XL Systems Technical Brief

Viper™ Connector

Physical Testing Program

The Viper weld-on connector has completed a complex physical testing program to make it the most extensively tested and analyzed large diameter connector. Developed as a true 'family of parts' product line, the entire array of OD and wall configurations of Viper were designed to identical criteria so that performance data could be justifiably extrapolated and interpolated from size to size. The majority of Viper connector physical testing has targeted the three outer diameters of 20-inch, 30-inch, and 36-inch, while wall thickness, material grade, and thread configuration have each varied throughout the test program. Finite element analysis of each Viper connector design ranging from 16-inch to 38-inch has also been completed and was used to verify the physical test data and establish performance ratings.

Major physical tests include harmonic fatigue, combined load sealability, full-scale bending, limit load, anti-rotation, and pile driving. This technical brief provides summary information for the Viper physical testing program. Detailed test data and engineering reports can be provided upon request.

Harmonic Fatigue

The Viper product line was designed for use in fatigue critical applications. Connector features such as stress relief grooves and large, full root radii on the threads dramatically improve fatigue resistance. An engineered weld neck on both the pin and the box also improves fatigue performance by shifting the weld away from the connector upset, an area of high stress concentration. This also moves the heat affected zone away from the connector and allows for a more thorough weld inspection.

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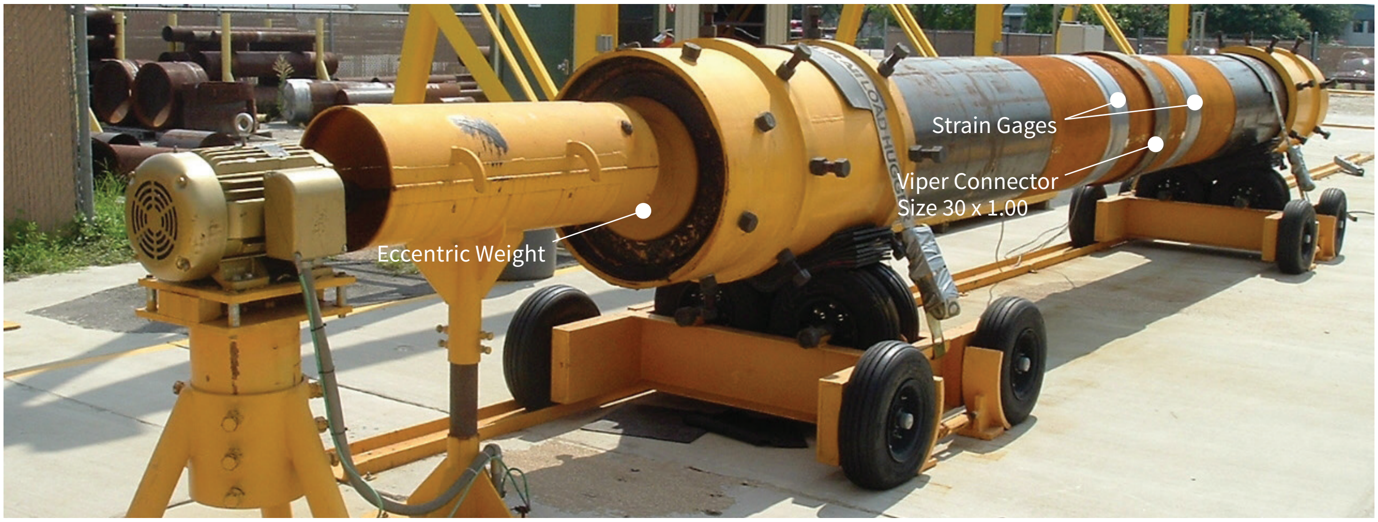


Figure 1: Harmonic Fatigue Testing Assembly

Fatigue testing focused on diameters of 20-inch, 30-inch, and 36-inch. More than fifty samples were tested utilizing a harmonic fixture (shown in Figure 1) that has become the standard for pipe and connector fatigue testing in recent years. A drive motor attached to an eccentric weight rotated the sample and induced peak circumferential stresses at the connector located at the center of the sample. Internal pressure was applied in order to detect a leak through a propagated crack in either the girth weld, the long seam weld, the pipe body, or the connector body.

Following testing, data points were plotted against the DNV RP-C203 (2012) 'B1' S-N design curve and a stress amplification factor (SAF) was generated for each individual diameter as well as the entire product line. A breakdown of tested sizes, number of samples, and SAF results are shown in Table 1.

With an overall SAF of 1.395, the Viper connector is the industry leading connector for fatigue critical applications.

Table 1

Fatigue Testing

Tested OD	Viper Connector Effective SAF	Tested Sizes	# Tested Samples
20-inch	1.299	20 x 1.00 Viper-1ST	13
30-inch	1.242	30 x 1.00 Viper-1ST	3
		30 x 1.00 Viper-1ST	9
		36 x 1.50 Viper-1ST	9
36-inch	1.467	36 x 1.50 Viper-1ST	6
		36 x 2.00 Viper-1ST	11
Overall	1.395	Total Samples	51

Combined Load Sealability

A total of ten combined load sealability tests were completed for the Viper test program. Each test combined tension and compression axial loading with internal and external pressure and exposed the connection to three complete passes around the four quadrant VME ellipse as specified in ISO 13679:2002 Series A test procedures. Two extreme tolerance samples, including a minimum and a maximum seal interference sample, were machined for each tested Viper connector size. All test procedures, including connector specimen threading, make-and-break, and combined loading, closely adhered to criteria specified in ISO 13679.

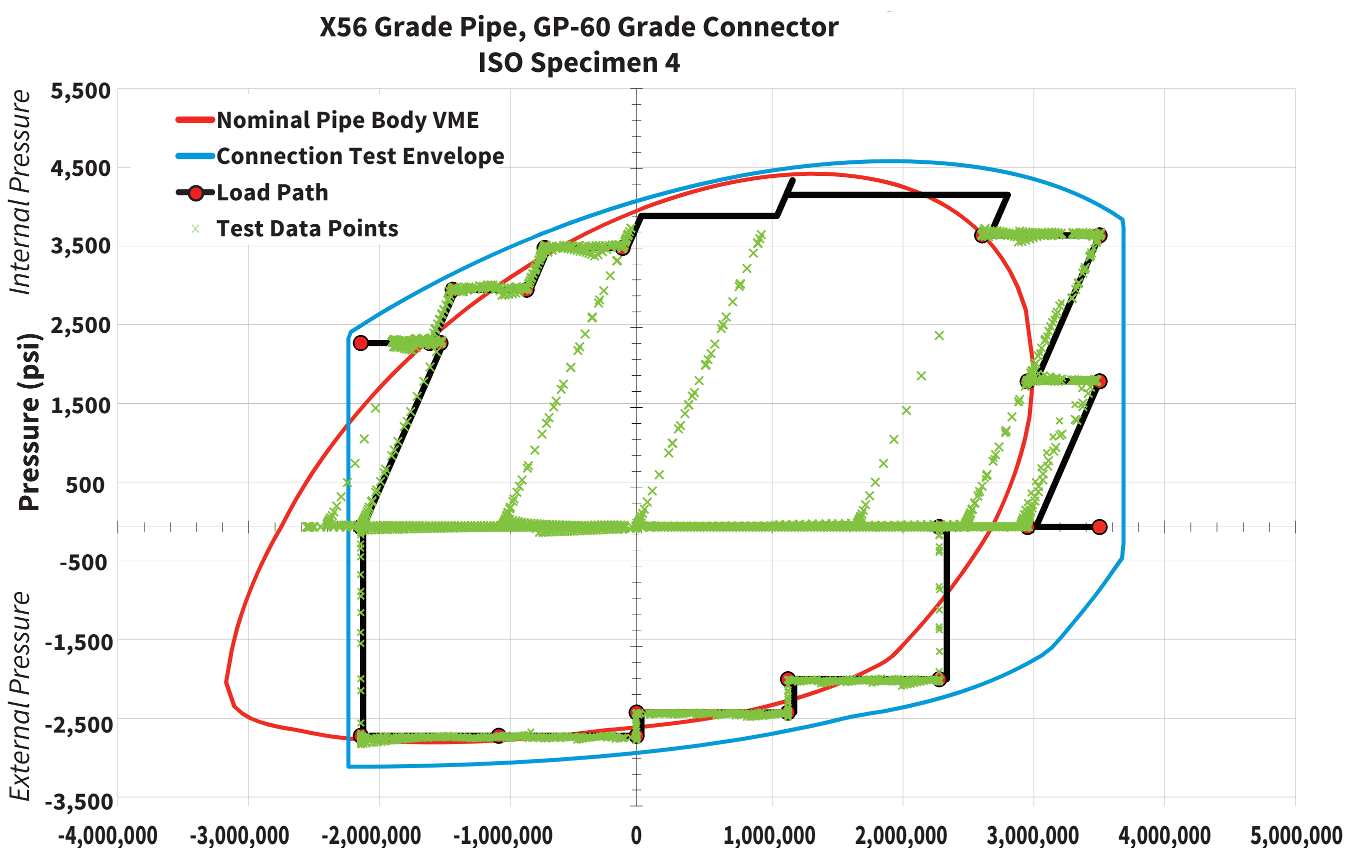
Load frame testing was completed at either XL Systems or Stress Engineering testing facilities, both located in Houston, TX. Hydraulic cylinders applied axial load while the connector was hydrostatic pressure tested both internally and externally. Each test sample was subjected to a performance envelope that targeted 95% of the connector body VME envelope. It should be noted that for most sizes, the axial tension and compression loading was limited by the capacity of the test frame and not the capacity of the connector. An example of test data from a Viper combined load sealability test is shown in Figure 2.

All Viper connectors passed the Series A testing with no detected inelastic deformation and no leaks, demonstrating the robust sealing characteristics of the Viper connector.

Combined Load and Limit Load Testing: Connector Size/Grade/Thread Type
18.625 x 0.500 GP-70 Viper-1ST
20 x 0.625 GP-70 Viper-1ST
20 x 0.625 GP-70 Viper-3ST
20 x 0.821 GP-70 Viper-1ST
30 x 1.00 GP-70 Viper-3ST

Figure 2

20 x 0.812 Viper-1ST Combined Load Test Data



Limit Load (Load to Failure)

Following combined load testing, each test specimen endured limit load testing in which loads were applied up to and beyond the yield point of the pipe body until failure occurred. Five different sized connectors were tested, and each size consisted of two specimens tested to different limit load cases:

LL Test #1: For this test, the sample was fitted with an external pressure chamber. External hydrostatic pressure was then applied and incrementally increased until failure occurred.

LL Test #2: This test was a capped-end internal pressure with tension. Prior to applying internal pressure, each sample was loaded in axial tension to 50% of pipe body capacity. At this tension, internal hydrostatic pressure was then applied and gradually increased to failure.

Each failure occurred at a point well beyond the yield of the pipe body. An example of test data from a limit load tested Viper sample is shown in Figure 3.

Figure 3

20 x 0.812 Viper-1ST Limit Load Test Data

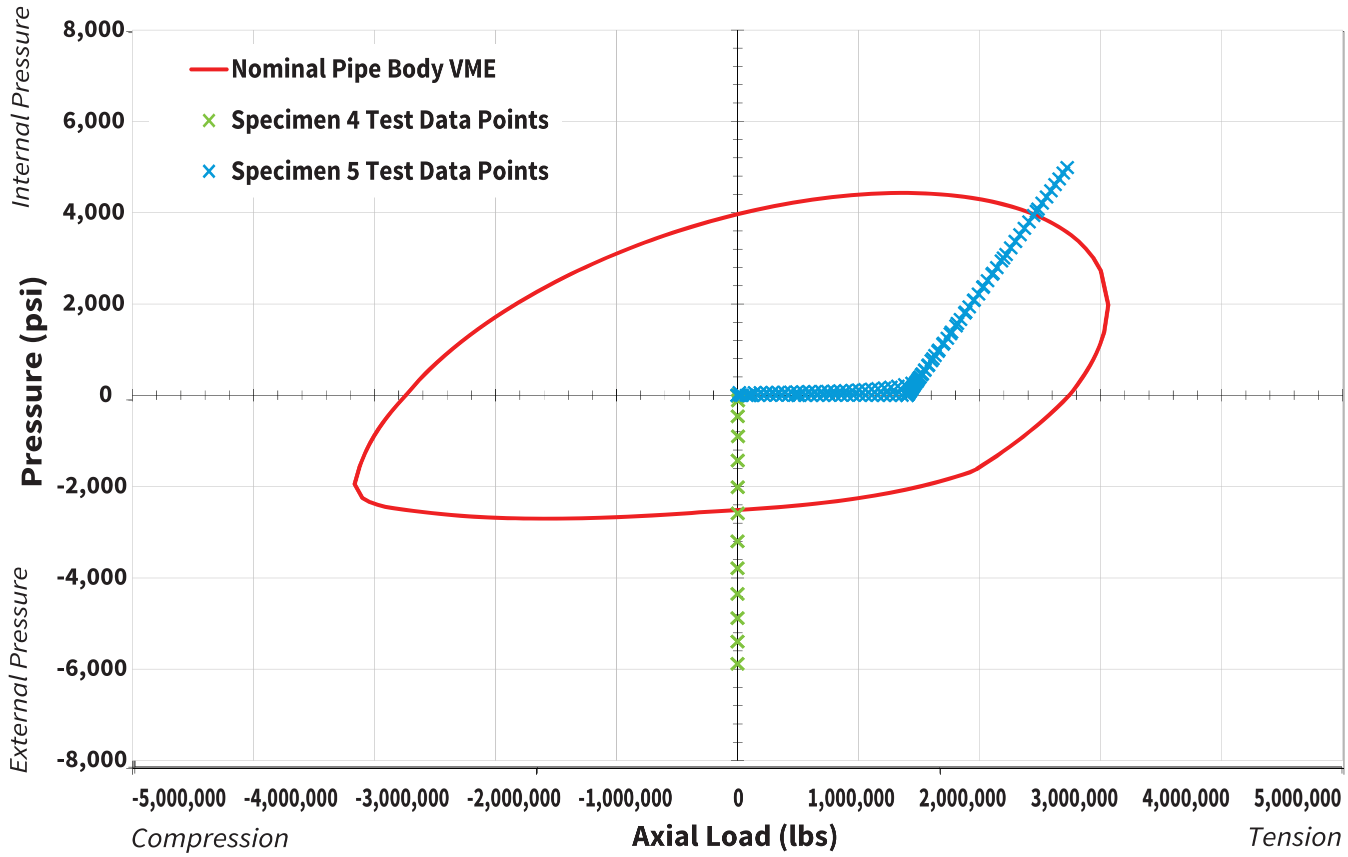


Figure 4: Four-Point Bending Frame

The Viper connector design incorporates three distinct features that highly reduce the risks of connector jump-out failure:

1. Capture feature on the OD of the pin
2. Hooked threads
3. Tapered load shoulder

In order to test the effectiveness of these features, we performed a series of full-scale bending tests. Hydraulic cylinders located on both sides of the connection appied load so that the maximum bending moment occurred in the connection located at the center of the test specimen. Table 2 shows each tested connector, the nominal bending yield strengths of both the pipe body and connector, and the maximum tested bending moment. There were no connector jump-outs or catastrophic failures for any test. Each test was stopped due to high strain gage readings in the sample, demonstrating the high bending capacities of the Viper connector. We have completed more than thirty full-scale make-and-break tests with the ViperLock anti-rotation device to confirm that the Viper connector will virtually eliminate the risks of a connector back-out and dropped string.

The ViperLock feature consists of up to four screws that are quickly and easily installed once the connector is made-up. The design of this device is such that high resistance to anti-rotation is provided through a large rotation. To back-off the connector with ViperLock screws installed, high torque must be applied continuously through a large rotation before the connector threads disengage. Figure 5 displays typical connector break-out characteristics with different anti-rotation screw configurations for the Viper connector.

Table 2

Bend Testing

Connector	Nominal Bending Yield [ft-kips]		Max Tested BendMoment [ft.kips]
	Pipe	Connector	
18.625 x 0.500 Viper-1ST	586	648	2,238
20 x 0.625 Viper-1ST	834	925	1,718
20 x 0.625 Viper-3ST	834	925	2,251
20 x 0.812 Viper-1ST	1,053	1,147	
30 x 1.00 Viper-3ST	2,983	4,685	
36 x 1.50 Viper-1ST	6,283	9,247	

A variety of make-and-break tests were performed in order to verify the torque resistance of ViperLock. Test variables included the number of screws, connector size, and thread configurations.

For ViperLock anti-rotation data comparison, the break-out torque was measured as a percentage of the actual make-up torque for each test. Table 3, grouped by the number of installed anti-rotation screws, displays the average break-out torques with respect to make-up torques for fully made-up connectors.

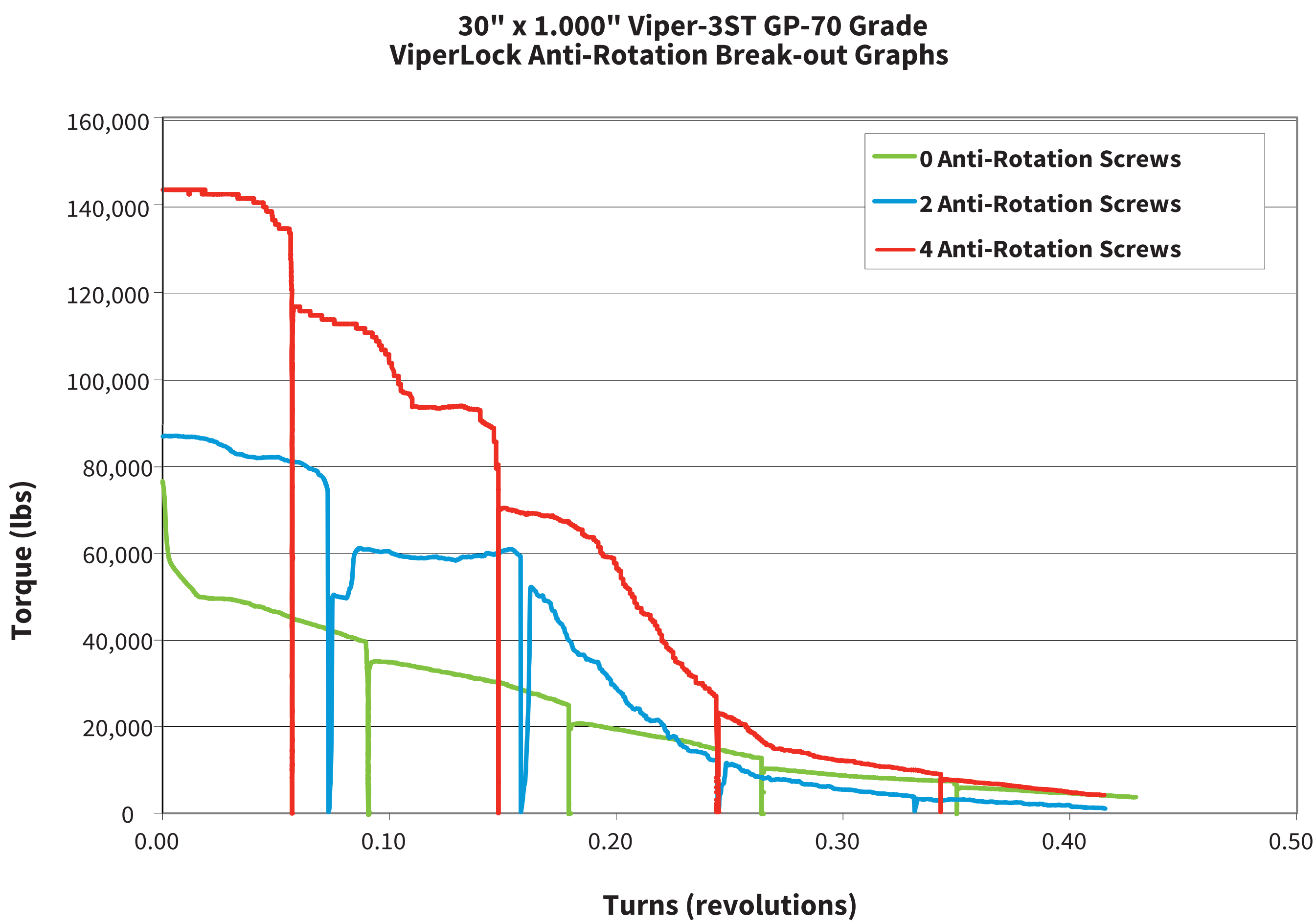
Table 3

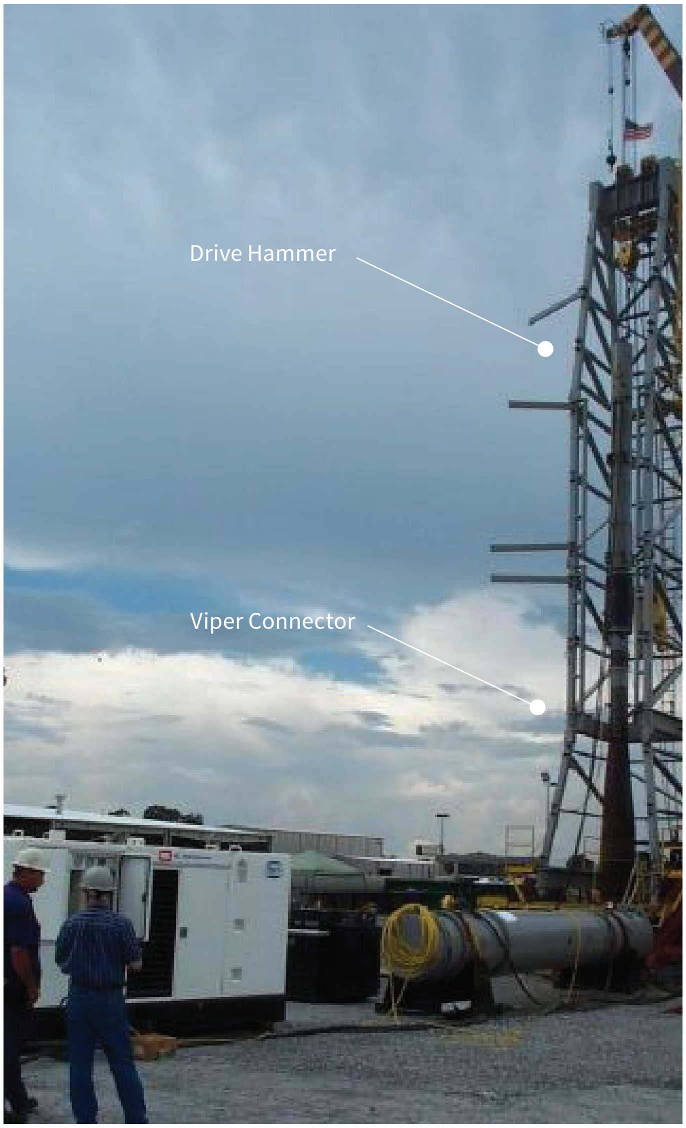
ViperLock Anti-Rotation Testing

Number of Anti-Rotation Screws	Average Make-up Torque [ft-lbs]	Average Break-up Torque [ft-lbs]	Average Break-out Torque as a Percentage of Make-up Torque
1 Screw	65,649	74,969	114.2%
2 Screws	54,028	75,769	140.2%
3 Screws	56,931	114,26	200,6%

Figure 5

ViperLock Break-out Torque-Turn Comparison





ViperLock test results have consistently shown excellent performance with break-out torque significantly higher than make-up torque.

Full scale pile driving tests have been performed on the 20-inch and 30-inch Viper connector designs. Each test was completed at the BJ Services facility in Broussard, Louisiana. An IHC S-70 Hydrohammer was used for the 20-inch test and both an IHC S-90 and an S-150 Hydrohammer were used to test the 30-inch samples.

The Viper drive sub provided the interface between the driving hammer and the Viper box connector. This drive sub is made up of three pre-assembled components: the driving pin, the guide sleeve, and the stabbing cone. The purpose of testing was not only to determine the driveability of the Viper connector but to also verify the driveability of the Viper drive sub.

Each test was worst case in that the pile was at refusal for the duration of the test. The pipe body above and below the test connector was instrumented with strain gages attached to a high-speed data acquisition system. This system constantly measured the peak tension and compression stresses in the pipe body during driving. Two ViperLock anti-rotation screws were installed on each sample prior to testing.

The hammer energy was gradually increased to the desired pipe body stress for each test. Table 4 shows details for each tested connector, which includes the hammer type, number of hammer blows, and the average peak pipe body stress.

Each Viper connector successfully endured the pile driving loading with no adverse connector behavior for any test. Following testing, visual inspections revealed no signs of connector or drive sub.

Table 4

Pile Driving Testing

Connector	Hammer Type	Average Peak Stress [ksl]	Total Blows
20 x 0.625 Viper-1ST	S-70	43.0	10,025
	S-70	36.5	10,008
30 x 1.00 Viper-3ST	S-90	32.4	10,000
	S-150	39.6	8,000

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