic Penetration Rating*
P1	*≤ 1 m (3.3 ft)*
P2	*1.01 m to 7 m (3.31 to 23.0 ft)*
P3	*7.01 m to 30 m (23.1 to 98.4 ft)*
P4	*30 m (98 ft) or greater*

The test reported herein was performed in accordance with March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates* and also in accordance with *ASTM 2656-07*. Appendix A presents brief descriptions of procedures followed for the test.

The test vehicle specified was a medium duty truck with diesel engine, tested at a gross vehicle weight of 6800 kg (15,000 lb) ±90 kg (200 lb), which satisfies both standards.

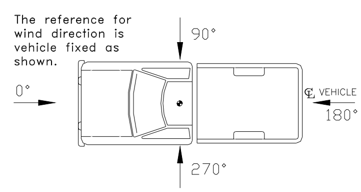
CRASH TEST 400001-USR13 (*SD-STD-02.01* K12 / *ASTM 2656-07* M50)

Test Vehicle

A 1997 NaviStar 4700 single-unit flatbed truck, shown in figures 11 and 12, was used for the crash test. Test inertia weight of the vehicle was 6804 kg (15,000 lb). The height to the lower edge of the vehicle front bumper was 51 cm (20.25 inches), and the height to the upper edge of the front bumper was 80 cm (31.5 inches). Figure 18 in appendix B gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The crash test was performed the morning of July 2, 2008. A total of 0.8 inch of rainfall was recorded during the three days prior to the test. Moisture content of the crushed limestone base material in which the test article was installed was 8.0 percent. Weather conditions at the time of testing were: Wind Speed: 6 km/h (4 mi/h); Wind Direction: 200 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); Temperature: 28 ºC (83 ºF); Relative Humidity: 72 percent.



Impact Description

The1997 NaviStar 4700 single-unit flatbed truck, traveling at an impact speed of 83.2 km/h (51.7 mi/h), impacted the GRAB-300 62-ft barrier net at an impact angle of 90.5 degrees. The centerline of the vehicle was aligned with the centerline of the net. Shortly after impact, the middle cable began to tighten around the front of the vehicle, and at 0.007 s, the top and bottom cables began to deform around the front of the vehicle. At 0.162 s, the truck began to yaw counterclockwise, and at 0.378 s, the middle cable was taut around the front of the vehicle. Forward motion of the truck stopped at 0.504 s, and the vehicle began to rebound at 0.508 s. The vehicle subsequently came to rest 0.68 m (2.23 ft) forward of the barrier net (on the impact side of the installation). Appendix C, figure 19, shows sequential photographs of the test period.

Figure 11. Vehicle/installation geometrics for test 400001-USR13.

Figure 12. Vehicle before test 400001-USR13.

Damage to Test Article

Damage to the GRAB-300 62-ft barrier net is shown in figure 13 and 14. The top right shock absorber pulled out 56.75 inches, the bottom right 58.38 inches, the top left 59.63 inches, and the bottom left 59.63 inches. The net remained intact, but was caught in the vehicle, grill and bumper. Very slight movement was noted in the right post (less than 1 degree of lean inward). Maximum dynamic penetration of the GRAB-300 62-ft barrier net was 20.9 ft (6.4 m). The vehicle then rebounded back close to the original impact location.

Vehicle Damage

Damage to the 1997 NaviStar 4700 single-unit flatbed truck is shown in figure 15. The flatbed was deformed toward the front along the cargo rack, and the rear of the cab was deformed inward. The windshield popped out, and there was a cut in the fuel tank. The right front spring mount was broken. Also damaged were the front bumper, hood, radiator, radiator support, and fan-water pump. Maximum exterior crush to the vehicle was 10 inches. Photographs of the interior of the vehicle are shown in figure 16.

Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk for informational purposes only. In the longitudinal direction, the occupant impact velocity was 6.1 m/s (20.0 ft/s) at 0.336 s, the highest 0.010-s occupant ridedown acceleration was -17.9 g's from 0.375 to 0.385 s, and the maximum 0.050-s average acceleration was -15.2 g's between 0.374 and 0.424 s. In the lateral direction, the occupant impact velocity was 0.5 m/s (1.6 ft/s) at 0.336 s, the highest 0.010-s occupant ridedown acceleration was 5.1 g's from 0.540 to 0.550 s, and the maximum 0.050-s average was 3.5 g's between 0.505 and 0.555 s. These data and other pertinent information from the test are summarized in figure 17. Vehicle accelerations versus time traces are presented in appendix D, figures 20 through 25.

Figure 13. Vehicle/barrier after test 400001-USR13.

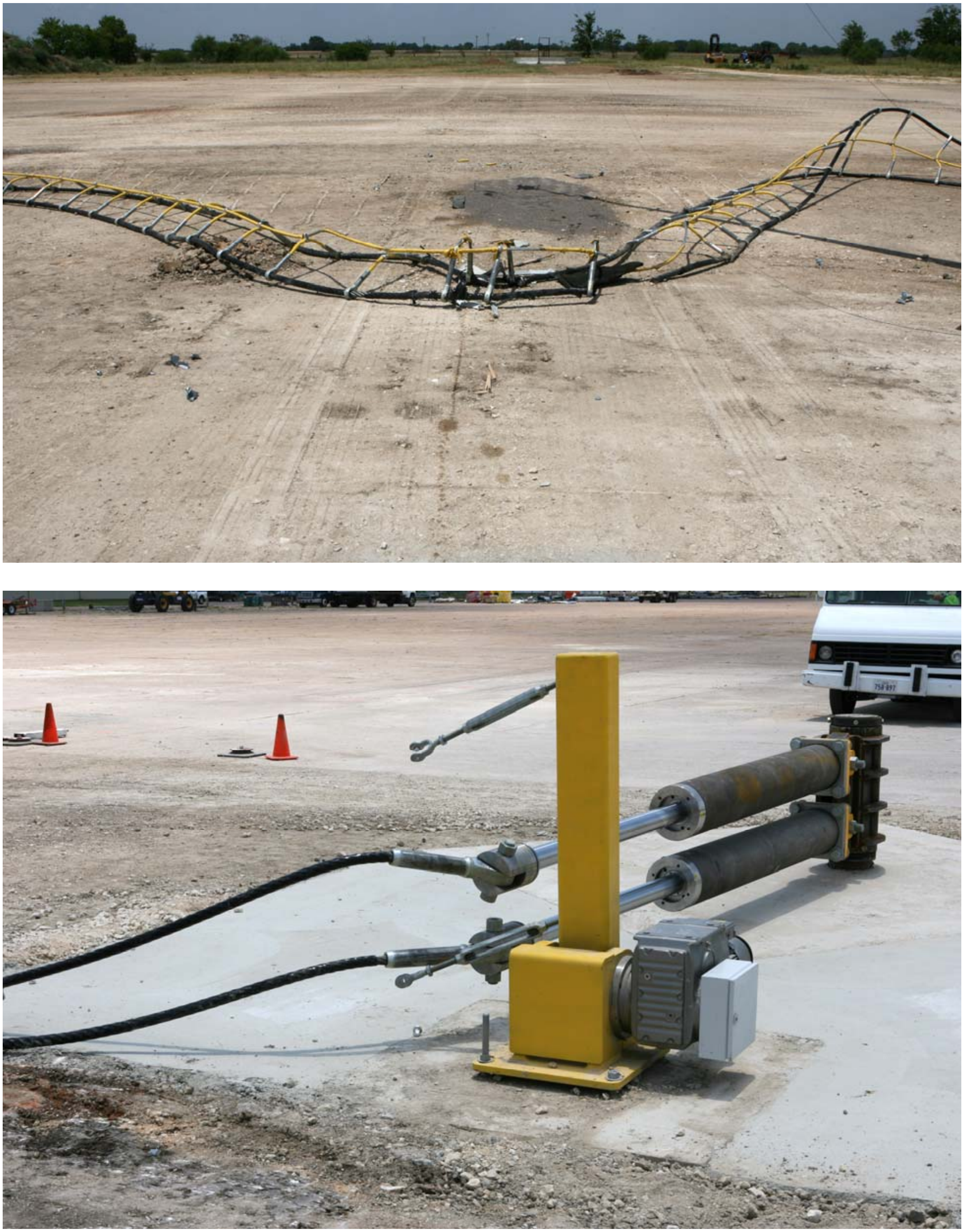


Figure 14. Installation after test 400001-USR13.

Figure 15. Vehicle after test 400001-USR13.

Before test

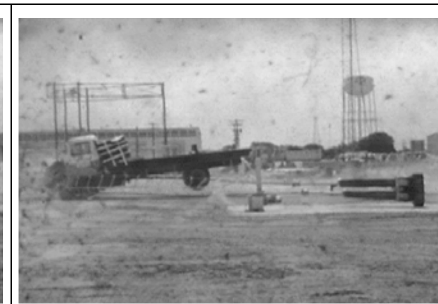
After test

Figure 16. Interior of vehicle for test 400001-USR13.

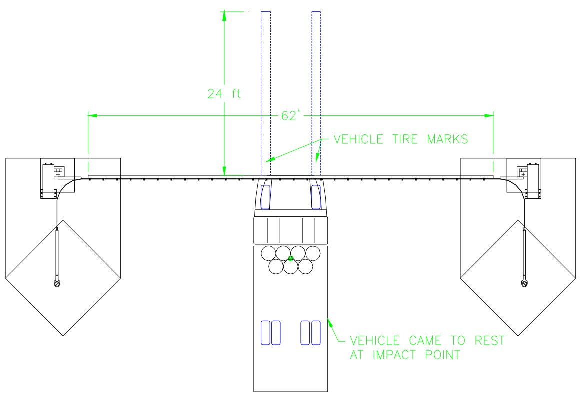
0.000 s

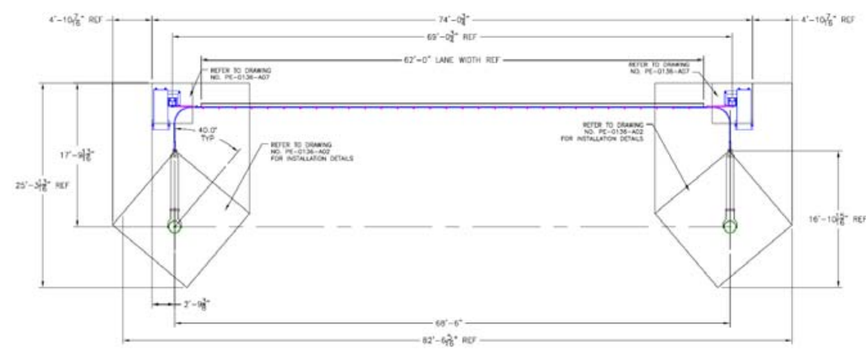
0.147 s

0.294 s



0.515 s





General Information
- Test Agency.............................. Texas Transportation Institute
- Test No. 400001-USR13
- Date 2008-07-02

Test Article
- Type.. Security Barrier
- Name .... GRAB-300 62-ft barrier net
- Installation Length (m) .... 18.9 (62 ft)
- Material or Key Elements .... Barrier net, anchor stanchions, and proprietary hydraulic shock absorbing pistons

Soil/Foundation Type .... Concrete foundation in crushed limestone, Damp @ 8.0%

Test Vehicle
- Type ....Production
- Designation ....K12 / M50
- Model.......................................1997 NaviStar 4700
- Mass (kg) single-unit flatbed truck
  - Curb ....5938 (13,090 lb)
  - Test Inertial ....6804 (15,000 lb)

Impact Conditions
- Speed (km/h)............................83.2 km/h (51.7 mi/h)
- Angle (deg)...............................90.5

Exit Conditions
- Speed (km/h)............................Stopped
- Angle (deg)...............................92.9

Occupant Risk Values
- Impact Velocity (m/s)
  - Longitudinal.......................... 6.1 (20.0 ft/s)
  - Lateral .... 0.5 (1.6 ft/s)
- Ridedown Accelerations (g's)
  - Longitudinal.......................... -17.9
  - Lateral 5.1
- Max. 0.050-s Average (g's)
  - Longitudinal.......................... -15.2
  - Lateral 3.5
  - Vertical ....

Penetration of Cargo Bed (m)
- Distance Beyond Inside
  - Edge of Barrier (m)................ 6.4 (20.9 ft)

Figure 17. Summary of results for test K12 / M50 on GRAB-300 62-ft barrier net.

SUMMARY AND CONCLUSIONS

ASSESSMENT OF TEST RESULTS

The acceptable range for impact speed for this Condition Designation K12 / M50 test was 75.0 km/h (50.0 mi/h) or above, and the actual impact speed was 83.2 km/h (51.7 mi/h). The 1997 NaviStar 4700 single-unit flatbed truck impacted the barrier at 90.5 degrees, with the centerline of the vehicle aligned with the centerline of the GRAB-300 62-ft barrier net. The GRAB-300 62-ft barrier net brought the vehicle to a complete stop. The cargo remained onboard the vehicle. The front of the cargo bed penetrated beyond the inside edge of the barrier by a distance of 6.4 m (20.9 ft).

CONCLUSIONS

As stated above, the cargo bed penetrated 6.4 m (20.9 ft) beyond the inside edge of the barrier net.

ST-STD-02.01, Revision A performance criteria limits penetration of the leading edge of the cargo bed to 1 m (3.3 ft) beyond the pre-impact, inside edge of the barrier. According to the results of the full-scale crash test, the GRAB-300 62-ft (19 m) barrier net does not meet the requirements for Condition Designation K12 in accordance March 2003 standard, *SD-STD-02.01, Revision A – Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates*.

ASTM 2656-07 provides a range of vehicle test designations and penetration levels that allow agencies to select perimeter barriers that satisfy their specific facility needs. The amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for each condition designation. According to *ASTM 2656-07*, the GRAB-300 62-ft (19 m) barrier net meets Condition Designation/Penetration Rating M50/P2, which allows penetration of 1.01 m to 7 m (3.31 to 23.0 ft).

REFERENCES

1. “Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates,” *SD-STD-02.01, Revision A*, Physical Security Division, United States Department of State, Washington, D.C., March 2003.

2. “Specification for Vehicle Crash Test of Perimeter Barriers and Gates,” *SD-STD-02.01,* Physical Security Division, United States Department of State, Washington, D.C., April 1985.

3. “Standard Test Method for Vehicle Crash Testing of Perimeter Barriers,” *ASTM Designation: F2656-07*, American Standards for Testing Materials International, West Conshohocken, PA, August 2007.

4. 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.

APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were in accordance with guidelines presented in *SD-STD-2.01, Revision A*. Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicle was instrumented with 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 are transmitted to a base station by means of an 8-channel, proportional-bandwidth, Inter-Range Instrumentation Group (IRIG), FM/FM telemetry link for digital recording. 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 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-millisecond (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.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

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

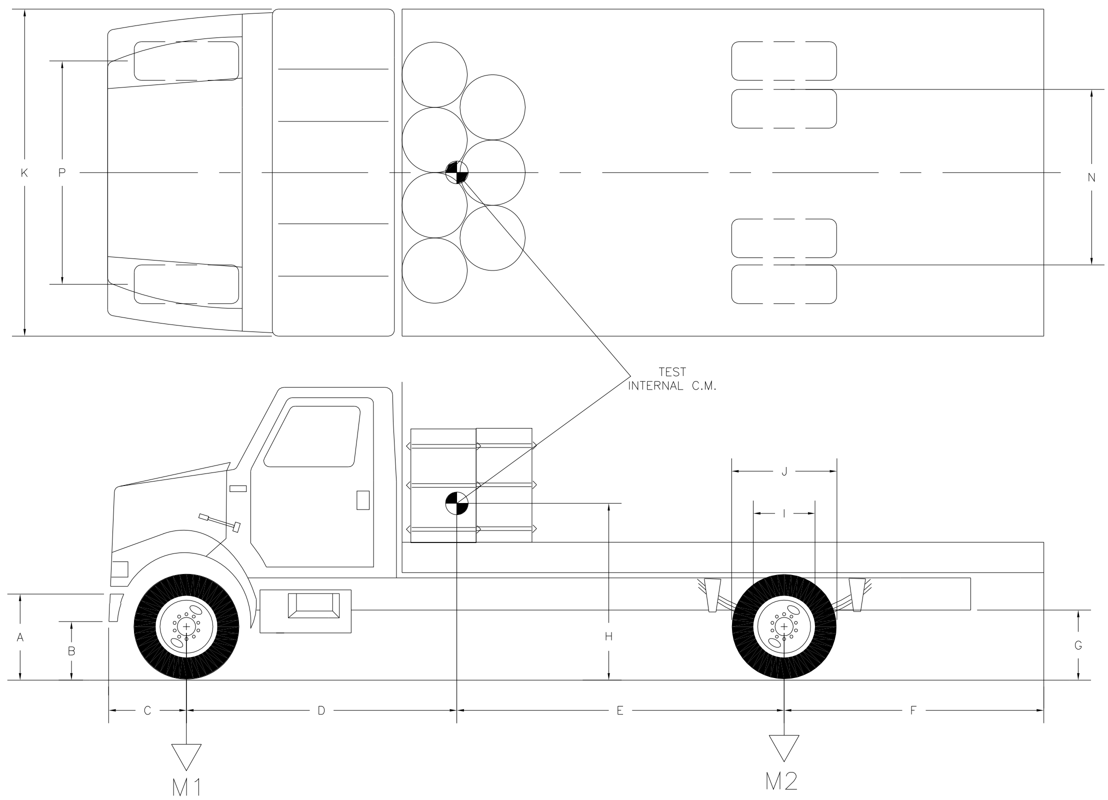
APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

Vehicle Measurements for State Department Testing

DATE: 2008-07-02 TEST NO.: 400001-USR13 VIN NO.: 1HTSCABN5VH55906

YEAR: 1997 MAKE: NaviStar MODEL: 4700

TIRE SIZE: 275/80/R22.5 ODOMETER: 177903



GEOMETRY (inches)

A	31.5	B	20.25	C	30.5	D	99.4	E	106.6	F	94.0	G	29.0
H		I	23.5	J	39.5	K	93.5	L	80.5	N	73.0		

MASS DISTRIBUTION (lb)

LF	3990	RF	3770	LR	3650	RR	3590

MASS (kg)	CURB	TEST INERTIAL
M_1	6840	7760
M_2	6250	7240
M_{Total}	13,090	15,000

Figure 18. Vehicle properties for test 400001-USR13.

APPENDIX C. SEQUENTIAL PHOTOGRAPHS

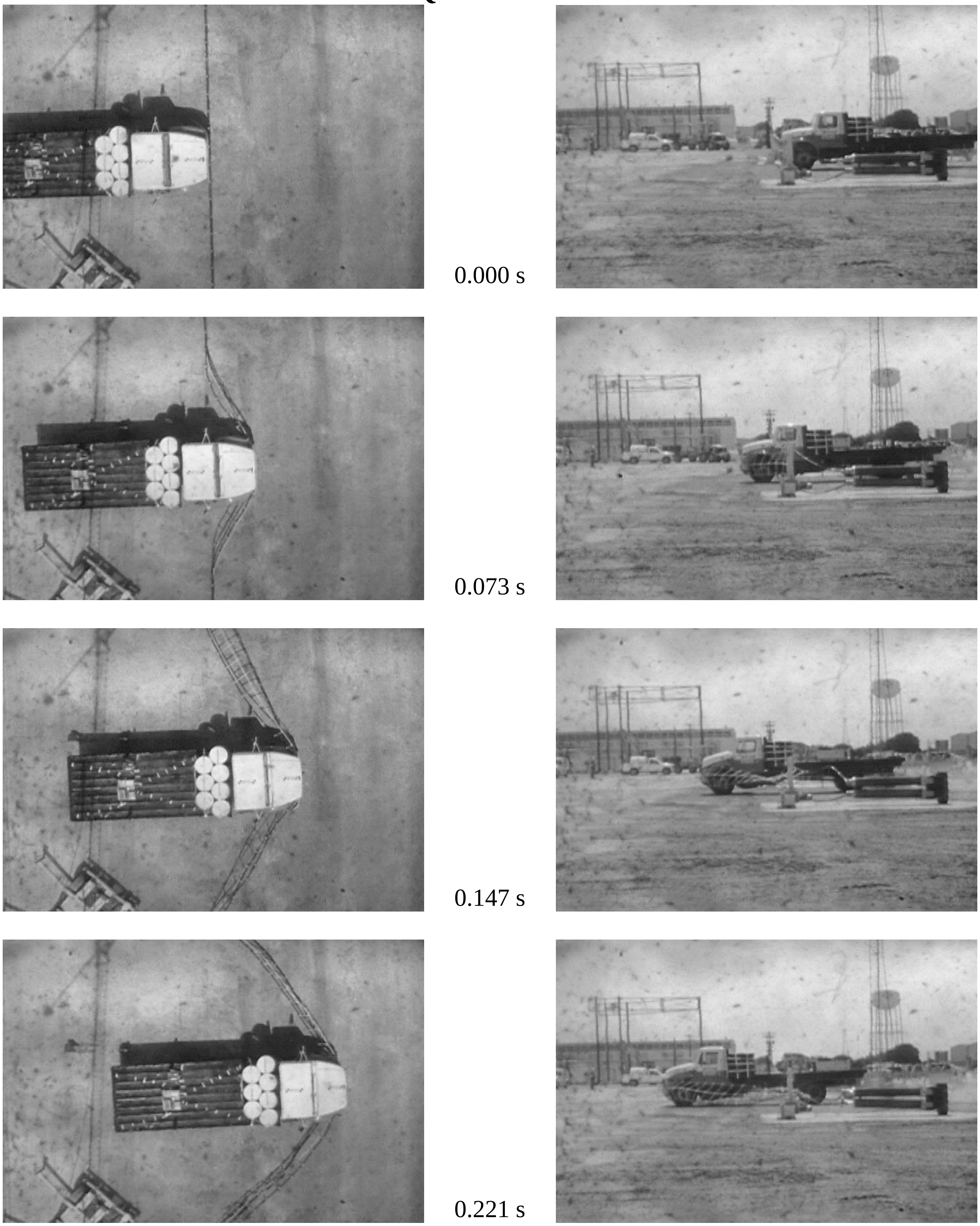
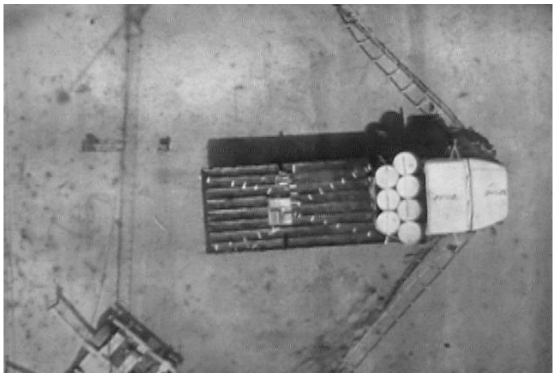
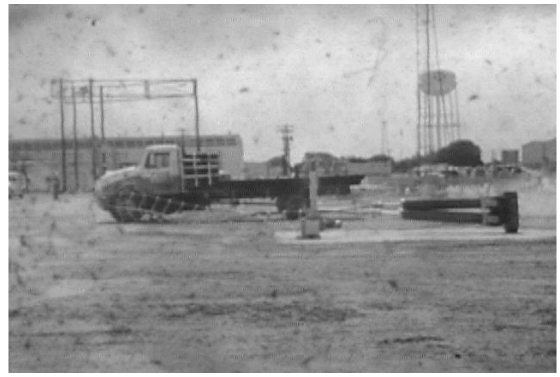
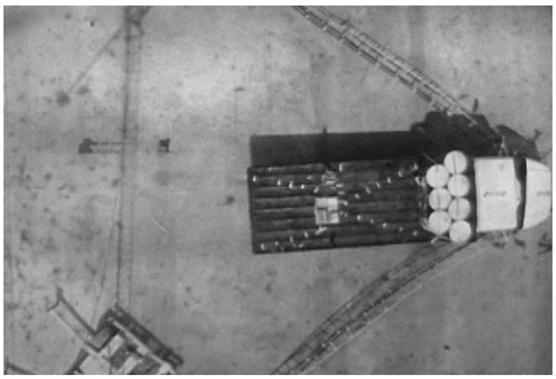


Figure 19. Sequential photographs for test 400001-USR13
(overhead and frontal views).

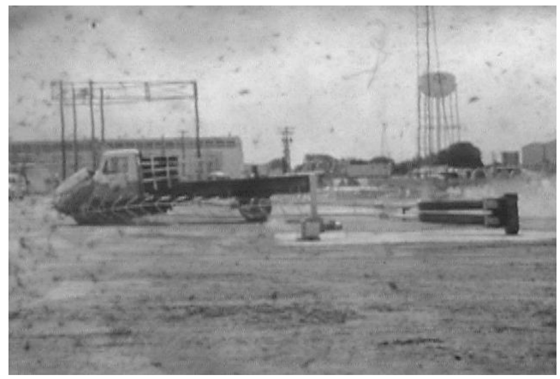


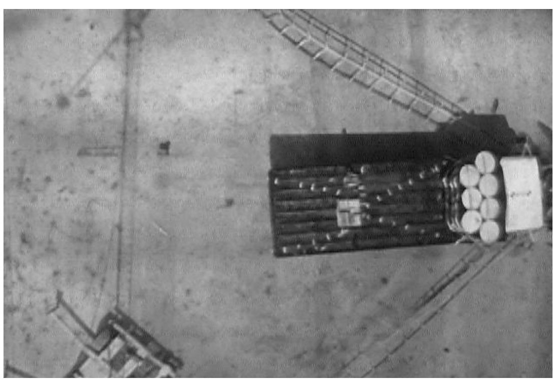
0.294 s





0.368 s





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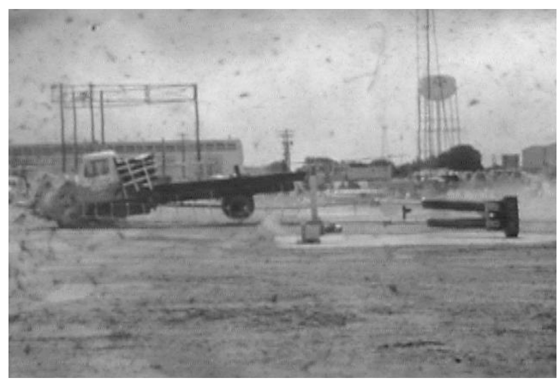

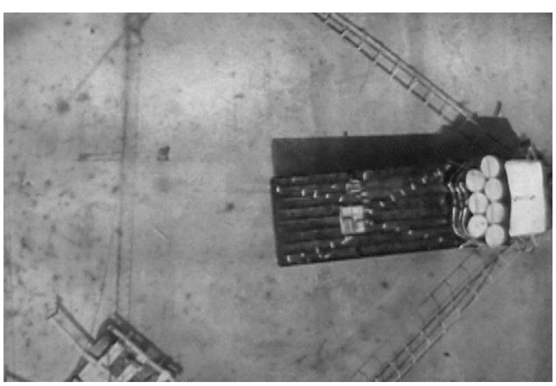

0.515 s

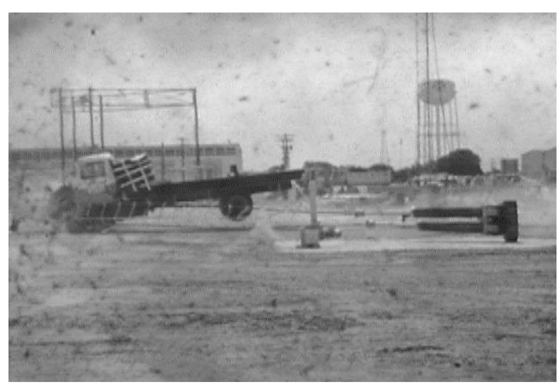

Figure 19. Sequential photographs for test 400001-USR13
(overhead and frontal views) (continued).

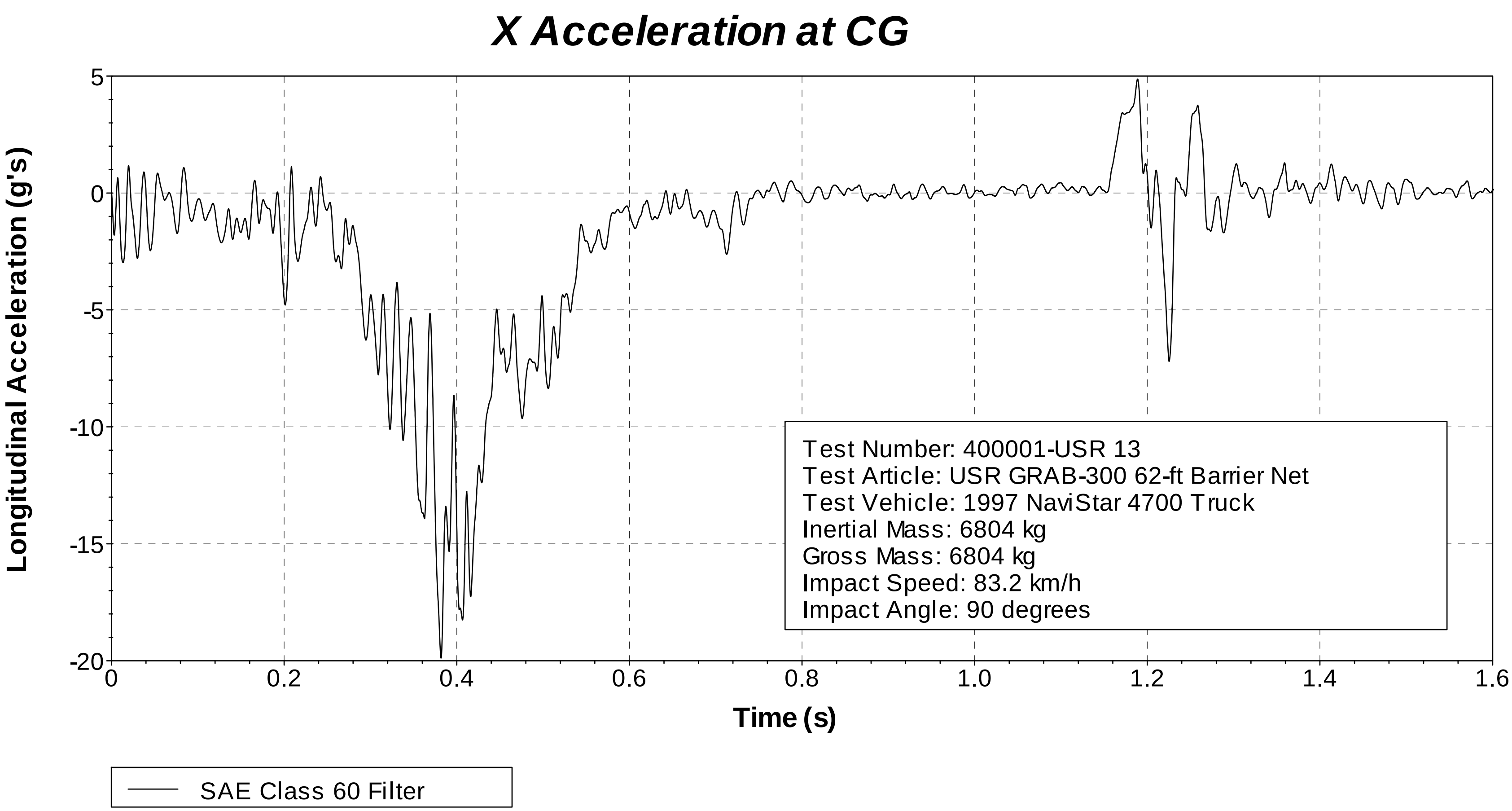

Figure 20. Vehicle longitudinal accelerometer trace for test 400001-USR13
(accelerometer located at center of gravity).

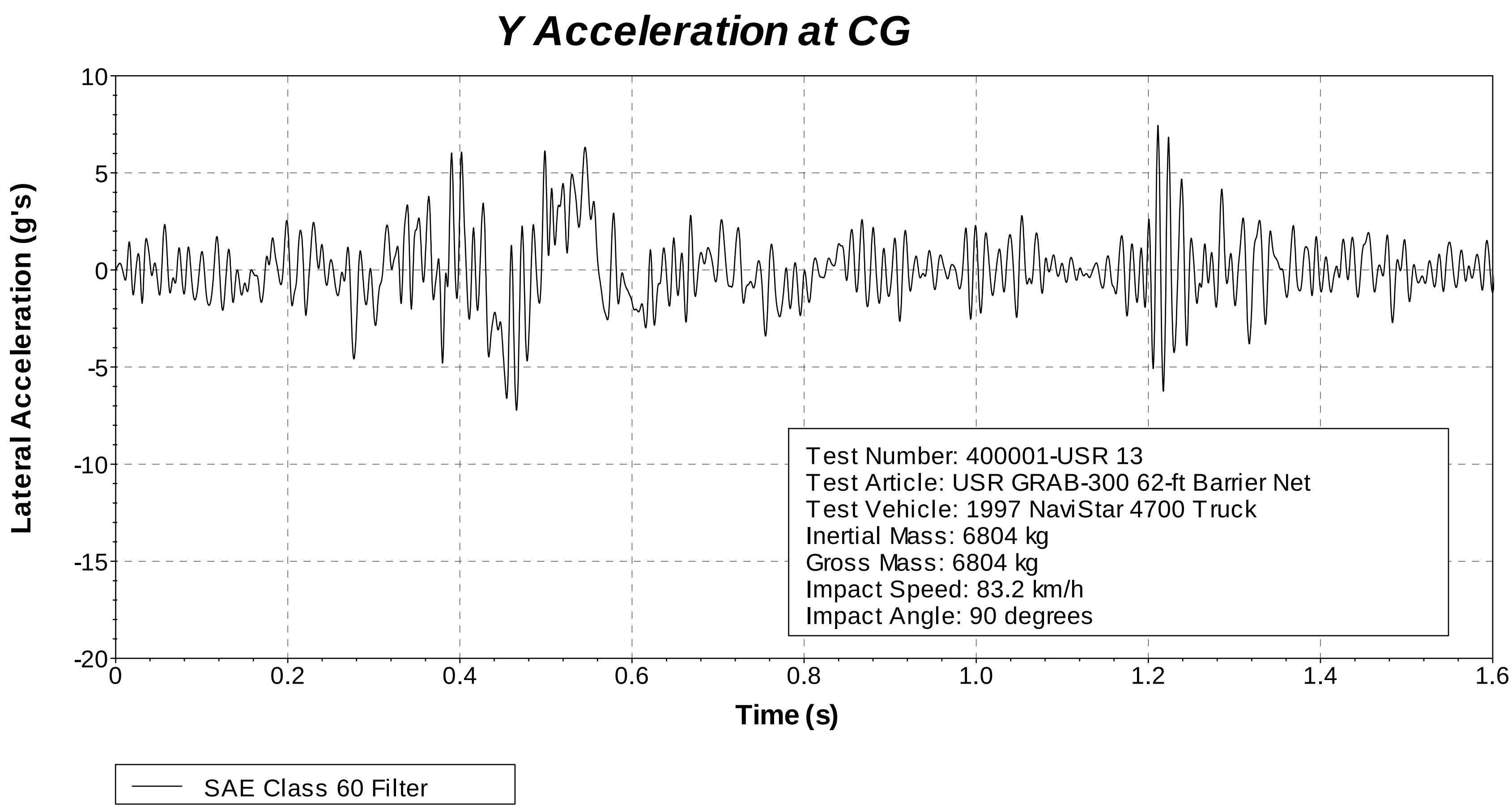

Figure 21. Vehicle lateral accelerometer trace for test 400001-USR13 (accelerometer located at center of gravity).

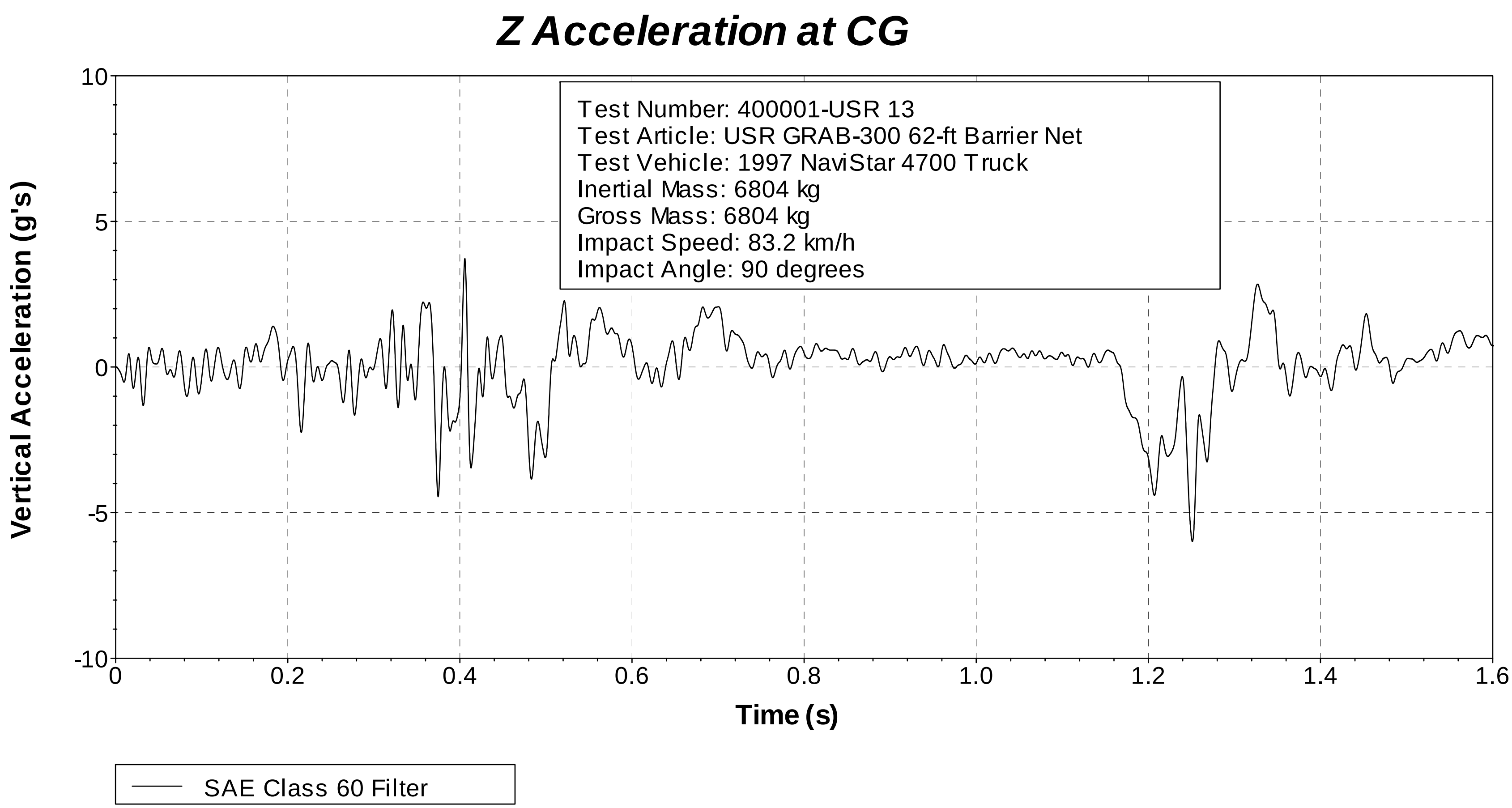

Figure 22. Vehicle vertical accelerometer trace for test 400001-USR13
(accelerometer located at center of gravity).

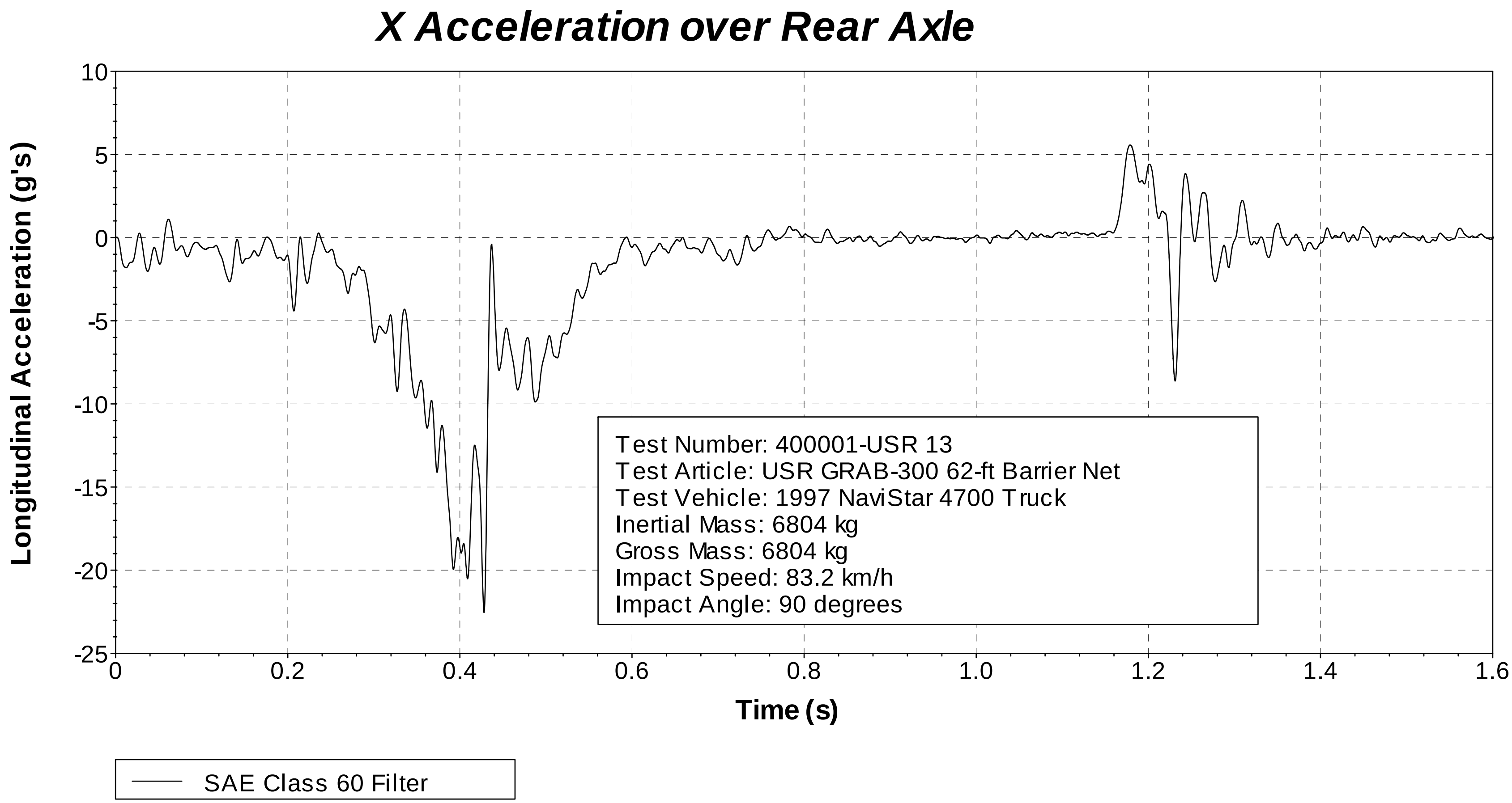

Figure 23. Vehicle longitudinal accelerometer trace for test 400001-USR13 (accelerometer located over rear axle).

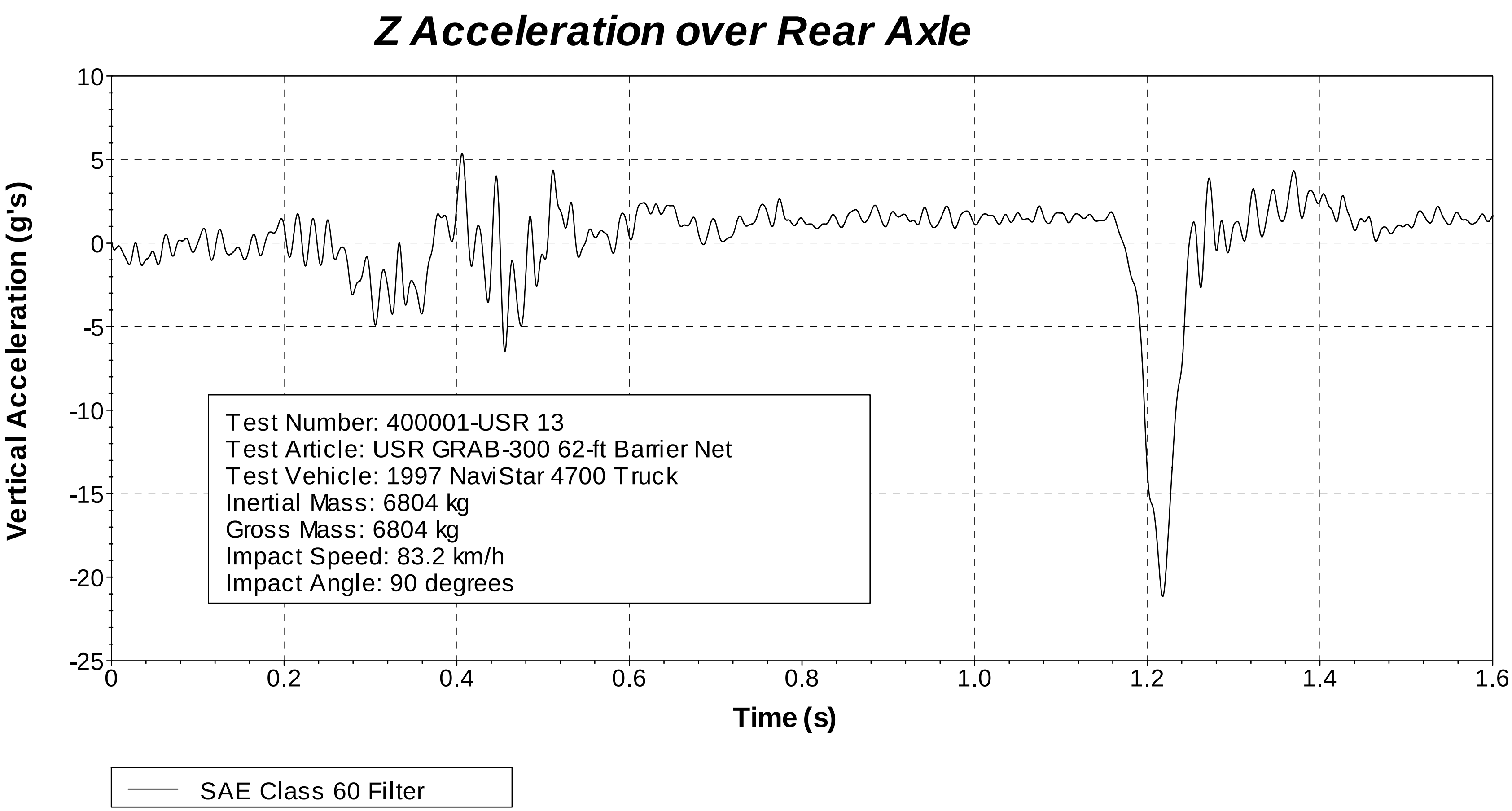

Figure 25. Vehicle vertical accelerometer trace for test 400001-USR13
(accelerometer located over rear axle).