Dynamic Properties of Stay Cables on the Penobscot Narrows Bridge

PUBLICATION NO. FHWA-HRT-14-067

SEPTEMBER 2014

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

FOREWORD

Cable-stayed bridges have become the form of choice over the past several decades for bridges in the medium- to long-span range. In some cases, serviceability problems involving large amplitude vibrations of stay cables under certain wind and wind-rain conditions have been observed. This study was conducted in response to State transportation departments' requests to develop improved design guidance for mitigation of excessive cable vibrations on cable-stayed bridges. The study included full scale forced vibration tests on the cables of a new cable-stayed bridge to characterize cable dynamic behavior and evaluate effectiveness of mitigation details such as dampers. The results of this study will be made available to the Post-Tensioning Institute's DC-45 Cable-Stayed Bridge Committee for consideration during their periodic updates of the Guide Specification, *Recommendations for Stay Cable Design, Testing, and Installation*.

This report will be of interest to bridge engineers, wind engineers, and consultants involved in the design of cable-stayed bridges. It is the second in a series of reports addressing the subject of aerodynamic stability of bridge stay cables that will be published in the coming months.

Jorge E. Pagán-Ortiz
Director, Office of Infrastructure
Research and Development

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-HRT-14-067	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Dynamic Properties of Stay Cables on the Penobscot Narrows Bridge		5. Report Date September 2014
		6. Performing Organization Code
7. Author(s) Harold R. Bosch and James R. Pagenkopf		8. Performing Organization Report No.
9. Performing Organization Name and Address Genex Systems, LLC 2 Eaton Street, Suite 603 Hampton, VA 23669		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTFH61-07-D-00034
12. Sponsoring Agency Name and Address Office of Infrastructure R&D Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered Laboratory Report December 2006 to December 2010
		14. Sponsoring Agency Code HRDI-50
15. Supplementary Notes The Contracting Officer's Technical Representative (COTR): Harold R. Bosch (HRDI-50)		

16. Abstract

Cable-stayed bridges have been recognized as the most efficient and cost effective structural form for medium to long span bridges over the past several decades. With their widespread use, cases of serviceability problems associated with large amplitude vibration of stay cables have been reported. Stay cables are laterally flexible structural members with very low inherent damping and thus are highly susceptible to environmental conditions such as wind and rain/wind combination.

Recognition of these problems led to the incorporation of different types of mitigation measures on many cable-stayed bridges around the world. These measures included surface modifications, cable crossties and external dampers. Modification of cable surfaces has been widely accepted as a means to mitigate rain/wind vibrations. Recent studies have firmly established the formation of a water rivulet along the upper side of the stay and its interaction with wind flow as the main cause of rain/wind vibrations. Appropriate modification of exterior cable surface effectively disrupts the formation of a water rivulet.

The objective of this study was to supplement the existing knowledge base on some of the outstanding issues of stay cable vibrations and develop technical recommendations that may be incorporated into design guidelines. Specifically, this project focused on identification of in-situ cable dynamic properties and performance of external viscous dampers on the Penobscot Narrows Bridge. Forced vibration tests were conducted on the stay cables during the latter stages of construction, just prior to and following installation of viscous dampers. Cable properties, such as vibration frequencies and damping levels, were established and compared with design targets.

17. Key Words Cable-Stayed Bridges, Cables, Vibrations, Wind, Rain, Dampers, Hazard Mitigation		18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, VA 22161 http://www.ntis.gov	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 179	22. Price

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

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

A_n Amplitude of in-plane displacement due to the *n*th mode of vibration.
c Viscous damping coefficient per unit length.
D Diameter of cable pipe.
H Pretension of string or cable.
L Length of string or cable.
$L_{1,2}$ Chord length distance along cable to box 1 or 2.
m Cable mass per unit length.
Sc Non-dimensional Scruton number.
T_{dn} Damped natural period of the *n*th mode of vibration.
t Time.
U Wind speed.
U_{ave} Average wind speed.
U_{eq} Normalized equivalent wind speed.
u Time-dependent part of transverse in-plane displacement due to vibration.
w Transverse in-plane displacement due to vibration.
x Distance.
α_n Phase angle of time-dependent part of transverse in-plane displacement due to *n*th mode of vibration.
β Inclination angle of the cable from horizontal.
δ Non-dimensional logarithmic decrement ratio.
ζ_n Non-dimensional damping ratio of the *n*th mode of vibration.
θ Angle of the wind direction normal to the vertical plane of the cable.
θ_{ave} Average angle of the wind direction normal to the vertical plane of the cable.
ρ Mass density of air.
ω_n Natural angular frequency of the *n*th mode of vibration.
ω_{dn} Damped natural angular frequency of the *n*th mode of vibration.

CHAPTER 1. INTRODUCTION

Of particular importance is the dynamic behavior of the deck's supporting cables for cable-stayed bridges. These structurally critical components are often excited into several vibration modes by the ambient wind conditions. Study of the damped behavior of cables is fundamental to ensure a safe and structurally sound system.

Stay cable vibration up to amplitudes of 6.5 ft (2 m) under conditions of moderate wind, sometimes in conjunction with light rain, has been observed with increasing frequency in recent years.(1) This problem is not new and has been studied extensively over a period of several decades; however, gaps remain in our understanding of the problem. With a growing inventory of cable-stayed bridges, we have experienced a significant increase in reports of large amplitude cable vibrations. Some structures have been retrofitted to mitigate these vibrations. Cable-stayed bridges under design and/or construction are currently incorporating dampers, cross-ties, and/or aerodynamic surface treatments into the cable system. While retrofits have been deployed to fix existing problems and mitigation details have been evolving for new structural designs, few full-scale investigations have been conducted to either establish the detailed site/structure conditions or evaluate the effectiveness of mitigation measures. To fill the information gap, the Federal Highway Administration (FHWA) is performing long term monitoring of cables on existing cable-stayed bridges and is conducting vibration tests on cables during various stages of construction on new bridges.

The Penobscot Narrows Bridge is a cable-stay bridge connecting the town of Prospect and Verona Island in Maine, which opened to the public on December 30, 2006. During construction, the Maine Department of Transportation (MaineDOT) and the FHWA agreed to test the longer cable-stays to determine their mode frequencies and damping ratio values, both before and after the installation of dampers. Figure 1 below shows the bridge next to the suspension bridge it replaces, while the inset shows a close up view of the cable-stays threading the pylon.

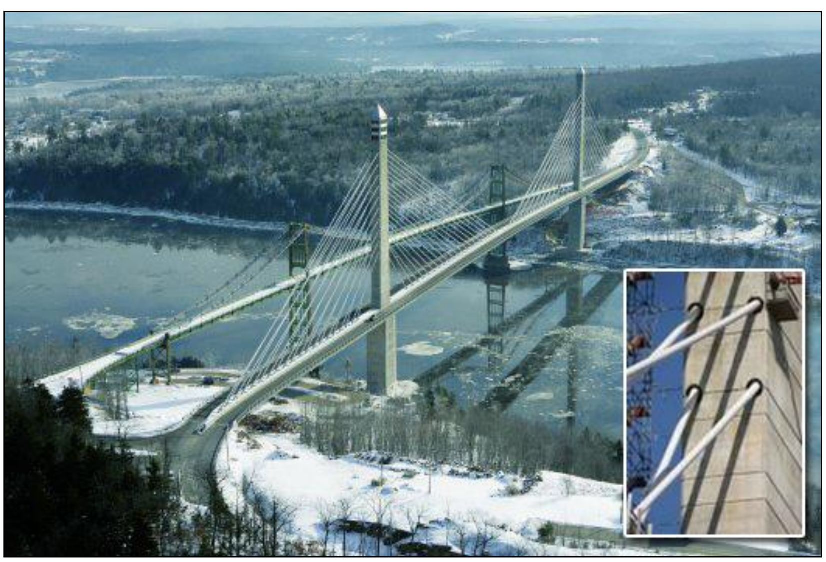


Figure 1. Photo. The Penobscot Narrows Bridge.

Identical dampers were installed on each cable-stay, with a damping value chosen based on specifications determined by the Figg Engineering Group, the bridge designers. These short-term tests would serve to establish and benchmark cable properties such as vibration frequencies and inherent damping of each stay cable as well as the additional damping provided by viscous dampers installed on each cable. Information obtained in this study can be used not only to assess if design objectives have been met, but also to catalog representative cable properties and for comparison with future measurements to determine if performance has changed perhaps requiring inspection and/or repairs.

CHAPTER 2. THEORETICAL BACKGROUND

VIBRATION OF TAUT STRING WITH DISTRIBUTED DAMPING

The transverse vibration of a taut string with uniformly distributed viscous damping can be described by:

$$m\frac{\partial^2 w}{\partial t^2} + c\frac{\partial w}{\partial t} = H\frac{\partial^2 w}{\partial x^2}$$

Figure 2. Equation. Equation of motion (EOM) for a string.

where $w(x,t)$ = transverse displacement, m = mass density per unit length, c = viscous coefficient per unit length, and H = pretension of the string.(2) For a string of length L, fixed at both ends, $w(x,t)$ can be approximated by a finite degrees of freedom (DOF) system:

$$w(x,t) \cong \sum_{n=1}^{N} \sin\frac{n\pi x}{L} u_n(t)$$

Figure 3. Equation. General solution of EOM.

where the sinusoidal spatial functions $\sin(n\pi x/L)$ are the normal modes for a string where $c = 0$. Substituting $w(x,t)$ into the equation in figure 2 and rearranging yields the following:

$$\ddot{u}_n(t) + 2\zeta_n\omega_n\dot{u}_n + \omega_n^2 u_n = 0 \text{ where } \omega_n = \sqrt{\frac{H}{m}}\frac{n\pi}{L} \text{ and } \zeta_n = \frac{c}{2m\omega_n}$$

Figure 4. Equation. EOM for a string.

for $n = 1, 2, \ldots, N$ (no sum on n). The equation in figure 4 represents the equation of motion for the nth mode vibration of the string, ω_n and ζ_n, respectively, denote the corresponding circular natural frequency and damping ratio of the mode. It is to be noted that the equations for this N-DOF system are fully decoupled and each mode can be handled separately. Using the standard solution technique for a single DOF system, a general solution to the equation in figure 4 follows:

$$u_n(t) = A_n e^{-\zeta_n\omega_n t}\cos(\omega_{dn}t - \alpha_n)$$

Figure 5. Equation. General solution to EOM.

where A_n and α_n are the amplitude and phase angle that are dependent on the initial conditions of the vibration, and the following:

$$\omega_{dn} \equiv \omega_n\sqrt{1-\zeta_n^2}$$

Figure 6. Equation. Damped natural frequency.

is the damped natural frequency.(3)

DETERMINATION OF DAMPING RATIOS

The damping ratio, or the fraction of critical damping, ζ_n , can be estimated experimentally. In the logarithmic decrement method, the damping ratio is found by measuring the amplitude of two consecutive peaks of damped free vibration and computing their ratio.[(3)] It can be shown that the ratio between the two consecutive peaks of the vibration is given by the following expression:

$$\frac{u_n(t)}{u_n(t+T_{dn})} = \exp(\zeta_n \omega_n T_{dn}) = \exp(\frac{2\pi\zeta_n}{\sqrt{1-\zeta_n^2}})$$

Figure 7. Equation. Ratio of two consecutive peaks.

where $T_{dn} = 2\pi / \omega_{dn}$ is the damped natural period of the *n*th mode. Selecting two consecutive peaks u_i and u_{i+1} and taking the natural logarithm of the equation in figure 7, one finds the expression for the logarithmic decrement defined by:

$$\delta \equiv \ln\left(\frac{u_i}{u_{i+1}}\right) = \frac{2\pi\zeta_n}{\sqrt{1-\zeta_n^2}}$$

Figure 8. Equation. Logarithmic decrement.

For lightly damped systems ($\zeta_n < 0.2$), the equation in figure 8 can be simplified to $\delta \cong 2\pi\zeta_n$. This simplification is valid for inherent damping ratios of most stay cables, which are almost always below 0.01. From this simplification and the equation in figure 8, the damping ratio can be obtained by:

$$\zeta_n \cong \left(\frac{1}{2\pi}\right)\ln\left(\frac{u_i}{u_{i+1}}\right)$$

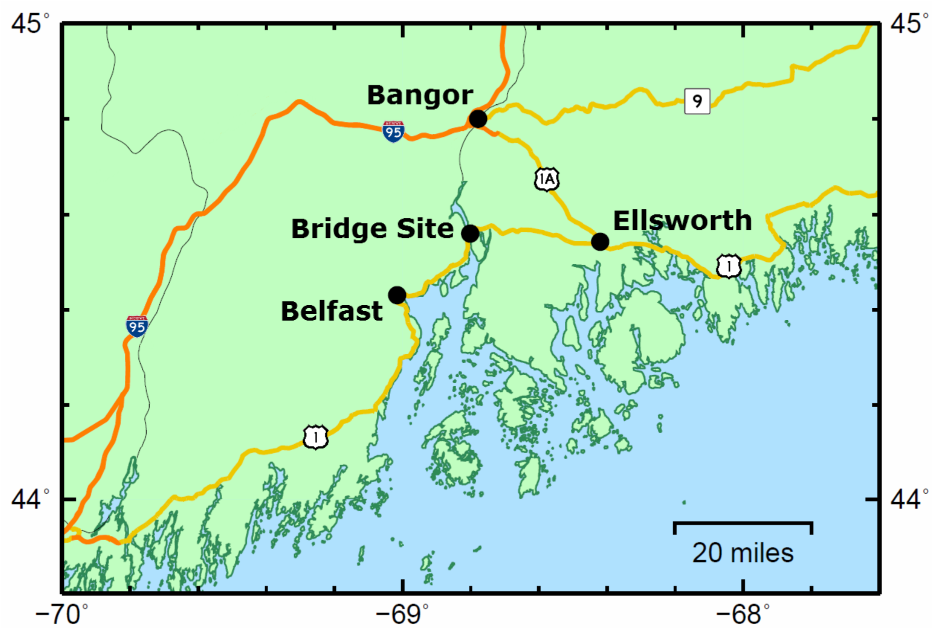
Figure 9. Equation. Damping ratio.

The equation in figure 9 is valid for both displacement and acceleration decay curves for lightly damped systems.

CHAPTER 3. EXPERIMENTAL PROCEDURES

THE TEST BRIDGE

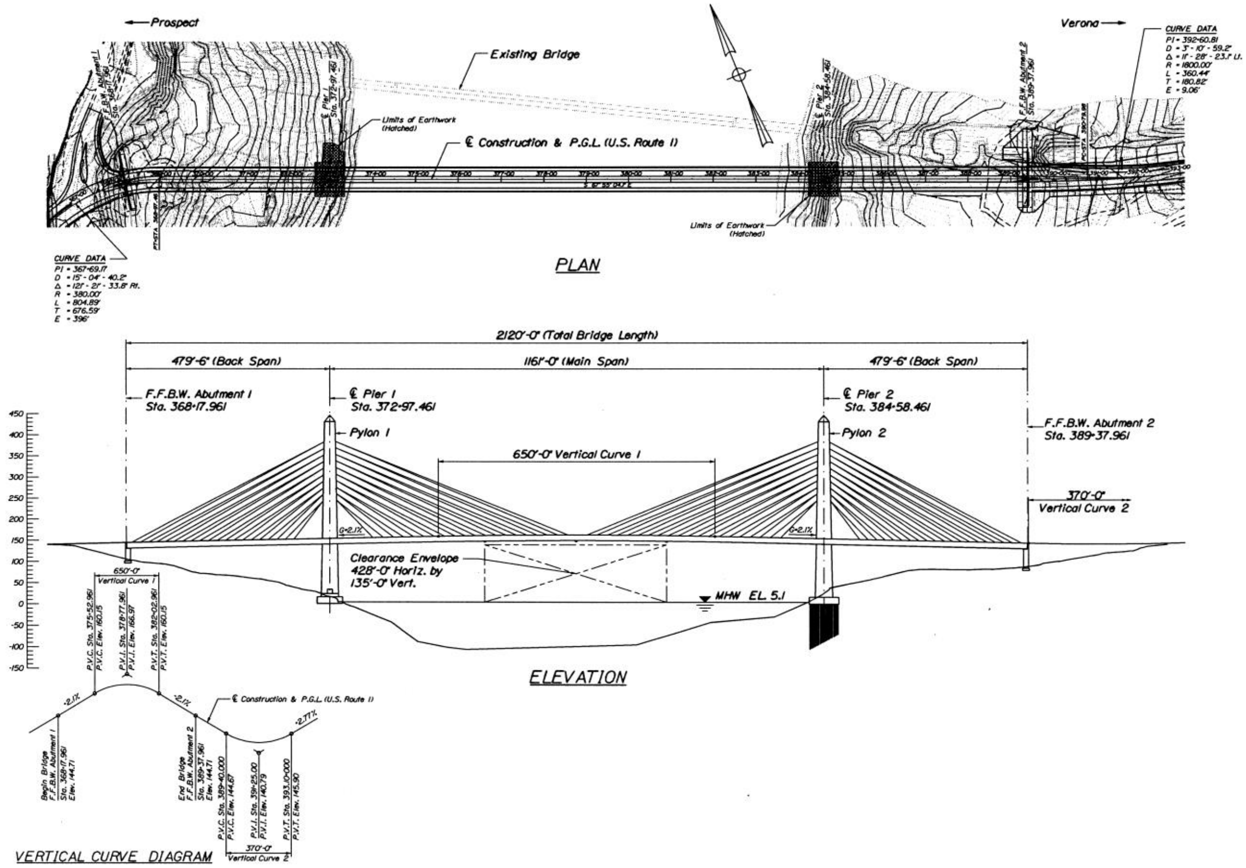
The Penobscot Narrows Bridge is a 2,120 ft (646 m) long cable-stayed bridge that carries U.S. Route 1 over the Penobscot River connecting Verona Island to Prospect in Maine. A map of the bridge site and the surrounding area is provided below in figure 10. This cast-in-place concrete structure was an emergency replacement for the Waldo-Hancock Bridge, an aging steel suspension bridge built at the same site in 1931. The “owner facilitated design/build project” spanned a mere 42 months from conception to completion; construction was started in 2004 and the bridge was opened to traffic on December 30, 2006.



1 mi = 1.61 km

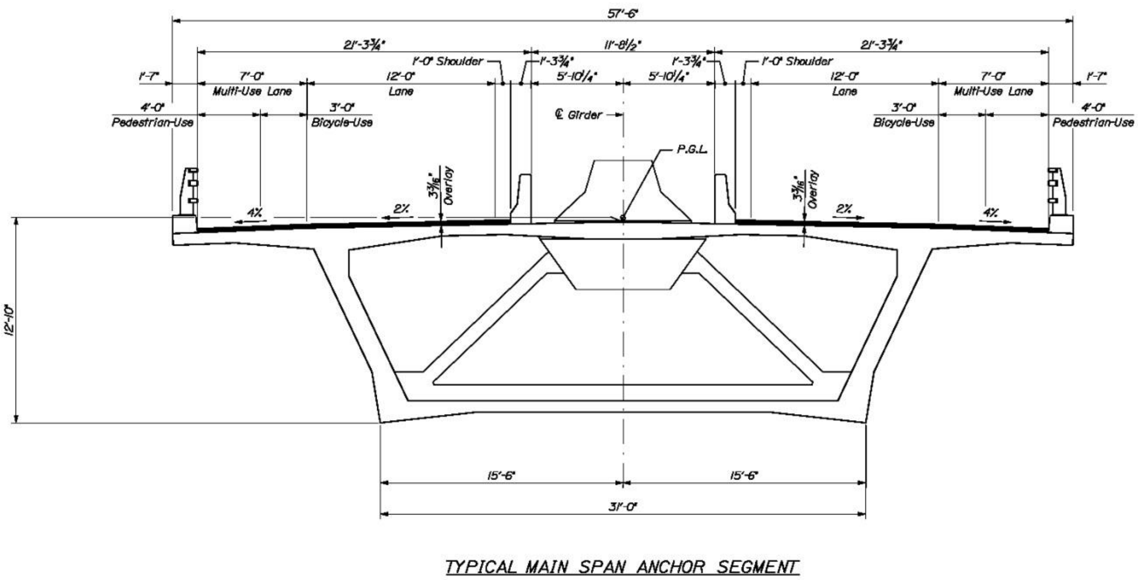
Figure 10. Illustration. Map of the Penobscot Narrows Bridge site.

The bridge, with its east-southeast orientation, has a main span of 1,161 ft (354 m) and side spans of 479.5 ft (146.2 m) each, as shown in figure 11. The span cross section is a single trapezoidal concrete box that is 12.8 ft (3.9 m) deep with a 57.5-ft (17.5-m)-wide deck. The deck configuration, as shown in figure 12, consists of a roadway with one 12-ft (3.65-m) lane in each traffic direction flanked by a 7-ft (2.1-m) shoulder on the right and 1-ft (0.3-m) shoulder on the left. A raised 14.3-ft (4.4-m) median, containing the cable anchor blocks, separates the two travel lanes.



Source: MaineDOT.

Figure 11. Illustration. Bridge plan and elevation.



1 ft = 0.305 m, 1 inch = 2.54 cm

Source: MaineDOT.

Figure 12. Illustration. Bridge main span cross-section.

The bridge spans are supported by two 430-ft (131.1-m) tall concrete pylons, each containing 40 stay cables. The pylons are tapered with height in the direction of traffic and are constant width transverse to the direction of traffic. A unique feature of the west pylon, Pier 1, is the public observatory, accessible by elevator, located at its top. Clad in glass, the bridge observatory is the only such feature in the United States and the highest public bridge observatory in the world. A photo of the observatory is shown in figure 13.

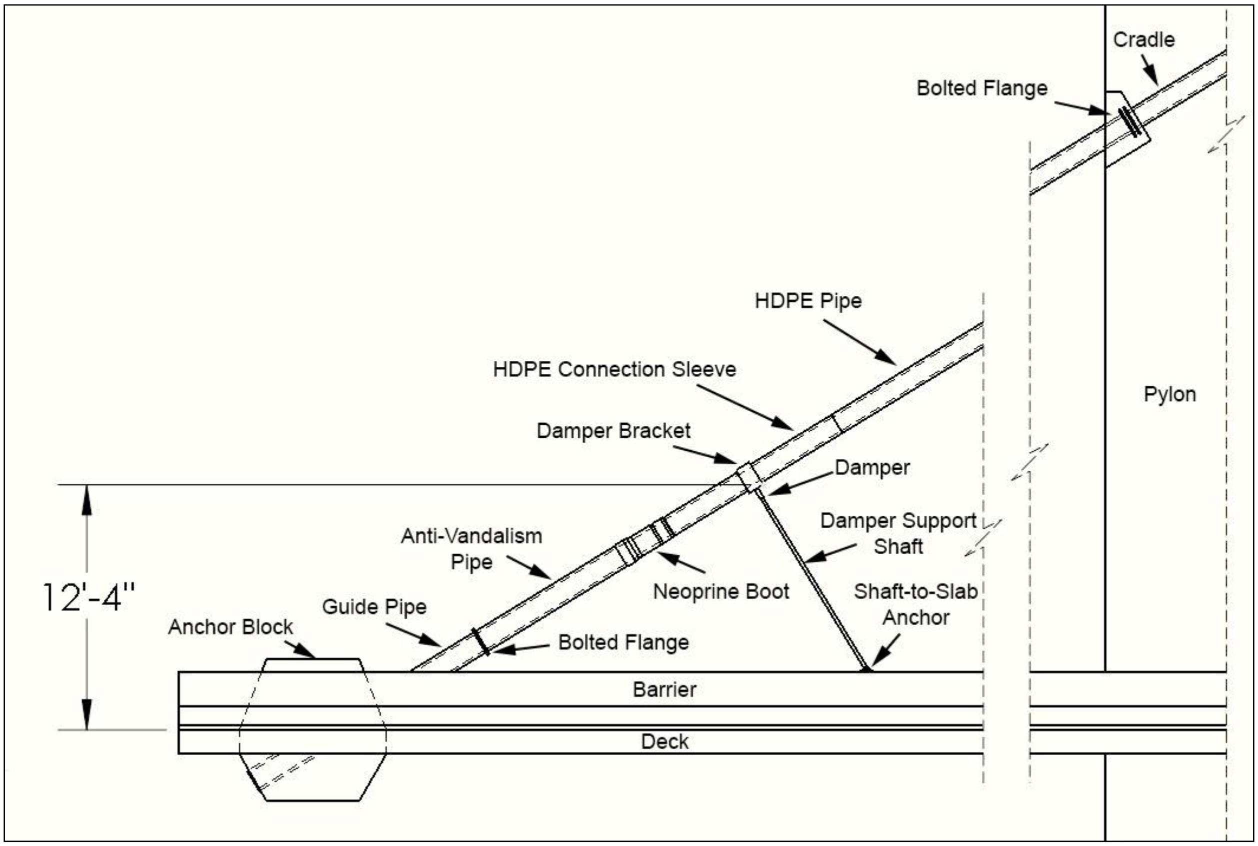
Figure 13. Photo. Bridge observatory.

The Penobscot Narrows Bridge has four centerline fans of stay cables between the bridge spans and pylons. The two fans on the outer side spans are essentially symmetrical, as are the two inner fans supporting the main span. A photo detailing the cable fan configuration is shown in figure 14. Chord lengths of the cables range from 119 to 594 ft (36.4 to 181.1 m) and inclination angles range from 22.1 to 52.8 degrees. The cables in the inner fans are roughly 13 percent longer than their counterparts in the outer fans. The fans are labeled A, B, C, and D running from the west to east end of the bridge. The cables are numbered 1–20 in each fan, with 20 being the longest. In this report, a cable will be referenced by its number, followed by its fan letter, e.g., cable 19A.

Figure 14. Photo. Bridge cable fan configuration.

The stay cables consist of 41 to 72 steel wire strands loosely encased in an ungrouted high-density polyethylene (HDPE) pipe. The HDPE pipe has a constant diameter of 15.75 inches (400 mm) for all cables, despite the varying number of strands for the different cable lengths, and includes a double helical fillet on its surface. The 0.6 inches (1.52 cm) diameter 7-wire strands are epoxy coated and filled. These strands are attached to anchor blocks at deck level and are continuous, passing through cradles, at each pylon. Each strand acts independently, allowing for removal, inspection, and replacement. The Penobscot Narrows Bridge is one of the first few bridges to incorporate the use of a cable-stay cradle system, eliminating the need for anchorages in the pylons and allowing for increased diameters of stays and, therefore, increased span lengths.(4) In June 2007, six strands in three stays were removed and replaced with carbon fiber strands to enable monitoring of the carbon fiber material in this special application. Each cradle assembly consists of a galvanized steel outer sheath with an outside diameter of 16 inches (488 mm) and individual stainless steel sleeves with 1 inch (2.54 cm) outside diameter for each strand. At the upper end of each stay cable, the HDPE pipe is attached to the cradle end through a bolted flange.

A galvanized steel guide sleeve, or guide pipe, extends from the concrete anchor block at the lower end of each stay cable. A galvanized steel anti-vandalism pipe is attached to the end of the guide sleeve through a bolted flange to extend protection from damage in this region of the cable. An HDPE "connection sleeve," with 17.72 inches (450 mm) outside diameter and no helical fillet, is used to make the transition from the anti-vandalism pipe to the primary HDPE pipe, and the joint between steel and HDPE is sealed with a neoprene boot and steel bands. No internal neoprene bushings or internal dampers are utilized at either end of the stay cables. A diagram detailing the numerous transitional elements of the lower stay cables is shown in figure 15, while figure 16 contains a photo of these elements on several cables towards the west end of the bridge.



1 ft = 0.305 m, 1 inch = 2.54 cm

Figure 15. Illustration. Bridge stay cable assembly details.

Figure 16. Photo. Detail of lower end of bridge cables.

External viscous dampers are installed in pairs near the lower end of all stay cables. The axes of the dampers in each pair are separated by an angle of less than 45 degrees to provide damping for out-of-plane as well as in-plane vibrations. Each damper-to-stay connection is located 12.33 ft (3.76 m) vertically above the bridge deck; therefore, its position up the length of the cable is a function of β, the cable inclination angle. For the range of inclination angles on this bridge, the dampers are positioned between 6.4 and 16.9 percent of the cable length from the lower anchorage. The dampers are attached to the HDPE connection sleeve using a galvanized steel bracket fabricated in two halves for ease of installation. A multi-sleeve, or cheese, block is installed inside the HDPE connection sleeve at the damper location to ensure that the individual steel strands and pipe move as a unit. The block consists of six HDPE cheese plates separated by five rubber cheese plates. Each damper rests atop a steel extension pipe that is solidly anchored to the top slab of the raised median.

SET-UP AND PROCEDURES

The cable-stays on the Penobscot Narrows Bridge were tested by staff from the FHWA Aerodynamics Lab in two phases, both before and after the installation of dampers. Phase 1 testing of the cable-stays was conducted in early December 2006 during construction, and phase 2 testing occurred in September 2007 with traffic on the bridge.

Data from the vibration testing was obtained by attaching two accelerometer boxes to each stay cable, the first box being from 19 to 21 percent up the length of the cable and the second being from 6 to 9 percent up the length of the cable. The lower box, or enclosure, was positioned close to the connection point for the dampers and the upper box was placed as high as possible on the cable and in a position that would avoid vibration nodes for the modes of interest. Figure 17 shows the accelerometers mounted on top of a stay cable, with the second one sitting further up the cable in the distance.

Figure 17. Photo. Accelerometers mounted on stay cable.

Multiple boxes ensured that useable data would be collected even in case of a malfunctioning sensor or if a sensor was inadvertently stationed at a frequency node. The accelerometers measured data from all three axes, although only data from the in-plane direction were required for analysis. The in-plane direction corresponds to the vertical plane of cables, which was measured as the z-direction on the accelerometer. Data from the accelerometers were recorded using a portable data acquisition system that was also connected to a vane-type anemometer to measure the wind direction and speed present during the test. In general, the anemometer was placed in the vicinity of the cables being tested and thus was moved about the bridge. The data acquisition system was connected to the bridge for power and is shown in figure 18. The scan frequency used for both the accelerometers and the anemometer was 100 Hz.

Figure 18. Photo. Data acquisition system.

The cables were manually excited in the vertical plane with a “pull” rope, while a spotter checked to make sure the proper amplitudes and modes were achieved. Positioned with a good view along the longitudinal axis of the cable under test, the spotter would signal the “pullers” to synchronize the pulling action with the cable motions. This approach enabled efficient excitation, vibrations primarily in the first vertical mode, and peak amplitudes of one cable diameter or more. When the cable reached a sufficient excitation, the rope was released, allowing the cable to freely oscillate and the vibrations to decay. The data acquisition system would be triggered to start recording before the excitation was started then continued recording until the decay subsided and only random traffic or wind-induced vibrations remained.

In addition to the data recorded from the sensors, general test notes were taken regarding sensor locations, weather conditions, quality of the vibration modes achieved, traffic problems, interference from construction activities, and any difficulties encountered while exciting the cable. Figure 19 shows a diagram of a stay cable illustrating the distance each accelerometer was placed from the anchor block, while table 1 contains a summary of the distances used during testing.

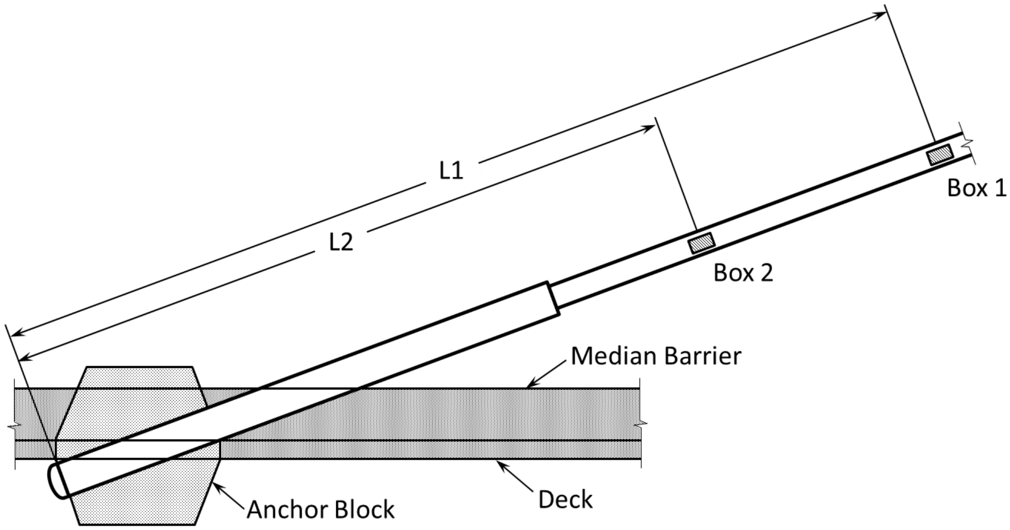


Figure 19. Illustration. Location of accelerometers during testing.

Table 1. Summary of accelerometer locations.

	Phase 1				Phase 2			
Cable	L1		L2		L1		L2	
	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
20A	108.34	33.02	32.80	10.00	108.34	33.02	33.93	10.34
19A	104.64	31.89	31.89	9.72	104.64	31.89	33.01	10.06
18A	99.29	30.26	32.40	9.88	99.29	30.26	33.53	10.22
17A	95.59	29.14	31.41	9.57	95.59	29.14	32.54	9.92
16A	90.23	27.50	31.88	9.72	90.23	27.50	33.00	10.06
15A	86.54	26.38	30.71	9.36	86.54	26.38	31.83	9.70
14A	81.17	24.74	31.17	9.50	81.17	24.74	32.30	9.84
13A	77.50	23.62	29.91	9.12	77.50	23.62	31.03	9.46
12A	72.12	21.98	30.34	9.25	72.12	21.98	31.47	9.59
20B	—	—	—	—	112.91	34.41	39.58	12.07
19B	—	—	—	—	108.70	33.13	38.17	11.63
18B	—	—	—	—	103.31	31.49	38.73	11.80
17B	—	—	—	—	99.12	30.21	37.25	11.35
16B	—	—	—	—	93.88	28.62	37.52	11.44
15B	—	—	—	—	89.73	27.35	35.97	10.96
20C	112.91	34.41	38.46	11.72	112.91	34.41	39.58	12.07
19C	108.70	33.13	37.04	11.29	108.70	33.13	38.17	11.63
18C	103.31	31.49	37.60	11.46	103.31	31.49	38.73	11.80
17C	99.12	30.21	36.13	11.01	99.12	30.21	37.25	11.35
16C	—	—	—	—	93.88	28.62	37.52	11.44
15C	—	—	—	—	89.73	27.35	35.97	10.96
14C	—	—	—	—	84.17	25.66	36.74	11.20
20D	—	—	—	—	108.39	33.04	34.14	10.41
19D	—	—	—	—	104.65	31.90	33.12	10.10
18D	—	—	—	—	99.31	30.27	33.61	10.24
17D	—	—	—	—	95.59	29.14	32.53	9.91
16D	—	—	—	—	90.23	27.50	33.00	10.06
15D	—	—	—	—	86.54	26.38	31.83	9.70
14D	—	—	—	—	81.17	24.74	32.30	9.84
13D	—	—	—	—	77.50	23.62	31.03	9.46

CHAPTER 4. PHASE 1 INVESTIGATION

TESTING

Phase 1 testing of the cable-stays on the Penobscot Narrows Bridge occurred in early December 2006. In order to achieve the largest representation of cables in only a week's allotment of test time, it was decided to test as many cables as possible in fan A, before switching over to inner cables located in fan C. Testing for each fan started with number 20, the longest cable, and proceeded to the shorter cables. Cables 20A through12A were tested in the first 3 days, while cables 20C through 17C were tested the following day before severe winter weather prevented any testing on the final day. Figure 20 shows the arrangement of the cables tested.

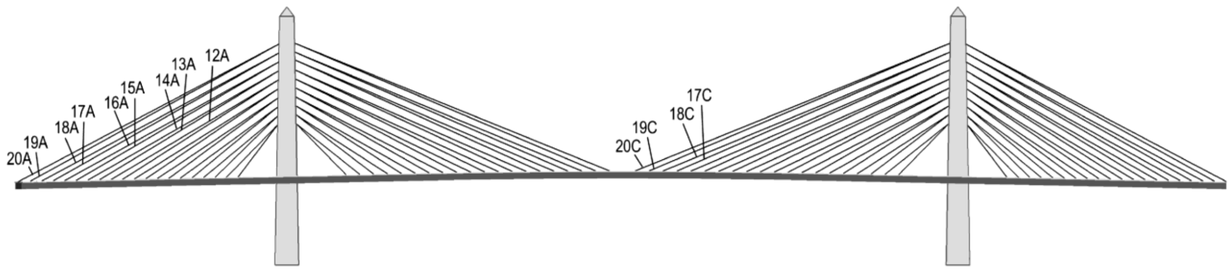


Figure 20. Illustration. Arrangement of cables tested during phase 1.

ANALYSIS

Frequency Content

To determine the fundamental mode frequencies for each cable, an estimated power spectral density (PSD) analysis was performed on the time-history series for each individual run. The density was calculated in Matlab® using Welch's averaged modified periodogram method, which produces a one-sided density of frequency versus power per frequency with an acquisition frequency of 100 Hz. The Welch function divides the input into eight segments with 50 percent overlap with each segment subjected to a Hamming window function. The average of the periodograms determines the PSD estimate. For these cable vibrations, the frequencies of interest are extremely low, in the single-digit Hz range. Appropriately, the density was graphed from 0 to 10 Hz, which contained the first 8 to10 fundamental frequencies. Figure 21 shows a sample plot of the Welch spectral density plot.

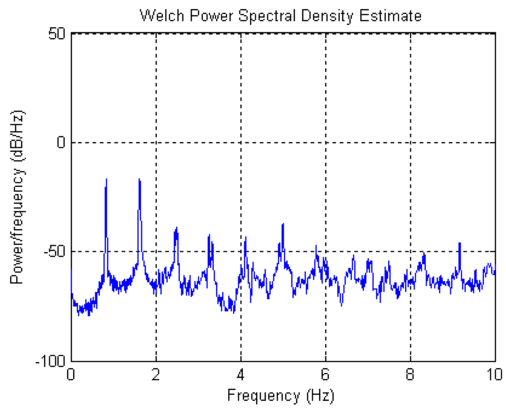


Figure 21. Graph. Phase 1 spectral density plot of cable 19A, run 3.

A cursor was placed on the plot and dragged along the points in order to determine the local maxima that correspond to the natural frequencies. The frequencies were found with an accuracy of three decimal places for the first mode, and two decimal places for the higher modes. The quality of the spectral density plots varied among the different runs. Some produced clear plots where each natural frequency could easily be recorded up to the ninth or tenth mode. Other plots were harder to interpret. Sometimes the higher frequencies would lack distinct peaks, and other times the energy would fall under a wider curve with multiple peaks. In these cases, some judgment was applied to determine which peaks were acceptable.

A table was compiled of the fundamental frequencies up to the seventh mode, if possible, for each time-series. This was done for both accelerometer boxes. Usually the frequencies would be equivalent between the two boxes and across the separate runs for each individual cable, but occasionally they would vary by a small percent. The table of frequency values can be found in appendix A. Once again, sometimes a judgment call was necessary when determining the average natural frequencies for a cable if it varied throughout the runs. If there were only a few outliers, the statistical mode was considered the average, but if there was greater variance among the runs, then the actual mean was calculated.

Damping Analysis

Once the fundamental frequencies were obtained for the first two modes, the damping ratios could then be calculated from the decay of the cable vibrations. Since the time-history for each run is the complex combination of numerous modes of vibration, a bandpass filter was used to isolate the decay associated with each mode. The pass band frequencies were determined from the spectral density plot, choosing frequencies that closely encompassed the entire energy peak for the desired mode. A fourth-order elliptic filter was utilized on the signal twice to completely suppress the unwanted noise outside the band while effectively preserving the signal within the cutoff frequencies. An example of the elliptic filter's effect on the spectral density plot of a data series is shown in figure 22.

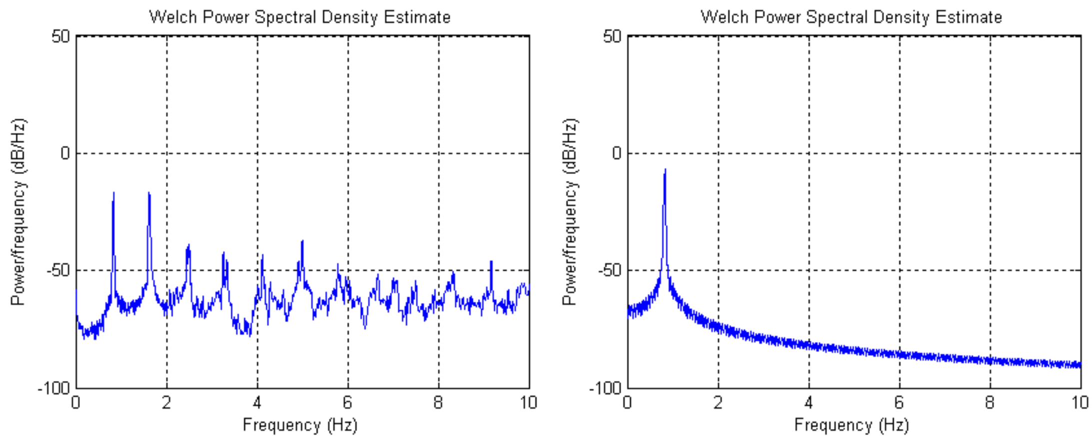


Figure 22. Graph. The effect of the bandpass filter on the spectral density, before (left) and after (right).

Once the bandpass filter had been applied, the time series resembled a more consistent logarithmic decay. A time filter was also established to eliminate the data associated with the manual excitation at the beginning of the run and the random excitations prevalent after the decay had subsided. Figure 23 shows a comparison of the time series before and after the bandpass and time filters are applied.

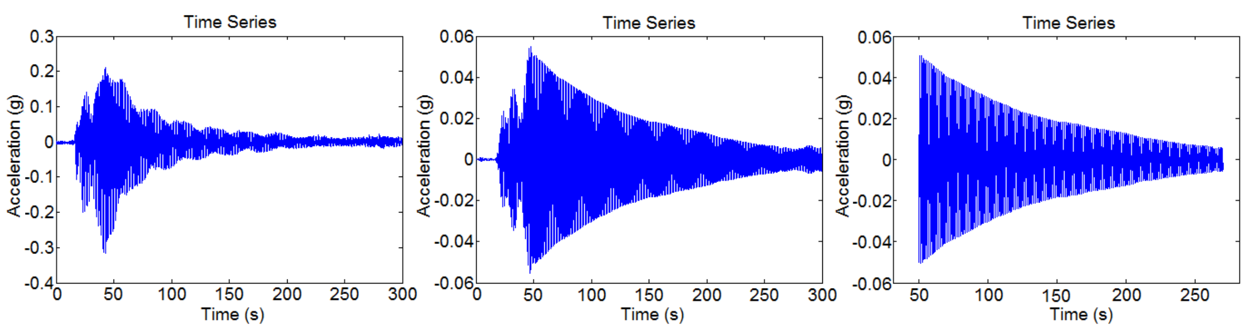


Figure 23. Graph. Phase 1 plots comparing the original time series (left), the bandpass filtered time series (center), and the truncated time series (right).

After the logarithmic decay curve has been revealed, the damping ratio can then be extracted using the equation from figure 9. Software created in Matlab® marked both the positive and negative peaks along the sinusoidal curve and then proceeded to take the natural log of the peaks. Since damping is found from the ratio between two distinct, consecutive peaks, and that ratio varies throughout the run as the peaks vary, a regression line was fitted to the data to minimize random errors. An average damping ratio was then calculated from this best-fit line. A close-up of the software capturing the peaks from phase 1 testing of cable 19A, run 6 and the resulting regression lines are shown in figure 24 to figure 27.

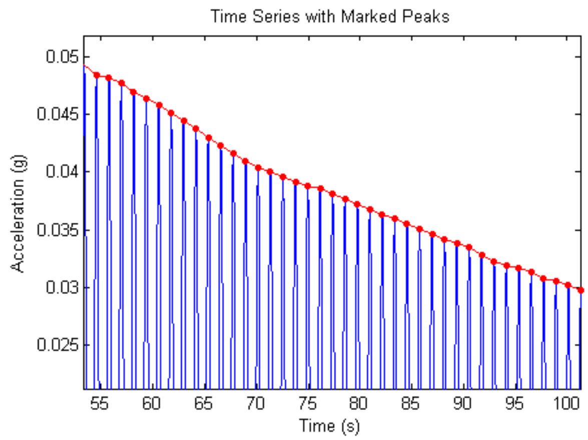


Figure 24. Graph. Marked peaks of the decay curve.

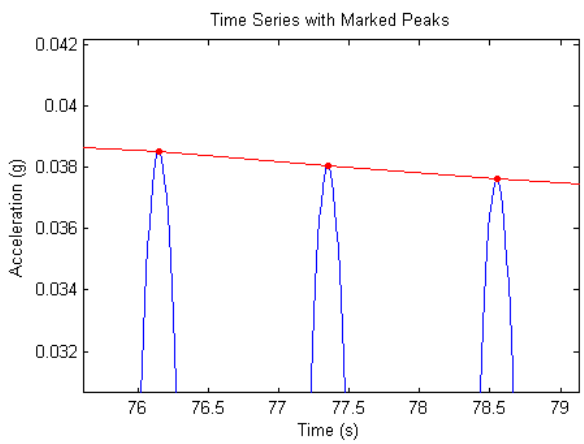


Figure 25. Graph. Closer view of the marked peaks.

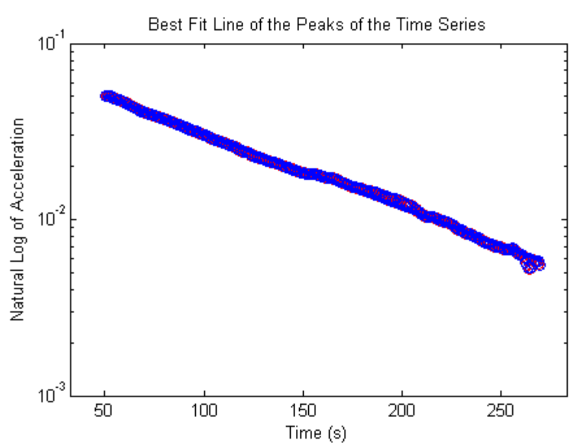


Figure 26. Graph. Best-fit line of the natural log of the peaks.

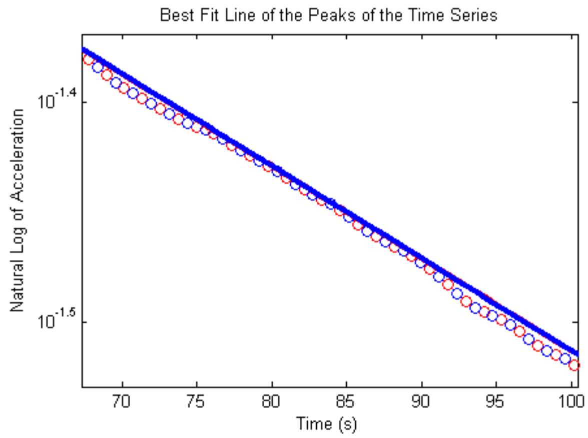


Figure 27. Graph. Closer view of a 30 second interval of the best-fit line of the peaks.

To determine the effectiveness of the best-fit line, the correlation was noted between the regression line and the actual peak data points. In general, the correlation throughout the runs was extremely high, usually averaging over 0.990 for the first mode. In most cables, the average correlation was even higher, averaging between 0.994 and 0.997, although one cable's data set only averaged 0.953. While that number still appears impressive, it was extremely difficult to accurately fit a line with that much variability in the decay.

The correlation was also important because it helped determine the length of the sample. The length of the decay was chosen to extend for as long as possible before random vibrations affected the signal. The best-fit line and correlation numbers helped determine when the damping ended and the logarithmic decay assumption was no longer valid. The length of the decay curve for the first frequency mode was longer than the second, usually averaging 50 s for the shorter cables to 260 s for the longer cables in the first mode, and 30 s to 130 s, respectively, in the second mode.

After the best-fit line was established, the damping ratio could be pulled for each cable. The number of runs performed for each cable varied between 4 and 11 with one additional run per cable used as a baseline with no manual excitation. Due to the small number of available sample data sets for each cable, and the fact that the population mean and variance are both unknown, the Student-t test was used to find a 90 percent confidence interval on the mean.[5] This statistical process was performed for every cable for both the first and second modes, and a graph of the results is shown in figure 28 to figure 31. Table 2 contains a summary of the damping ratio, correlation, and frequencies for each cable.

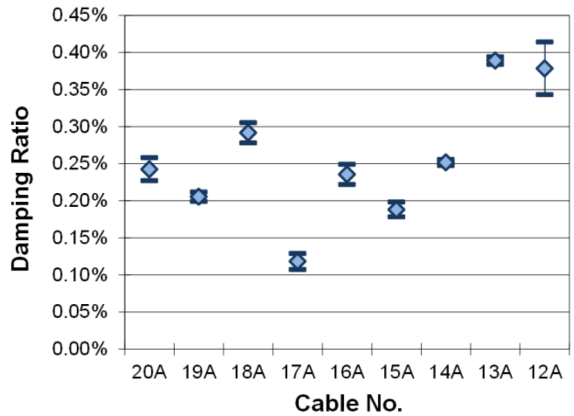


Figure 28. Graph. First mode, 90 percent confidence interval on the mean, fan A.

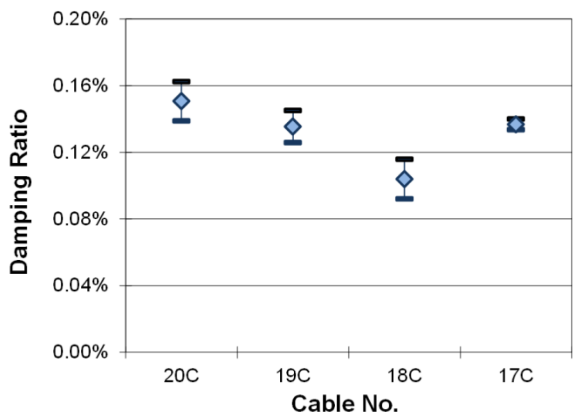


Figure 29. Graph. First mode, 90 percent confidence interval on the mean, fan C.

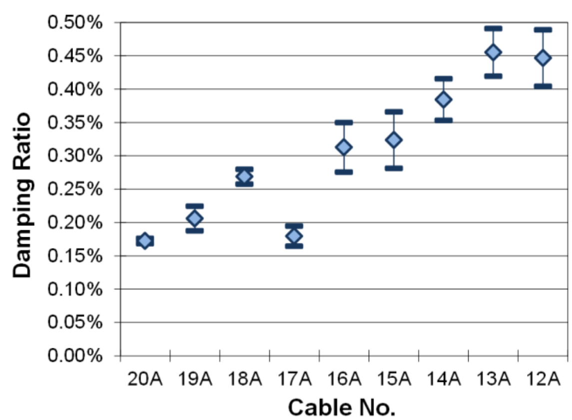


Figure 30. Graph. Second mode, 90 percent confidence interval on the mean, fan A.

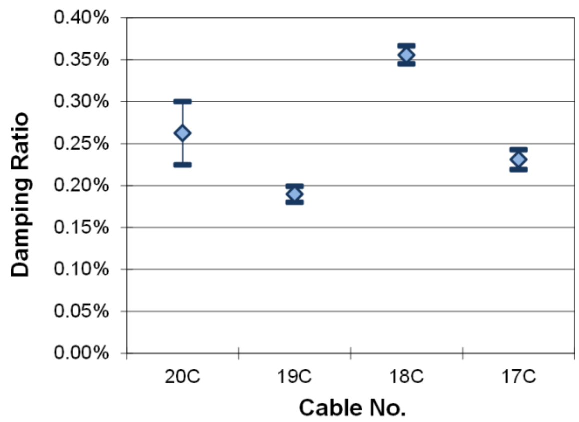


Figure 31. Graph. Second mode, 90 percent confidence interval on the mean, fan C.

Table 2. Phase 1 summary of results data.

Cable Number	First Mode			Second Mode		
	Average Damping Ratio (percent)	Correlation	Average Length of Time Sample (s)	Average Damping Ratio (percent)	Correlation	Average Length of Time Sample (s)
20A	0.242	0.9949	160.7	0.172	0.9919	101.4
19A	0.205	0.9933	160.0	0.206	0.9852	95.0
18A	0.292	0.9967	144.5	0.269	0.9949	92.8
17A	0.118	0.9535	140.0	0.179	0.9905	102.7
16A	0.235	0.9954	141.8	0.313	0.9902	64.3
15A	0.188	0.9968	197.9	0.323	0.9925	72.5
14A	0.252	0.9964	155.4	0.384	0.9973	54.2
13A	0.389	0.9976	52.9	0.455	0.9929	29.2
12A	0.378	0.9871	57.5	0.447	0.9872	26.9
20C	0.151	0.9968	213.8	0.262	0.9949	57.7
19C	0.135	0.9965	256.5	0.190	0.9940	116.0
18C	0.104	0.9949	223.0	0.356	0.9989	62.0
17C	0.137	0.9989	180.0	0.231	0.9952	135.0

DISCUSSION

Frequency Content

The frequency trends obtained from the power spectral densities generally matched what would be expected. The fundamental frequencies from the cables located in fan A increased as the length of the cable decreased. The four cables tested in fan C have lower fundamental frequencies than the longest cable in fan A, which is reasonable since all four of those cables are longer than their numerical counterpart in fan A. The cables located in the inside fans support a longer portion of the bridge deck than those located in the outside fans. Cables 20C to 17C range from 594 ft (181.1 m) to 522 ft (159.0 m), while cables 20A to 12A range from 516 ft (157.3 m) to 343 ft (104.7 m). First mode frequencies obtained from testing are presented in figure 32.

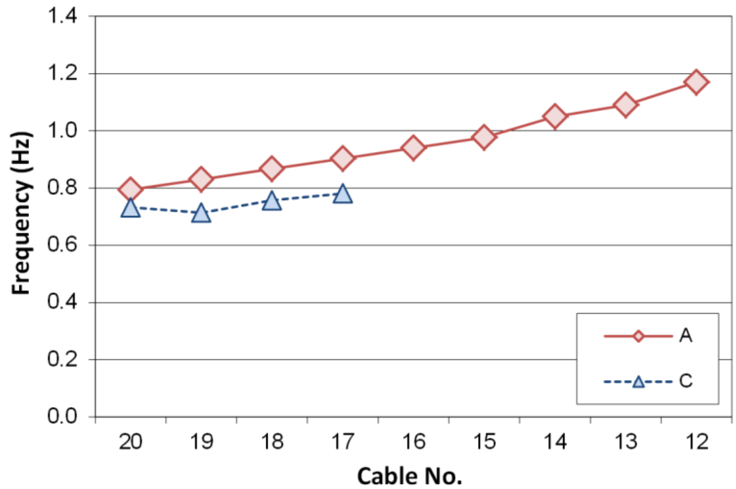


Figure 32. Graph. First mode frequencies from phase 1 testing.

Frequencies measured between the two accelerometers were usually in agreement, although they would occasionally vary by up to 6 percent. Similarly, the frequency measurements among the various runs for each cable were mainly consistent, with the maximum difference for any mode frequency for a cable in the range of 2 to 7 percent. Although the baseline runs did not have the energy necessary to produce a thorough power density spectrum, the ambient vibrations provided enough energy to mark the frequencies of at least the first two modes. These frequencies were always in line with those captured from the manual excitation runs.

The data from most cables produced clear power spectrum densities, allowing the recording of the first seven harmonic frequencies in at least one of the experimental runs, although cable 12A was one exception during the testing. Due to high winds in the 15 to 20 mi/h (24 to 32 km/h) range and its relatively short length, this cable was difficult to manually excite and the result was an extremely weak spectral density. The frequencies of the first two modes were visible, but the rest of the density produced no legible peaks. Fortunately, this cable was the only one that experienced this issue.

Damping Ratios

The damping ratios calculated for the cable-stays experienced both a wide range of values and consistency. A handful of cables had very narrow confidence interval bands indicating extremely consistent decay in their time series. Other cables did not contain equally uniform data, so their confidence bands stretched up to seven times wider. Additionally, the confidence intervals for the second mode were generally wider as their correlation tended to be worse compared to the first mode.

It is difficult to determine if the average damping values fall into any set pattern as the cable length decreased. It appears that there could be a weak linear trend connecting the damping ratio to the cable length, which is slightly more apparent for the second mode vibrations than the first. A slight negative trend indicates that the damping ratio is increasing as the cable length decreases. There are several possible factors that are hampering the ideal conditions necessary for a stronger trend to develop, including different cable diameters and masses, physical interactions between the steel strands and HDPE piping shell, and possible effects of the wind and aerodynamic damping. These factors introduce many complicated variables that could prevent theoretical values from being developed.

These complex factors may also be introducing some non-linearity to the cable vibrations. There were several measured instances where the damping ratio appeared to vary over the time of the decay, usually decreasing with time and often in a partial sinusoidal curve. In addition to the methodology described in the previous chapter to obtain the average damping ratio, alternative methods were tested in an attempt to discover an optimum way to calculate damping. The methods involved looking at the decay signal in smaller increments, averaging out the damping ratio in blocks of 10, 20, and 30 s, all the way up to half the signal length. For some of the tests, the increments overlapped, creating essentially a smoothing filter for the average damping across the data series.

When the damping ratio was averaged over these smaller intervals it became quite apparent that the ratio was not remaining steady over time. Figure 33 is an example of how the damping ratio for cable 19A, averaged in 20 and 80 s blocks, varies over time. The general trend is from higher damping to lower damping, which was true for all cables that were tested using these alternate methods. It seems that when the cable is vibrating at large amplitudes, the energy is dissipated at an unexpectedly higher rate. This could be due to the non-linear physical interactions between the steel strands and the HDPE outer piping shell.

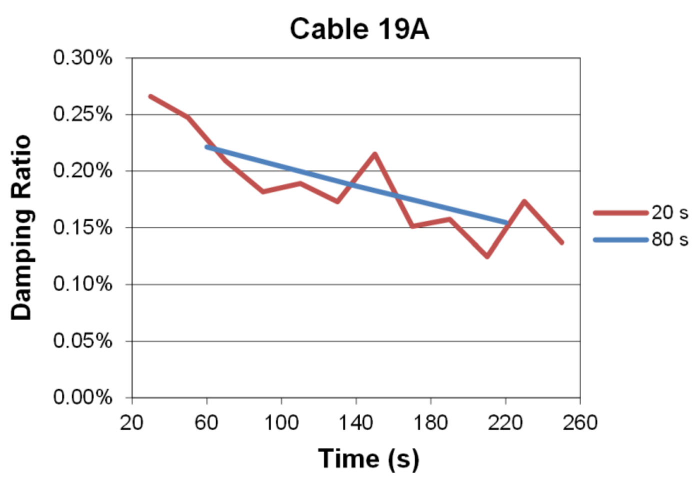


Figure 33. Graph. Cable damping varying when averaged over short intervals.

Despite the apparent existence of some non-linear trends, the damping ratio can still be estimated as an average throughout the entire decay, if properties are chosen consistently throughout the analysis. The best-fit lines from which the damping averages were originally obtained still had extremely high correlation to the actual values from the peaks of the decay curve. With the inclusion of the 90 percent confidence intervals derived from the Student-t test performed on the data, accurate comparisons can be made to vibration data obtained after the installation of dampers and other cable vibration mitigation techniques to rate their effectiveness.

Scruton Number Analysis

Another widely used mass-damping parameter indicating the level of cable damping with respect to vibration mitigation is the Scruton number, defined by:

$$Sc = \frac{\zeta m}{\rho D^2}$$

Figure 34. Equation. Scruton number.

where ζ = first-mode damping ratio, m = mass density per unit length of cable, ρ = mass density of air, and D = diameter of the cable pipe.(6) The Scruton number is frequently used in developing a criterion for controlling rain/wind-induced vibration of stay cables. For instance, based on Irwin's suggestion, the Post-Tensioning Institute committee on cable stayed bridges has suggested that rain/wind vibrations of stay cables can be avoided if the Scruton number is kept at a value of ten or higher.(7,8) Additionally, a reduced Scruton number of five has been suggested if the cable has an aerodynamic surface treatment.(9)

Plugging the measured damping values presented above in table 2 and the corresponding cable properties (found in appendix G) into the equation in figure 34 returns the following Scruton numbers, as shown in table 3. The Scruton numbers range from 0.6 to 2.1, far below the desired value of ten, indicating that the cable system under consideration was potentially vulnerable to rain/wind-induced (and perhaps wind-induced) vibrations. This would still be the case if a reduced Scruton number was used to account for the aerodynamic surface treatment. Based on these results, it is confirmed that an appropriate vibration mitigation measure, such as external viscous dampers, had to be incorporated into the cable system.

Table 3. Phase 1 Scruton number.

Cable Number	Scruton Number
20A	1.3
19A	1.1
18A	1.6
17A	0.6
16A	1.3
15A	1.0
14A	1.4
13A	2.1
12A	2.0
20C	0.8
19C	0.8
18C	0.6
17C	0.7

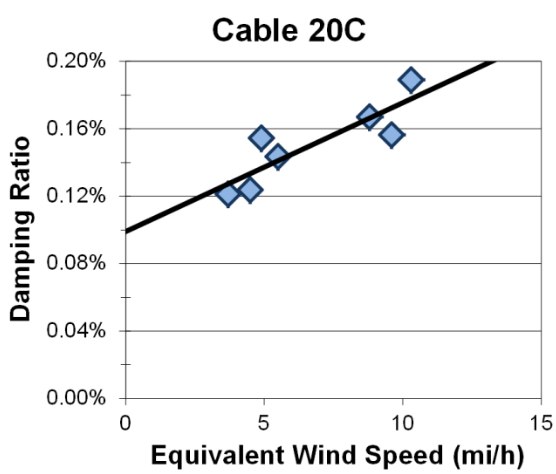
Aerodynamic Damping

An investigation was also initiated into the effects of aerodynamic damping on the cable vibrations. If it is assumed that the average damping measured from the regression line is essentially a total damping, comprised of both aerodynamic and structural damping, then the aerodynamic damping can be subtracted out, leaving only the structural damping of the cable-stay. Wind speed and direction data were recorded along with the accelerometer data and were entered into Macdonald's formula for finding the equivalent wind speed normal to the cable axis for in-plane vibrations.(10)

$$U_{eq} = U\left(\sqrt{\cos^2\theta + \sin^2\theta\sin^2\beta} + \frac{\sin^2\theta\sin^2\beta}{\sqrt{\cos^2\theta + \sin^2\theta\sin^2\beta}}\right)$$

Figure 35. Equation. Equivalent wind speed.

In this formula, θ is the reference wind direction normal to the vertical plane of the cable, β is the angle the cable is inclined from the horizontal, and U is the wind speed regardless of direction. For ease of calculation, both θ and U are averaged across the duration of the decay history. The equivalent wind speed is essentially a normalized value that can be directly compared between the various runs, despite the actual direction the wind is facing. Therefore, a plot can be constructed of average damping values versus equivalent wind speed. When the equivalent wind speed is zero, there is no aerodynamic damping acting on the cable, so a regression line through the data set can be traced to zero to determine the structural damping. Figure 36 is an example of this concept taken from cable 20C.



1 mi/h = 1.61 km/h

Figure 36. Graph. Damping ratio versus equivalent wind speed for cable 20C.

Plots were created for each cable, but it became readily apparent that there were several limiting factors to this approach. The biggest issue was sample size. Most cables did not have enough runs to create a regression line capable of being statistically significant. This was especially true for the cables exposed to the largest winds, which happened towards the end of the testing. Another issue was that winds were relatively calm during the first three days of testing, with average wind speeds remaining below 2 mi/h (3.2 km/h). To create an accurate plot of the aerodynamic damping, there needs to be a wider range of wind speeds during the tests. Despite these issues, the plots showed some potential for the possibility of calculating the aerodynamic damping, and being able to separate it from the structural damping of the cable-stay. Future tests require a larger sample size for significance purposes and if possible, a much wider range of wind speeds and directions.

CHAPTER 5. PHASE 2 INVESTIGATION

TESTING

Phase 2 testing of the cable-stays on the Penobscot Narrows Bridge was conducted in September 2007, post-damper installation, and lasted one week. Due to favorable weather conditions and shorter decay periods provided by the new dampers (shown in figure 37 and figure 38), it was possible to perform more than double the number of test runs completed during phase 1. During phase 2, the following cables from the four fans were tested: 20A through 12A, 20C through 14C, 20B through 15B, and 20D through 13D (shown in figure 39). The number of test runs performed for each cable varied between seven to ten runs, with the majority of cables undergoing eight or nine runs.

Figure 37. Photo. Dampers.

Figure 38. Photo. Damper's attachment to cable and median slab.

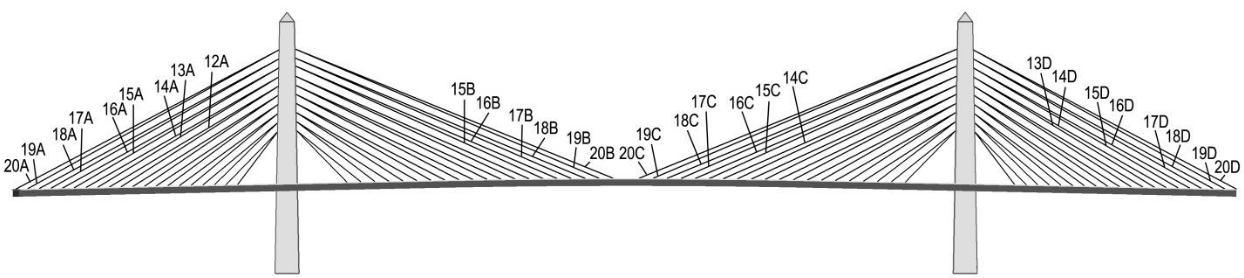


Figure 39. Illustration. Arrangement of cables tested during phase 2.

ANALYSIS

Frequency Content

As in phase 1, spectral density analyses were used to determine the fundamental mode frequencies for each cable tested during phase 2. Once again, the spectral densities were calculated in Matlab® using Welch's averaged modified periodogram method and plotted on a scale from 0 to 10 Hz. The mode frequencies were determined by tracing the peaks of the density plot. The data from phase 2 produced clear spectrums allowing frequencies up to the seventh mode to be recorded for each time-series. An example of the spectral density plot is show below in figure 40 for cable 19A. The full table of frequency values for the testing done in phase 2 can be found in appendix A.

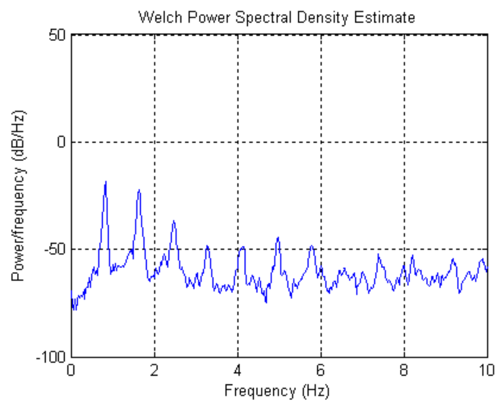


Figure 40. Graph. Phase 2 spectral density plot of cable 19A, run 2.

Damping Analysis

The damping analysis for phase 2 testing utilized the same initial procedures outlined above for phase 1. Differences between the two phases of testing became apparent after bandpass filters were applied to the phase 2 data sets. The effect of the newly installed dampers was obvious as the logarithmic decay of the damping curves occurred much faster. Figure 41 shows the effects of the bandpass and time filters on the signal.

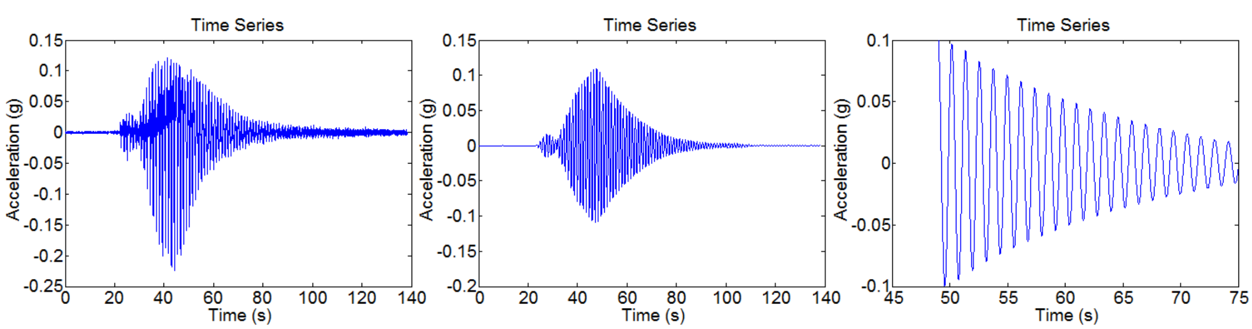


Figure 41. Graph. Phase 2 plots of the original time series (left), the bandpass filtered time series (center), and the truncated time series (right).

Once again, best-fit lines of the positive and negative peaks were used to determine the appropriate length of the decay curve. The correlation between the best-fit line and the peaks was kept above .990 by adjusting the length of the sample of the decay curve used. The length of the decay curves ranged between 12 and 50 s for testing done on the first mode, and between 6 and 25 s for testing done on the second mode. Similar to phase 1, shorter cables had shorter decay periods, but unlike phase 1, data obtained between the two boxes were not identical. In general, cable data obtained from box 2 had shorter decay periods than data obtained from the same run from box 1. This was due to box 2's placement on the cable and the corresponding close proximity to the damper attachment.

After best-fit lines were established for each cable run, the damping ratios could again be calculated and then averaged for each individual cable. During phase 2 testing, each cable had a minimum of 7 runs, with the majority getting 8 to 10 runs. Again, the Student-t test was utilized to find a 90 percent confidence on the mean of the damping ratio for each cable for both the first and second modes. Graphs of the results are shown in figure 42 to figure 49, while table 4 contains a summary of the damping ratio, correlation, and frequencies for each cable. The figures and table show the averaged data from the two boxes.

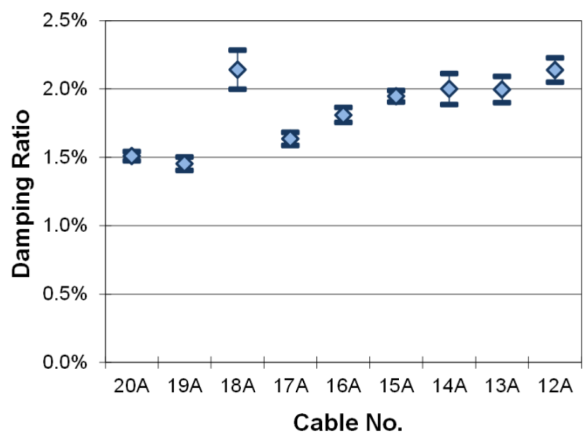


Figure 42. Graph. First mode, 90 percent confidence interval on the mean, fan A.

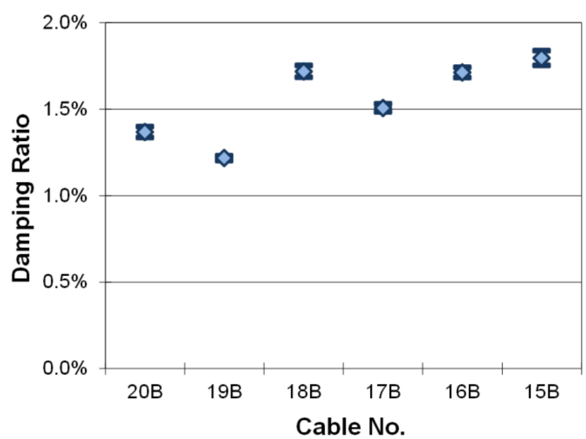


Figure 43. Graph. First mode, 90 percent confidence interval on the mean, fan B.

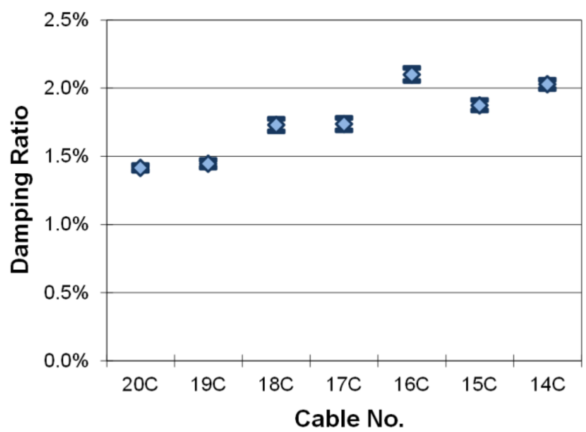


Figure 44. Graph. First mode, 90 percent confidence interval on the mean, fan C.

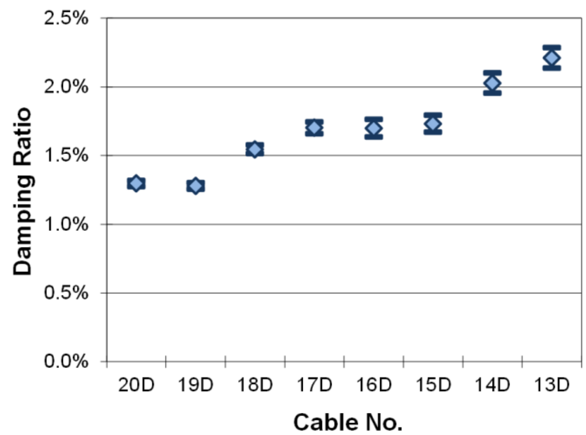


Figure 45. Graph. First mode, 90 percent confidence interval on the mean, fan D.

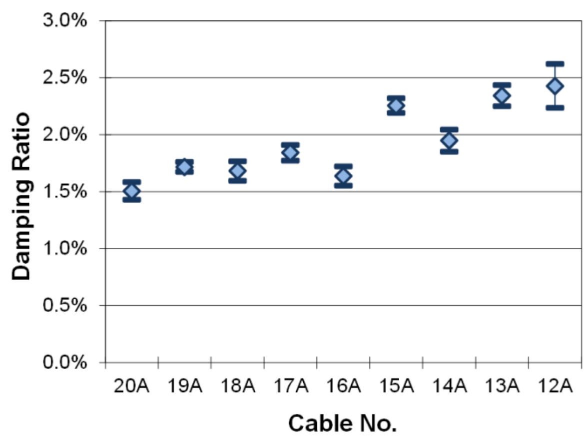


Figure 46. Graph. Second mode, 90 percent confidence interval on the mean, fan A.

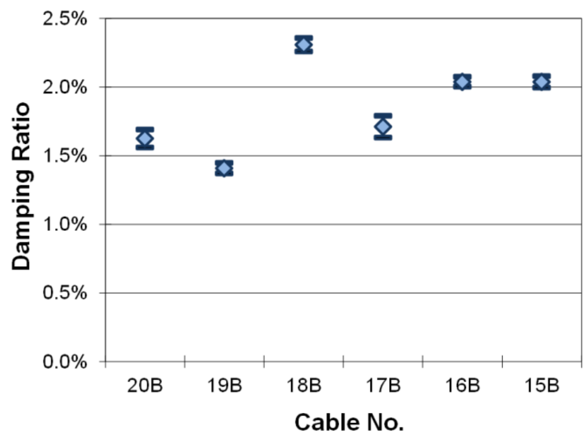


Figure 47. Graph. Second mode, 90 percent confidence interval on the mean, fan B.

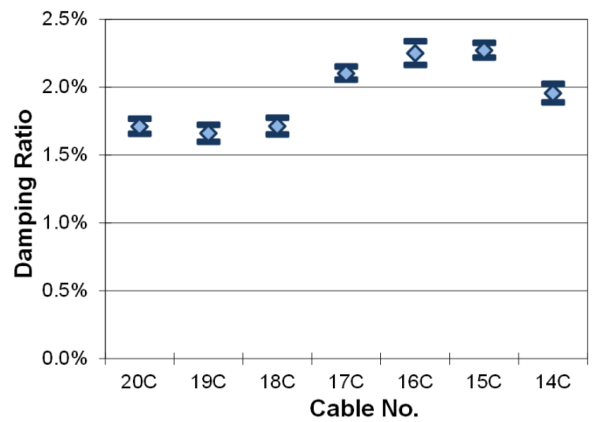


Figure 48. Graph. Second mode, 90 percent confidence interval on the mean, fan C.

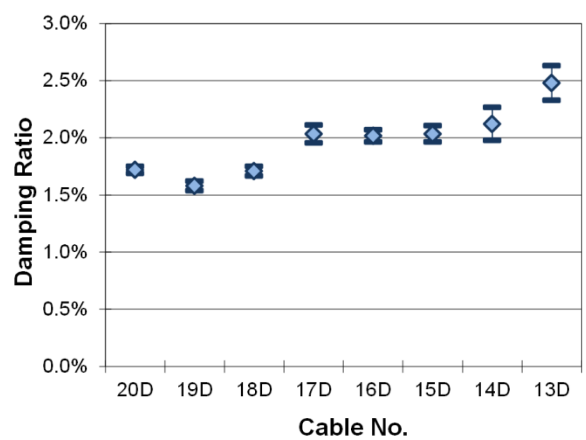


Figure 49. Graph. Second mode, 90 percent confidence interval on the mean, fan D.

Table 4. Phase 2 summary of results data.

Cable Number	First Mode			Second Mode		
	Average Damping Ratio (percent)	Correlation	Average Length of Time Sample (s)	Average Damping Ratio (percent)	Correlation	Average Length of Time Sample (s)
20A	1.51	0.9969	22.7	1.5	0.9942	16.8
19A	1.45	0.9976	25.1	1.72	0.9968	19.4
18A	2.14	0.9941	21.2	1.68	0.9975	16.2
17A	1.63	0.9964	25.3	1.84	0.9951	14.6
16A	1.81	0.9973	24.2	1.64	0.9914	16.6
15A	1.95	0.9974	20.0	2.25	0.9965	14.4
14A	2.00	0.9983	20.0	1.95	0.9961	12.7
13A	2.00	0.9967	16.5	2.34	0.9969	7.0
12A	2.14	0.9972	15.9	2.43	0.9921	7.1
20C	1.41	0.9975	23.1	1.71	0.9976	16.7
19C	1.44	0.9957	36.1	1.66	0.9935	16.2
18C	1.73	0.9962	28.7	1.71	0.9948	20.1
17C	1.74	0.9970	27.0	2.10	0.9963	15.6
16C	2.10	0.9959	22.4	2.25	0.9947	15.2
15C	1.87	0.9964	23.4	2.27	0.9967	14.1
14C	2.03	0.9970	26.4	1.95	0.9952	15.9
20B	1.37	0.9968	30.1	1.62	0.9956	23.8
19B	1.22	0.9984	31.8	1.41	0.9978	24.8
18B	1.72	0.9970	24.1	2.31	0.9972	16.1
17B	1.51	0.9976	24.8	1.71	0.9964	20.7
16B	1.71	0.9976	25.3	2.04	0.9983	16.7
15B	1.80	0.9973	20.2	2.04	0.9943	16.9
20D	1.30	0.9984	26.1	1.72	0.9989	19.3
19D	1.28	0.9986	40.3	1.58	0.9969	20.3
18D	1.54	0.9978	20.8	1.71	0.9976	20.3
17D	1.70	0.9982	20.4	2.03	0.9966	13.8
16D	1.70	0.9975	28.3	2.02	0.9981	11.8
15D	1.73	0.9988	26.2	2.03	0.9953	12.4
14D	2.03	0.9981	21.8	2.12	0.9940	11.1
13D	2.21	0.9986	18.1	2.48	0.9922	9.3

DISCUSSION

Frequency Content

Phase 2 testing also produced consistent results for frequency analysis. The main differences between the two phases were that over twice the number of cables was tested during the second phase and, more importantly, cables from all fans were tested. While in phase 1, cables were tested in only one outer and one inner fan (fans A and C, respectively), phase 2 tested both sets of outer and inner fans so they could be appropriately compared. Once data from all of the runs were averaged for each cable, the resulting average frequencies were entered into graphs so they could be compared across all cables for each mode. Figure 50 below shows the graph for the first mode comparing the frequencies obtained across each fan of cables during phase 2 testing. Take note that fans A and D are the cables outside the pylons, while fans B and C are the longer cables supporting the main bridge deck. The remaining graphs for modes 2 through 7 can be found in appendix B.

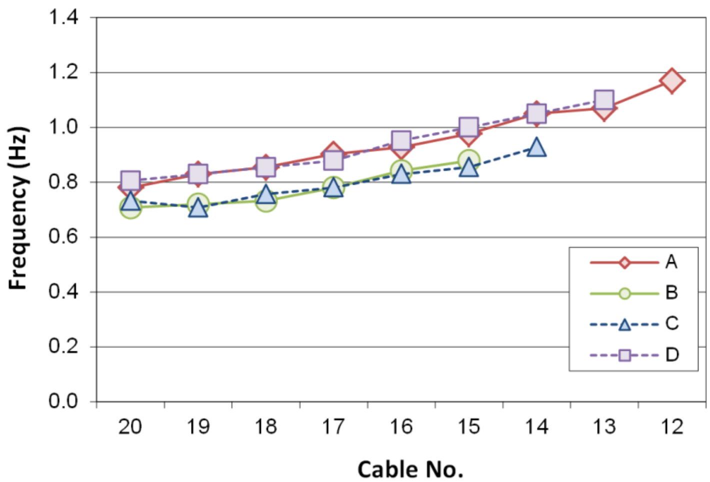


Figure 50. Graph. First mode frequencies from phase 2 testing.

Similar to the first phase of testing, the data obtained from phase 2 produced clear power spectrum densities, allowing the capture of mode frequencies up to the seventh harmonic. The spectral density graphs were slightly clearer in the higher frequencies, allowing a value for each mode to be extracted for over 97 percent of the cable runs performed.

Damping Ratios

The installation of dampers on the cable-stays had a noticeable impact on the damping ratio values, causing the damping ratios to increase by at least a factor of 5, and sometimes as high as 15. In general, first mode damping ratios for phase 1 testing were between 0.10 to 0.39 percent, where in phase 2 they ranged between 1.22 to 2.21 percent.

The damping ratios obtained during phase 2 testing were generally more consistent than their phase 1 counterparts, but still had some discrepancies that need to be addressed.

Since two accelerometers are used during testing to provide redundancy in the data, mainly to address the possibility of one being mounted in the proximity of a node at higher frequency, it was found that the two boxes rarely produced identical damping ratio data. For the majority of cases, the damping ratio obtained from box 2 was higher, for some cables up to 30 percent higher. For first mode data, 28 of 30 cables had higher damping ratios from box 2 data, while for the second mode data this ratio fell to 21 of 30 cables. Since the accelerometer in box 2 was mounted on the cable closer to the anchorage and the damper, it experienced higher levels of damping than the accelerometer located closer to the cable's mid-span.

There is a greater correlation in phase 2 data between cable length and damping ratio. As the cable length decreases, the damping ratio almost always increases. There are a few exceptions visible within the plots for each fan of cables, but there is definitely a stronger correlation than in similar plots from phase 1. Conversely, there is no correlation between cable length and the size of the confidence interval. The Student-t test gives a range of values from which between there is a 90 percent confidence that the mean of the damping ratio is located. For phase 2 testing, this range varied from 0.05 to 0.40 for the damping ratio, comparable to 2.5 to 16 percent of the mean value, and it varied in no pattern related to cable length or size. These correlations and lack thereof held true for both the first and second modes.

Another obvious result of the addition of dampers was that the length of the decay period was shortened significantly. For first mode decay, the period lasted on average 28.5 s for box 1 and 20.6 s for box 2, where the period was measured as the longest amount of time a best-fit line could overlay the data points with a correlation greater than 0.9900. Some periods were measured as high as 50.2 s. For second mode decay, the periods were much shorter, averaging 16.3 s for box 1 and 15.4 s for box 2.

In order to help determine the period length that would correspond to damping ratio with the highest correlation, multiple values for cable 20A were tested and plotted against each other to see if there were any advantages to any specific method. First, frequencies were chosen for the low and high bandpass values, which remained constant for each set of tests. Next, the peaks were analyzed using overlapping and increasing period lengths. The lengths would start at 15 s and be staggered by 5 s intervals across the duration of the decay. Then the period length would increase to 20 s and the method repeated until the period length roughly matched the entire decay, which usually happened between 35 and 45 s. The results of these tests are varied. The damping ratios obtained using the shorter periods had great variance proving that the decay curve is not linear and where the ratio is calculated will affect the final damping value obtained. Sometimes the damping ratio would start out low and get higher as the interval was delayed, other times the opposite happened, and yet other times the damping ratio would increase then decrease. Using shorter interval periods did not ensure higher correlation either, as sometimes the correlation would actually be lower than one calculated over a longer period.

This analysis was instrumental in deciding that a decay period would be chosen by the longest possible sample time span without dropping below a desired correlation threshold usually set around 0.995 or higher.

Scruton Number Analysis

Damping values obtained during phase 2 testing were entered into the equation in figure 34 in order to calculate the resulting Scruton number. The results varied between 7 and 12, which is significantly above the target value of 5 for cables with aerodynamic surface treatments. Table 5 shows the full range of Scruton numbers for the cable-stays tested.

Table 5. Phase 2 Scruton number.

Cable Number	Scruton Number
20A	8.4
19A	8.0
18A	11.9
17A	8.9
16A	9.9
15A	10.3
14A	10.8
13A	10.6
12A	11.4
20C	7.8
19C	8.0
18C	9.6
17C	9.4
16C	11.5
15C	9.9
14C	11.0
20B	7.6
19B	6.7
18B	9.5
17B	8.2
16B	9.4
15B	9.5
20D	7.2
19D	7.1
18D	8.6
17D	9.2
16D	9.3
15D	9.2
14D	11.0
13D	11.7

Aerodynamic Damping

After inconclusive results regarding the effects of aerodynamic damping for phase 1 data, the effect was again studied, this time for the data obtained during phase 2 testing. Wind speed and direction data were plugged into the equation in figure 35, Macdonald's formula for finding an equivalent wind speed, and the results were tabulated and then plotted. Since phase 2 contained both a higher average number of tests completed for each cable and more cables tested in total, the hope was to find better evidence of the aerodynamic damping effect.

The results from the formula were plotted against the average damping values, where a regression line could connect the data points and the corresponding crossing on the y-axis would be the remaining structural damping. However, once again, virtually every plot showed little correlation between equivalent wind speed and damping, and no best-fit lines could be accurately determined. Despite the higher number of data points, the data did not trend in any consistent direction. Almost 90 percent of R^2-values of the regression lines for each cable were below 0.3, indicating very poor correlation. Further studies using the formula should be conducted focusing on fewer cables and a much broader variation of wind speeds and directions.

CHAPTER 6. SUMMARY OF COMPARISONS

FREQUENCY

The frequencies obtained from phase 1 and phase 2 testing for the cables in fans A and C were nearly equivalent, confirming that damper installation did not affect frequency. Phase 2 testing also showed that frequencies compared well between similar cables from the symmetrically matching fans. The graphs comparing the first two modes between the two phases are shown in figure 51 and figure 52. The remaining graphs for modes 3 through 7 can be found in appendix B. On average, the frequencies match within 3 percent, although the frequencies on some of the shorter cables in the higher modes differed as much as 8 percent.

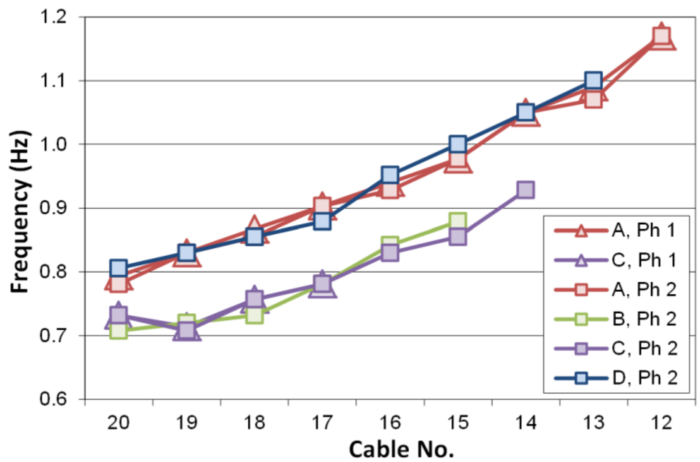


Figure 51. Graph. First mode frequencies.

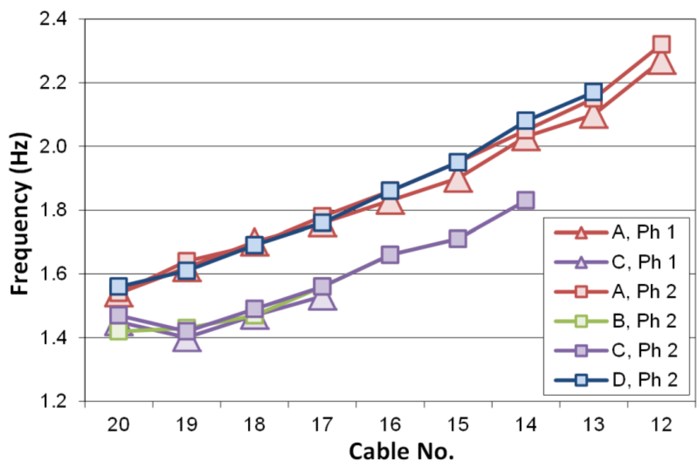


Figure 52. Graph. Second mode frequencies.

First mode theoretical frequencies were calculated for each cable using the string theory equation whose solution is shown in figure 4. These frequencies were then plotted against the field data and the results are shown in figure 53 and figure 54, from phase 1 and phase 2 testing, respectively. Results compared favorably between field and theory, however the longest cables found in fans B and C varied by a small percentage. Complete tables of the numerical values of the first mode theoretical frequencies are presented in appendix A.

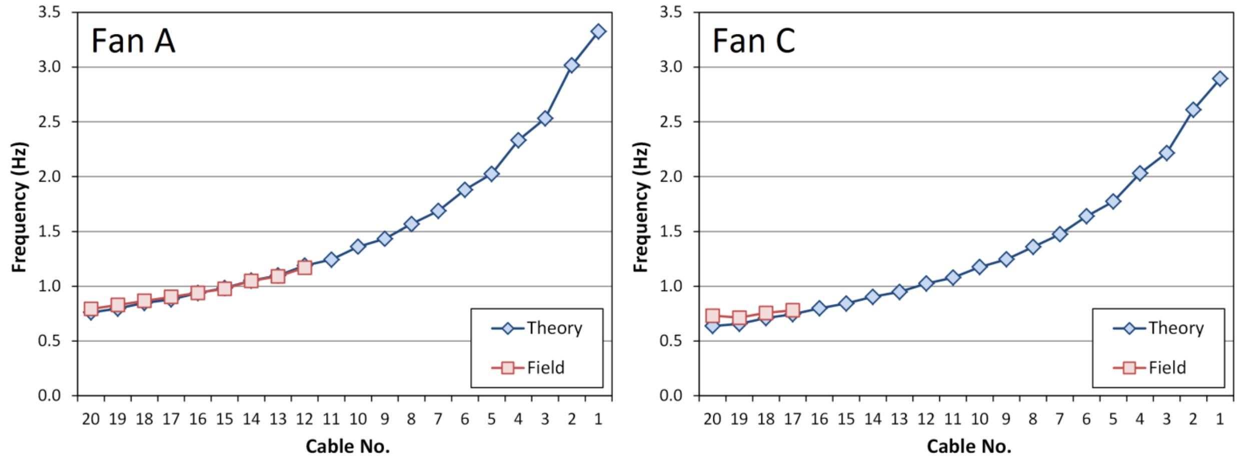


Figure 53. Graph. First mode theoretical frequencies versus phase 1 field data.

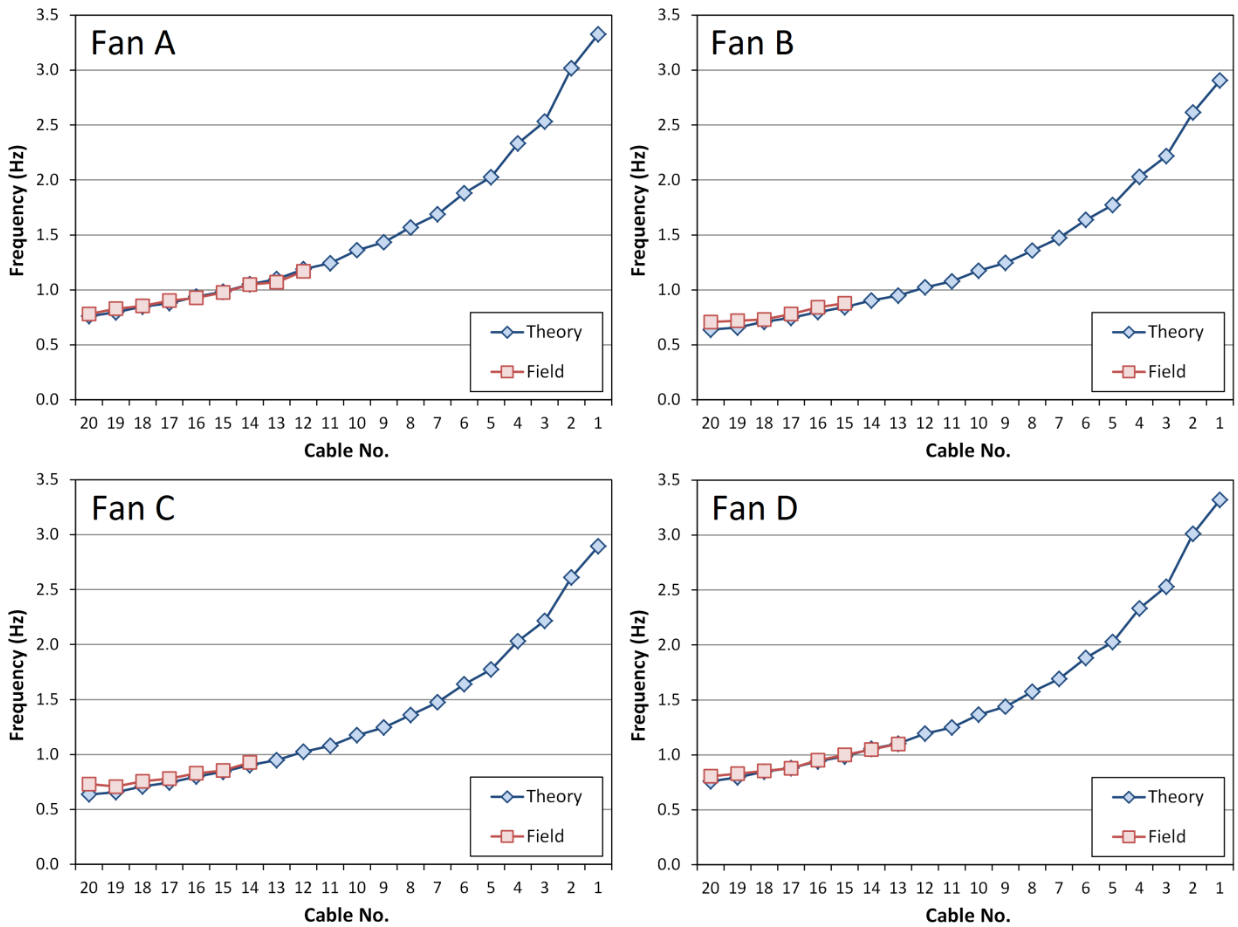


Figure 54. Graph. First mode theoretical frequencies versus phase 2 field data.

DAMPING

Differences in damping between phase 1 and phase 2 data were readily apparent. Cable vibrations comparatively lasted only a fraction of the time after damper installation, which was clearly evident in the damping curves. Figure 55 shows a comparison of the decay curves before and after damper installation.

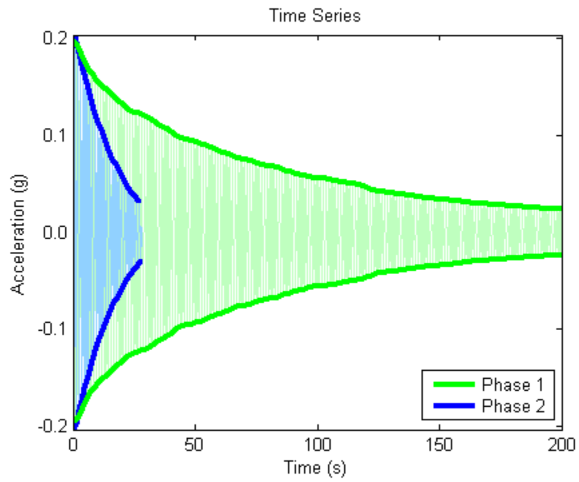


Figure 55. Graph. Comparison of the decay curves between phase 1 and phase 2 for cable 19A.

The installation of dampers on the cable-stays had a tremendous impact on the damping ratio values, causing the damping ratios to increase by at least a factor of 5, and sometimes as high as 15. In general, first mode damping ratios for phase 1 testing were between 0.10 and 0.39 percent, where in phase 2 they ranged from 1.22 to 2.21 percent. Second mode damping ratios increased from 0.17 to 0.46 percent in phase 1 to 1.41 to 2.48 percent in phase 2. Figure 56 and figure 57 show the comparison of the damping ratios obtained from the cables tested in fan A between the two phases.

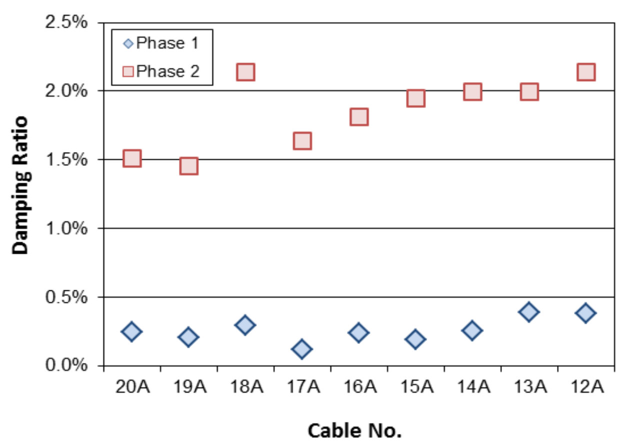


Figure 56. Graph. Comparison of first mode damping ratios.

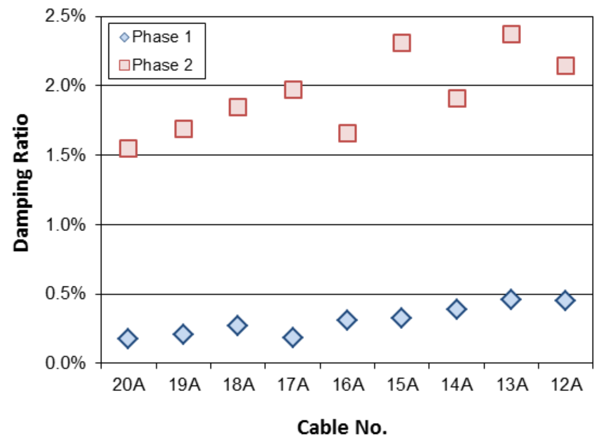


Figure 57. Graph. Comparison of second mode damping ratios.

SCRUTON NUMBER

Before the installation of dampers, Scruton numbers for the cable stays were much lower than the recommended minimum value of 10 for controlling rain/wind-induced vibrations, even falling below the reduced value of 5 allowed for cables with an aerodynamic surface treatment. Phase 1 testing produced Scruton numbers ranging between 0.6 and 2.0. In phase 2 testing, the Scruton numbers climbed to acceptable levels, ranging between 7 and 12. A comparison of the values for the two phases of testing in fan A is shown in figure 58.

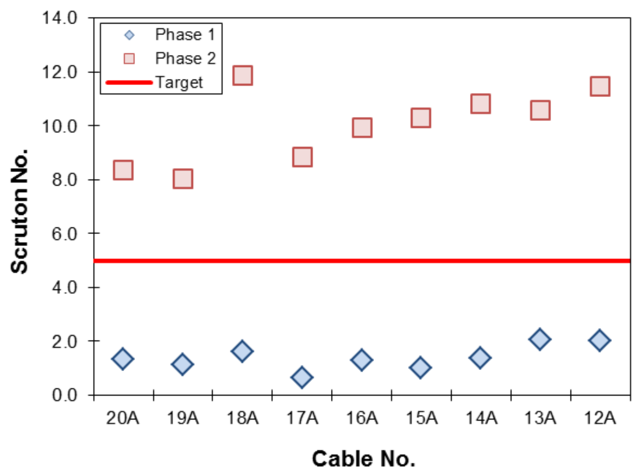


Figure 58. Graph. Comparison of Scruton numbers.

CHAPTER 7. CONCLUSIONS

Vibration testing was performed on the cable-stays of the Penobscot Narrows Bridge, located between Verona Island and Prospect, ME, by manually exciting the cable-stays and measuring the decay with accelerometers and a portable data acquisition system. The vibration data underwent post-processing using various filters. Natural frequencies and damping ratios were extracted for the tested cable-stays. Confidence intervals on the mean were found for the cables in both the first and second modes.

For phase 1 testing, measured first mode frequencies for the fan A cables tested varied from 0.79 to 1.17 Hz, while those for the longer fan C cables varied from 0.71 to 0.81 Hz. Following installation of the external dampers (phase 2), frequencies were similar indicating that the dampers had little effect on frequency. Results for similar fans A and D as well as those for fans B and C compared well indicating that cables with similar unit mass, tension, and details in different locations have the same dynamic behavior. Measured frequencies compared well with theoretical values based upon the string formula and bridge information provided by the designers.

For phase 1 testing, damping ratios for all cables tested varied from 0.10 to 0.39 percent for the first mode and from 0.17 to 0.46 percent for the second mode. As expected, these ranges increased for phase 2 testing after the installation of dampers, from 1.22 to 2.21 percent for the first mode and from 1.41 to 2.48 percent for the second mode. Analysis indicated that measured damping ratios depend on the magnitude of vibration, suggesting the possibility of nonlinear or nonviscous type behavior of the cables.

The effects of aerodynamic damping on total damping were also studied. While a trend between wind speed and total damping is still possible, the total number of test runs for each cable was relatively modest and the wind conditions during the test period were too limited in scope to create a statistically significant regression line for separating aerodynamic from total damping. Future testing that focuses on the extraction of aerodynamic damping should consider more test runs for each cable, preferably during a much broader range of wind speeds and directions than in the testing reported here.

Initial Scruton values, which are used as a criterion to determine effective cable vibration mitigation, ranged from 0.6 to 2.1 before the installation of dampers. This is well below the target value of five for cables with aerodynamic surface treatments, such as the helical fillet used here. On the other hand, final Scruton values following installation of the dampers ranged from 7 to 12 and were well above the target value of 5 for the cables tested.

APPENDIX A. MODE FREQUENCY TABLES

Table 6. Phase 1 mode frequencies (Hz).

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
20A	1[A]	0.794	1.54	—	—	—	—	—	0.794	1.54	—	—	—	—	—
20A	2	0.794	1.54	2.36	3.11	3.88	4.72	5.48	0.794	1.54	2.33	3.08	3.91	4.72	5.48
20A	3	0.781	1.54	2.36	3.11	3.81	4.72	5.47	0.781	1.54	2.33	3.08	3.80	4.72	5.47
20A	4	0.787	1.54	2.36	3.11	3.74	4.72	5.47	0.787	1.54	2.33	3.08	3.82	4.72	5.47
20A	5	0.794	1.54	2.37	3.11	3.89	4.72	5.47	0.794	1.54	2.33	3.08	3.89	4.72	5.48
20A	6	0.781	1.54	2.36	3.11	3.88	4.72	5.48	0.781	1.54	2.33	3.08	3.89	4.72	5.48
20A	7	0.794	1.54	2.30	3.11	3.83	4.72	5.51	0.794	1.54	2.30	3.08	3.82	4.77	5.51
20A	8	0.787	1.54	2.29	3.11	—	—	—	0.787	1.54	2.29	3.08	—	—	—
19A	1[A]	0.830	1.64	—	—	—	—	—	0.830	1.64	—	—	—	—	—
19A	2	0.830	1.64	2.41	3.27	—	—	—	0.830	1.64	2.41	3.27	—	—	—
19A	3	0.830	1.62	2.50	3.26	4.13	5.01	5.79	0.830	1.62	2.50	3.26	4.13	5.01	5.80
19A	4	0.830	1.54	2.31	3.09	3.85	—	—	0.830	1.54	2.31	3.09	—	—	—
19A	5	0.830	1.62	2.39	3.26	3.99	—	—	0.830	1.62	2.41	3.26	3.99	4.82	—
19A	6	0.836	1.62	2.39	3.25	4.13	4.99	—	0.836	1.62	2.41	3.26	3.97	4.99	—
19A	7	0.830	1.62	2.38	3.21	3.99	4.86	—	0.830	1.62	2.39	3.27	3.97	4.85	—
19A	8	0.830	1.64	2.49	3.27	4.13	4.93	—	0.830	1.64	2.49	3.27	4.13	4.91	5.81
19A	9	0.830	1.64	2.34	3.32	4.13	5.01	—	0.830	1.64	2.49	3.30	—	5.01	—
18A	1[A]	0.879	1.71	2.47	—	—	—	—	0.879	1.71	2.47	—	—	—	—
18A	2	0.856	1.69	2.54	3.37	4.20	5.10	5.88	0.856	1.69	2.54	3.39	4.25	5.10	5.86
18A	3	0.855	1.69	2.47	3.37	4.18	4.98	—	0.855	1.69	2.47	3.30	4.10	4.98	—
18A	4	0.879	1.69	2.44	3.25	4.15	4.96	—	0.879	1.69	2.44	3.25	4.12	4.86	—
18A	5[B]	0.879	1.71	2.50	—	—	—	—	—	—	—	—	—	—	—
18A	6	0.867	1.71	2.41	3.41	4.14	—	—	0.867	1.71	2.53	3.41	4.14	—	—
18A	7	0.867	1.71	2.43	3.24	4.16	4.85	—	0.867	1.71	2.44	3.25	4.15	4.85	—
18A	8	0.867	1.70	2.52	3.41	4.19	5.14	—	0.867	1.70	2.53	3.42	4.18	5.14	—
18A	9	0.867	1.70	2.54	3.41	4.22	—	—	0.867	1.70	2.54	3.41	4.27	5.23	—
18A	10	0.867	1.70	2.49	3.39	4.19	5.23	—	0.867	1.70	2.49	3.39	4.18	5.23	—
18A	11	0.879	1.71	2.47	3.37	4.18	5.20	—	0.878	1.71	2.47	3.27	4.15	5.23	—
18A	12	0.867	1.70	2.41	3.39	—	—	—	0.867	1.70	2.42	—	—	—	—
17A	1[A]	0.903	1.76	—	—	—	—	—	0.903	1.76	—	—	—	—	—
17A	2	0.903	1.76	2.42	3.20	—	—	—	0.903	1.76	2.42	3.20	—	—	—
17A	3[B]	0.903	1.76	2.49	3.53	4.25	—	—	—	—	—	—	—	—	—
17A	4	0.928	1.76	2.49	3.27	4.35	—	—	0.928	1.76	—	—	—	—	—
17A	5	0.794	1.76	2.38	3.17	4.35	—	—	0.794	1.76	2.43	3.25	—	—	—
17A	6	0.903	1.76	2.37	3.16	—	—	—	0.903	1.76	2.38	3.24	—	—	—
17A	7	0.818	1.76	2.44	3.41	4.24	—	—	0.818	1.76	2.44	3.24	4.20	—	—
17A	8	0.903	1.76	2.48	3.53	4.30	5.27	—	0.903	1.76	2.50	3.53	4.24	—	—
17A	9	0.903	1.76	2.66	3.52	4.42	5.27	6.19	0.903	1.76	2.66	3.52	4.36	5.27	6.19
16A	1[A]	0.940	1.84	2.75	—	—	—	—	0.940	1.84	2.75	—	—	—	—
16A	2	0.940	1.84	2.66	3.67	4.57	5.65	6.54	0.940	1.84	2.66	3.67	4.60	5.65	—
16A	3	0.940	1.83	2.63	3.67	—	—	—	0.940	1.83	2.63	—	—	—	—
16A	4	0.940	1.83	2.77	3.67	4.63	5.64	6.52	0.940	1.83	2.78	3.78	4.63	5.64	6.52
16A	5	0.940	1.83	2.77	3.65	4.59	5.63	6.52	0.940	1.83	2.82	3.70	4.59	5.63	6.52
16A	6	0.940	1.82	2.64	3.64	4.53	5.63	—	0.940	1.82	2.73	3.64	4.53	5.63	6.37
16A	7	0.940	1.83	2.77	3.76	4.59	5.64	6.52	0.940	1.83	2.82	3.70	4.60	5.64	6.53
16A	8	0.940	1.83	2.77	3.64	4.62	5.63	—	0.940	1.83	2.81	3.71	4.62	5.63	—
15A	1[A]	0.977	1.93	—	—	—	—	—	0.977	1.93	—	—	—	—	—
15A	2	0.977	1.90	2.88	3.80	4.77	5.87	—	0.977	1.90	2.80	3.82	4.77	5.87	—

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
15A	3	0.977	1.90	2.76	3.67	4.63	—	—	0.977	1.90	2.80	—	—	—	—
15A	4	0.977	1.89	2.87	3.78	4.76	—	—	0.977	1.90	2.83	3.80	4.76	—	—
15A	5	0.977	1.90	2.87	3.78	4.79	5.87	6.64	0.977	1.90	2.84	3.86	4.79	5.87	6.65
15A	6	0.977	1.90	2.87	3.92	4.76	5.87	6.69	0.977	1.90	2.93	3.81	4.76	5.87	6.69
15A	7	0.977	1.90	2.87	3.79	4.77	5.87	6.65	0.977	1.90	2.84	3.79	4.83	5.87	6.68
14A	1[A]	1.05	2.06	—	—	—	—	—	1.05	2.06	—	—	—	—	—
14A	2	1.05	2.04	2.98	4.05	5.16	6.30	7.14	1.05	2.04	2.99	4.19	5.15	6.30	—
14A	3	1.05	2.03	3.08	4.03	5.15	6.27	—	1.05	2.03	3.05	4.18	5.15	6.27	—
14A	4	1.04	2.03	2.99	4.03	5.14	6.26	7.25	1.04	2.03	3.00	4.18	5.14	6.26	7.25
14A	5	1.04	2.03	3.08	4.04	5.15	6.26	7.25	1.04	2.03	3.06	4.18	5.14	6.26	7.25
14A	6	1.04	2.03	2.92	3.92	4.90	6.26	—	1.04	2.03	2.93	—	—	—	—
14A	7	1.05	2.05	—	3.93	5.18	—	—	1.05	2.05	—	3.91	5.18	—	—
14A	8	1.04	2.03	2.95	3.99	5.09	6.26	7.25	1.04	2.03	2.95	4.18	5.09	6.26	—
13A	1[A]	1.09	2.12	—	—	—	—	—	1.09	2.12	—	—	—	—	—
13A	2	1.09	2.11	2.97	4.04	—	—	—	1.09	2.11	2.98	3.90	—	—	—
13A	3	1.09	2.11	3.14	4.19	5.24	6.37	7.40	1.09	2.10	3.14	—	5.24	6.37	—
13A	4	1.09	2.10	2.99	4.20	—	—	—	1.09	2.10	3.16	—	—	—	—
13A	5	1.09	2.10	3.17	4.18	5.24	6.31	—	1.09	2.10	3.15	—	5.25	6.30	7.30
13A	6	1.09	2.10	3.13	4.05	5.13	—	—	1.09	2.10	3.08	—	—	—	—
13A	7	1.09	2.10	3.15	4.18	5.24	6.37	7.32	1.09	2.10	3.14	—	5.25	6.32	7.30
12A	1[A]	1.17	2.28	3.26	—	—	—	—	1.17	2.28	—	—	—	—	—
12A	2	1.17	2.28	3.17	—	—	—	—	1.17	2.28	—	—	—	—	—
12A	3	1.17	2.28	—	—	—	—	—	1.17	2.28	—	—	—	—	—
12A	4	1.17	2.26	3.21	4.40	—	—	—	1.17	2.26	3.21	—	—	—	—
12A	5	1.17	2.27	3.30	4.52	—	—	—	1.17	2.27	—	—	—	—	—
12A	6	1.17	2.27	3.17	4.41	—	—	—	1.17	2.27	—	—	—	—	—
12A	7	1.17	2.26	3.27	4.36	—	—	—	1.17	2.26	—	—	—	—	—
12A	8	1.16	2.27	3.25	4.43	—	—	—	1.16	2.27	—	—	—	—	—
12A	9	1.17	2.25	3.24	4.33	—	—	—	1.17	2.25	—	—	—	—	—
12A	10	1.17	2.27	3.28	4.37	—	—	—	1.17	2.27	—	—	—	—	—
20C	1[A]	0.732	1.47	—	—	—	—	—	0.732	1.47	—	—	—	—	—
20C	2	0.745	1.45	2.20	2.89	3.66	4.43	5.14	0.745	1.45	2.22	2.87	3.66	4.44	5.14
20C	3	0.739	1.45	2.19	2.95	3.67	4.44	5.15	0.739	1.45	2.22	2.91	3.70	4.44	5.15
20C	4	0.745	1.45	2.19	2.95	3.66	4.43	5.14	0.745	1.45	2.22	2.87	3.70	4.43	5.14
20C	5	0.732	1.44	2.19	2.88	3.66	4.42	5.14	0.732	1.44	2.21	2.92	3.69	4.42	5.14
20C	6	0.732	1.44	2.22	2.93	3.66	4.42	5.13	0.732	1.44	2.22	2.93	3.66	4.42	5.13
20C	7	0.732	1.45	2.19	2.92	3.66	4.42	5.14	0.732	1.45	2.19	2.92	3.66	4.42	5.14
20C	8	0.732	1.45	2.19	2.91	3.66	4.43	5.14	0.732	1.45	2.17	2.89	3.66	4.43	5.14
19C	1[A]	0.720	1.40	—	—	—	—	—	0.720	1.40	—	—	—	—	—
19C	2	0.714	1.40	2.08	2.80	3.53	4.30	4.96	0.714	1.40	2.08	2.80	3.53	4.30	4.96
19C	3	0.714	1.40	2.12	2.80	3.53	4.28	4.96	0.714	1.40	2.11	2.80	3.53	4.30	4.96
19C	4	0.708	1.40	2.09	2.80	3.54	4.29	4.96	0.708	1.39	2.09	2.78	3.53	4.29	4.97
19C	5	0.714	1.40	2.11	2.80	3.53	4.30	4.91	0.714	1.40	2.09	2.79	3.53	4.28	4.96
19C	6	0.714	1.40	2.11	2.80	3.53	4.30	4.96	0.714	1.40	2.10	2.80	3.53	4.30	4.96
18C	1[A]	0.757	1.49	—	—	—	—	—	0.757	1.49	—	—	—	—	—
18C	2	0.751	1.47	2.17	2.94	3.70	4.52	5.18	0.751	1.47	2.18	2.94	3.70	4.52	5.18
18C	3	0.751	1.47	2.22	2.95	3.74	4.52	5.24	0.751	1.47	2.22	2.95	3.72	4.52	5.23
18C	4	0.751	1.47	2.16	2.95	3.73	4.52	5.24	0.751	1.47	2.15	2.97	3.71	4.52	5.23
18C	5	0.757	1.47	2.22	2.94	3.70	4.50	5.15	0.757	1.47	2.20	2.94	3.71	4.43	5.15
18C	6	0.757	1.48	2.14	2.94	3.73	4.52	5.24	0.757	1.48	2.14	2.98	3.72	4.52	5.24
17C	1[A]	0.781	1.54	2.25	2.98	—	—	—	0.781	1.54	2.25	3.05	—	—	—

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
17C	2	0.781	1.53	2.27	3.04	3.86	4.68	5.43	0.781	1.53	2.27	3.06	3.85	4.68	5.42
17C	3	0.781	1.53	2.26	3.03	3.86	4.69	5.42	0.781	1.53	2.26	3.05	3.83	4.69	5.42
17C	4	0.781	1.53	2.30	3.05	3.86	4.68	5.43	0.781	1.53	2.28	3.06	3.86	4.68	5.42
17C	5	0.781	1.53	2.30	3.05	3.86	4.68	5.43	0.781	1.53	2.27	3.05	3.86	4.68	5.43

[A] Baseline run.
[B] Unreadable data.

Table 7. Phase 1 averaged mode frequencies (Hz).

Cable	1	2	3	4	5	6	7
20A	0.794	1.54	2.33	3.11	3.89	4.72	5.48
19A	0.830	1.62	2.41	3.27	4.13	4.99	5.80
18A	0.867	1.70	2.47	3.37	4.18	5.10	5.88
17A	0.903	1.76	2.49	3.41	4.30	5.27	6.19
16A	0.940	1.83	2.75	3.67	4.59	5.64	6.52
15A	0.977	1.90	2.87	3.80	4.76	5.87	6.65
14A	1.05	2.03	3.00	4.05	5.14	6.26	7.25
13A	1.09	2.10	3.13	4.18	5.24	6.37	7.30
12A	1.17	2.27	3.24	4.40	—	—	—
20C	0.732	1.45	2.19	2.92	3.66	4.43	5.14
19C	0.714	1.40	2.09	2.80	3.53	4.29	4.96
18C	0.757	1.47	2.18	2.94	3.72	4.52	5.23
17C	0.781	1.53	2.27	3.05	3.86	4.68	5.43

Table 8. Phase 1 theoretical frequencies of the first mode (Hz).

Cable	Frequency	Cable	Frequency
20A	0.761	20C	0.637
19A	0.796	19C	0.657
18A	0.848	18C	0.710
17A	0.880	17C	0.745
16A	0.939	16C	0.799
15A	0.984	15C	0.843
14A	1.052	14C	0.904
13A	1.099	13C	0.949
12A	1.189	12C	1.025
11A	1.244	11C	1.079
10A	1.361	10C	1.176
9A	1.434	9C	1.246
8A	1.567	8C	1.360
7A	1.687	7C	1.475
6A	1.880	6C	1.638
5A	2.025	5C	1.773
4A	2.332	4C	2.030
3A	2.531	3C	2.216
2A	3.017	2C	2.611
1A	3.325	1C	2.894

Table 9. Phase 2 mode frequencies (Hz).

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
20A	1	0.781	1.54	2.32	3.10	3.88	4.69	5.44	0.781	1.54	2.32	3.10	3.88	4.69	5.44
20A	2	0.781	1.54	2.27	3.08	3.88	4.64	5.44	0.781	1.54	2.32	3.10	3.88	4.66	5.44
20A	3	0.781	1.56	2.37	3.13	3.93	4.71	5.47	0.781	1.56	2.39	3.15	3.93	4.71	5.47
20A	4	0.781	1.54	2.34	3.10	3.91	4.69	5.44	0.781	1.54	2.32	3.10	3.91	4.69	5.44
20A	5	0.781	1.54	2.34	3.10	3.88	4.69	5.44	0.781	1.54	2.32	3.10	3.88	4.66	5.44
20A	6	0.781	1.54	2.34	3.10	3.91	4.69	5.44	0.781	1.54	2.32	3.10	3.91	4.69	5.44
20A	7	0.781	1.54	2.34	3.10	3.91	4.69	5.44	0.781	1.56	2.32	3.10	3.91	4.69	5.44
20A	8	0.781	1.56	2.34	3.13	3.91	4.69	5.47	0.781	1.56	2.34	3.10	3.91	4.69	5.47
20A	9	0.781	1.56	2.34	3.13	3.91	4.69	5.47	0.781	1.56	2.37	3.13	3.91	4.69	5.47
20A	10	0.781	1.56	2.34	3.10	3.91	4.69	5.47	0.781	1.56	2.32	3.10	3.91	4.69	5.47
19A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19A	2	0.830	1.64	2.47	3.27	4.15	4.98	5.79	0.830	1.64	2.47	3.27	4.15	4.96	5.79
19A	3	0.830	1.64	2.47	3.27	4.13	4.98	5.81	0.830	1.64	2.47	3.27	4.13	4.96	5.79
19A	4	0.830	1.64	2.47	3.30	4.15	4.98	5.81	0.830	1.64	2.44	3.27	4.15	4.96	5.79
19A	5	0.830	1.66	2.49	3.32	4.15	4.98	5.79	0.830	1.66	2.49	3.30	4.15	4.98	5.79
19A	6	0.830	1.64	2.47	3.30	4.13	4.96	5.79	0.830	1.64	2.47	3.30	4.13	4.96	5.76
19A	7	0.830	1.64	2.47	3.30	4.10	4.98	5.84	0.830	1.64	2.44	3.27	4.13	4.93	5.81
19A	8	0.830	1.64	2.47	3.30	4.13	4.98	5.81	0.830	1.64	2.47	3.30	4.13	4.98	5.79
18A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18A	2	0.855	1.69	2.56	3.39	4.20	5.13	6.03	0.855	1.69	2.61	3.37	4.30	5.13	6.01
18A	3	0.855	1.69	2.54	3.39	4.22	5.13	6.03	0.855	1.69	2.54	3.37	4.27	5.13	6.03
18A	4	0.855	1.69	2.54	3.37	4.18	5.10	6.06	0.855	1.69	2.54	3.37	4.37	5.10	5.88
18A	5	0.855	1.69	2.56	3.39	4.25	5.13	5.91	0.855	1.69	2.54	3.37	4.27	5.13	5.91
18A	6	0.855	1.71	2.56	3.42	4.27	5.15	6.03	0.855	1.71	2.59	3.37	4.27	5.15	6.01
18A	7	0.855	1.69	2.54	3.37	4.25	5.08	5.98	0.855	1.69	2.54	3.37	4.27	5.08	5.98
18A	8	0.855	1.69	2.56	3.39	4.27	5.13	6.06	0.855	1.69	2.54	3.37	4.27	5.13	5.93
18A	9	0.855	1.69	2.54	3.39	4.25	5.10	6.06	0.855	1.69	2.54	3.37	4.27	5.10	5.98
17A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17A	2	0.903	1.76	2.66	3.52	4.42	5.42	6.30	0.903	1.76	2.64	3.56	4.37	5.40	6.42
17A	3	0.903	1.78	2.71	3.59	4.52	5.42	6.40	0.903	1.78	2.66	3.76	4.54	5.42	6.40
17A	4	0.903	1.78	2.71	3.52	4.42	5.42	6.37	0.903	1.78	2.64	3.54	4.52	5.42	6.27
17A	5	0.903	1.78	2.69	3.56	4.42	5.42	6.30	0.903	1.78	2.66	3.59	4.37	5.42	6.42
17A	6	0.903	1.76	2.73	3.59	4.54	5.44	6.40	0.903	1.76	2.73	3.81	4.54	5.44	6.40
17A	7	0.903	1.78	2.66	3.56	4.44	5.42	6.35	0.903	1.78	2.76	3.59	4.54	5.42	6.32
17A	8	0.903	1.81	2.71	3.66	4.52	5.42	6.42	0.903	1.81	2.69	3.61	4.52	5.42	6.40
17A	9	0.903	1.78	2.71	3.59	4.52	5.42	6.42	0.903	1.78	2.71	3.69	4.54	5.42	6.42
17A	10	0.903	1.78	2.71	3.59	4.52	5.44	6.42	0.928	1.81	2.73	3.61	4.54	5.42	6.30
16A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16A	2[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16A	3	0.928	1.83	2.78	3.69	4.61	5.64	6.59	0.928	1.83	2.76	3.71	4.61	5.64	6.57
16A	4	0.928	1.83	2.78	3.69	4.61	5.64	6.57	0.928	1.83	2.73	3.69	4.61	5.64	6.54
16A	5	0.928	1.86	2.76	3.69	4.61	5.64	6.54	0.928	1.86	2.76	3.71	4.64	5.64	6.57
16A	6	0.928	1.81	2.78	3.71	4.59	6.62	6.59	0.928	1.86	2.73	3.71	4.59	5.62	6.54
16A	7	0.928	1.86	2.81	3.69	4.66	5.64	6.59	0.952	1.86	2.81	3.74	4.69	5.64	6.59
16A	8	0.952	1.86	2.83	—	4.69	5.64	6.62	0.952	1.86	2.83	3.74	4.69	5.64	6.62
16A	9	0.928	1.86	2.83	3.71	4.69	5.66	6.64	0.928	1.86	2.83	3.71	4.69	5.66	6.64
16A	10	0.952	1.83	2.81	3.69	4.61	5.64	6.62	0.952	1.83	2.78	3.71	4.61	5.64	6.64
16A	11	0.952	1.90	2.83	3.71	4.59	5.66	6.69	0.952	1.90	2.83	3.71	4.66	5.66	6.71
15A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15A	2	0.977	1.95	2.93	3.91	4.91	5.91	6.89	0.977	1.95	2.91	3.91	4.91	5.88	6.93

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
15A	3	0.977	1.95	2.93	3.91	4.91	5.91	6.89	0.977	1.93	2.88	3.86	4.88	5.88	6.91
15A	4	0.977	1.95	2.95	3.93	4.93	5.91	6.98	0.977	1.95	2.95	3.93	4.91	5.91	6.98
15A	5	0.977	1.93	2.93	3.88	4.86	5.91	6.84	0.977	1.93	2.88	3.88	4.88	5.88	6.91
15A	6	0.977	1.93	2.93	3.88	4.86	5.88	6.84	0.977	1.93	2.88	3.88	4.86	5.88	6.93
15A	7	0.977	1.95	2.95	3.93	4.92	5.93	6.79	0.977	1.95	2.98	4.00	4.91	5.91	6.93
15A	8	0.977	1.93	2.93	3.88	4.86	5.88	6.93	0.977	1.93	2.88	3.91	4.86	5.88	6.91
15A	9	0.977	1.95	2.93	3.91	4.83	5.86	6.84	0.977	1.95	2.93	3.86	4.93	5.86	6.84
15A	10	0.977	1.93	2.93	3.88	4.86	5.88	6.86	0.977	1.93	2.91	3.91	4.88	5.88	6.91
14A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14A	2	0.977	1.98	2.95	3.93	4.91	5.86	7.06	1.00	1.98	2.95	4.08	4.91	—	—
14A	3	1.03	2.05	3.13	4.15	5.23	6.30	7.28	1.03	2.05	3.17	4.15	5.18	6.30	7.37
14A	4	1.05	2.08	3.17	4.18	5.23	6.30	7.32	1.05	2.08	3.17	4.18	5.20	6.30	7.37
14A	5	1.05	2.03	3.03	4.13	5.15	6.30	7.25	1.05	2.03	3.03	4.13	5.15	6.27	7.35
14A	6	1.05	2.03	3.08	4.13	5.15	6.30	7.25	1.05	2.05	3.05	4.10	5.15	6.30	7.20
14A	7	1.03	2.05	3.13	4.15	5.18	6.30	7.23	1.03	2.05	3.13	4.10	5.18	6.25	7.23
14A	8	1.05	2.05	3.15	4.15	5.18	6.30	7.25	1.05	2.05	3.13	4.13	5.18	6.30	7.23
14A	9	1.05	2.05	3.08	4.15	5.15	6.30	7.25	1.05	2.05	3.08	4.13	5.18	6.27	7.23
14A	10	1.05	2.08	3.10	4.15	5.18	6.30	7.28	1.05	2.08	3.10	4.13	5.20	6.27	7.37
14A	11	1.07	2.05	3.17	4.20	5.23	6.30	7.37	1.07	2.05	3.22	4.20	5.18	6.30	7.37
13A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13A	2	1.10	2.15	3.22	4.32	5.40	6.54	7.57	1.10	2.15	3.22	4.40	5.40	6.54	7.67
13A	3	1.07	2.12	3.22	4.32	5.40	6.54	7.54	1.07	2.15	3.20	4.35	5.37	6.54	7.59
13A	4	1.10	2.15	3.25	4.32	5.40	6.54	7.50	1.10	2.15	3.32	4.40	5.37	6.54	7.62
13A	5	1.07	2.12	3.20	4.30	5.40	6.47	7.67	1.07	2.15	3.27	4.37	5.40	6.47	7.47
13A	6	1.07	2.15	3.22	4.30	5.37	6.47	7.69	1.07	2.15	3.22	4.44	5.37	6.47	7.52
13A	7	1.07	2.12	3.20	4.27	5.37	6.45	7.52	1.07	2.12	3.20	4.27	5.37	6.45	7.45
13A	8	1.05	2.10	3.17	4.20	5.27	6.32	7.37	1.05	2.10	3.15	4.22	5.27	6.32	—
13A	9	1.07	2.12	3.17	4.22	5.30	6.35	7.37	1.07	2.12	3.17	4.25	5.27	6.35	7.45
13A	10	1.07	2.10	3.17	4.30	5.35	6.37	7.40	1.07	2.10	3.13	4.25	5.27	6.32	—
13A	11	1.07	2.12	3.22	4.30	5.37	6.49	7.47	1.07	2.12	3.27	4.30	5.37	6.49	7.57
12A	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12A	2	1.16	2.31	3.46	4.66	5.81	7.06	8.06	1.16	2.31	3.53	4.60	5.80	7.06	8.14
12A	3	1.17	2.30	3.44	4.57	5.86	7.08	8.01	1.17	2.30	3.52	4.57	5.74	7.08	8.20
12A	4	1.17	2.27	3.47	4.59	5.81	7.08	8.03	1.17	2.30	3.54	4.54	5.79	7.08	8.15
12A	5	1.17	2.32	3.49	4.66	5.84	7.08	8.03	1.17	2.32	5.54	4.66	5.81	7.08	8.23
12A	6	1.17	2.32	3.49	4.69	5.84	7.08	8.06	1.17	2.32	3.54	4.69	5.81	7.08	8.30
12A	7	1.20	2.39	3.54	4.83	5.88	7.20	8.33	1.20	2.42	3.56	4.81	5.88	7.13	8.30
12A	8	1.17	2.39	3.54	4.74	5.91	7.13	8.28	1.17	2.39	3.56	4.96	5.91	7.10	8.30
12A	9	1.17	2.32	3.49	4.66	5.84	7.10	8.23	1.17	2.32	3.47	4.69	5.81	7.10	8.25
12A	10	1.17	2.37	3.54	4.69	5.84	7.10	8.33	1.17	2.37	3.59	4.74	5.81	7.10	8.23
12A	11	1.17	2.37	3.52	4.69	5.86	7.10	8.20	1.17	2.37	3.54	4.71	5.93	7.10	8.23
20C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20C	2[B]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20C	3[B]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20C	4[B]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20C	5	0.745	1.47	2.22	2.93	—	4.41	5.18	0.745	1.47	2.22	2.94	3.70	4.41	5.18
20C	6	0.732	1.47	2.22	2.91	3.66	4.37	5.15	0.732	1.47	2.17	2.88	3.69	4.37	5.15
20C	7	0.732	1.44	2.22	2.91	3.69	4.40	5.18	0.732	1.47	2.20	2.95	3.69	4.40	5.18
20C	8	0.732	1.47	2.22	2.93	3.69	4.44	5.18	0.732	1.47	2.20	2.95	3.69	4.44	5.18
20C	9	0.732	1.47	2.22	2.91	3.66	4.37	5.15	0.732	1.47	2.20	2.95	3.69	4.40	5.15
20C	10	0.732	1.44	2.20	2.93	3.64	4.35	5.18	0.732	1.44	2.17	2.95	3.69	4.40	5.18

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
20C	11	0.732	1.47	2.20	2.93	3.66	4.42	5.15	0.732	1.47	2.20	2.95	3.69	4.40	5.15
20C	12	0.732	1.47	2.22	2.93	3.69	4.40	5.18	0.732	1.47	2.22	2.98	3.69	4.40	5.18
20C	13	0.732	1.44	2.22	2.95	3.64	4.40	5.18	0.732	1.44	2.20	2.95	3.69	4.40	5.18
20C	14	0.732	1.47	2.21	2.93	3.66	4.38	5.15	0.732	1.47	2.22	2.95	3.69	4.40	5.15
19C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19C	2	0.708	1.42	2.15	2.84	3.58	4.27	5.02	0.702	1.42	2.15	2.84	3.58	4.27	4.99
19C	3	0.708	1.42	2.15	2.86	3.59	4.27	5.01	0.708	1.42	2.15	2.86	3.59	4.27	5.01
19C	4	0.732	1.42	2.15	2.83	3.52	4.25	5.03	0.708	1.42	2.15	2.86	3.56	4.25	5.03
19C	5	0.708	1.42	2.15	2.83	3.56	4.27	4.98	0.708	1.42	2.15	2.86	3.56	4.27	4.98
19C	6	0.708	1.42	2.15	2.83	3.56	4.27	4.96	0.708	1.42	2.15	2.76	3.59	4.27	5.01
19C	7	0.708	1.42	2.15	2.83	3.56	4.27	4.98	0.708	1.42	2.12	2.86	3.56	4.27	5.01
19C	8	0.708	1.42	2.17	2.86	3.54	4.30	4.98	0.708	1.42	2.15	2.81	3.59	4.27	4.98
19C	9	0.708	1.42	2.15	2.83	3.56	4.27	5.01	0.708	1.42	2.15	2.88	3.59	4.27	5.01
19C	10	0.720	1.40	2.15	2.83	3.54	4.26	4.96	0.720	1.42	2.16	2.86	3.58	4.26	4.96
18C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18C	2	0.757	1.49	2.25	2.98	3.74	4.52	5.35	0.757	1.49	2.22	3.00	3.76	4.52	5.32
18C	3	0.757	1.49	2.23	2.99	3.74	4.52	5.27	0.757	1.49	2.23	2.99	3.77	4.52	5.27
18C	4	0.757	1.49	2.27	2.98	3.78	4.52	5.35	0.757	1.49	2.25	2.98	3.78	4.52	5.23
18C	5	0.757	1.49	2.27	3.00	3.81	4.52	5.23	0.757	1.49	2.25	3.00	3.78	4.52	5.27
18C	6	0.757	1.49	2.27	3.00	3.78	4.52	5.27	0.757	1.49	2.25	3.00	3.78	4.52	5.27
18C	7	0.757	1.49	2.27	3.00	3.78	4.52	5.27	0.757	1.49	2.25	3.00	3.78	4.52	5.27
18C	8	0.757	1.49	2.27	2.98	3.71	4.52	5.25	0.757	1.49	2.25	2.98	3.81	4.52	5.25
18C	9	0.757	1.49	2.27	3.00	3.81	4.52	5.27	0.757	1.50	2.27	3.00	3.77	4.52	5.27
18C	10	0.757	1.49	2.27	2.98	3.74	4.52	5.27	0.757	1.49	2.25	3.00	3.81	4.52	5.25
17C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17C	2	0.781	1.55	2.37	3.11	3.80	4.70	5.54	0.781	1.55	2.43	3.11	3.88	4.70	5.54
17C	3	0.781	1.56	2.34	3.13	3.88	4.69	5.52	0.781	1.56	2.37	3.13	3.96	4.69	5.54
17C	4	0.781	1.55	2.36	3.13	3.88	4.70	5.53	0.794	1.55	2.37	3.14	3.94	4.70	5.53
17C	5	0.781	1.54	2.32	3.10	3.83	4.69	5.52	0.781	1.54	2.30	3.10	3.86	4.69	5.52
17C	6	0.781	1.56	2.34	3.13	3.91	4.69	5.52	0.781	1.56	2.34	3.13	3.93	4.69	5.52
17C	7	0.781	1.56	2.34	3.13	3.91	4.69	5.52	0.781	1.56	2.34	3.13	3.91	4.69	5.52
17C	8	0.781	1.56	2.34	3.13	3.88	4.69	5.52	0.781	1.56	2.34	3.13	3.93	4.69	5.52
17C	9	0.781	1.56	2.37	3.15	3.98	4.69	5.54	0.781	1.56	2.37	3.15	3.98	4.69	5.54
16C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16C	2	0.830	1.66	2.49	3.32	4.13	5.01	5.86	0.830	1.66	2.49	3.32	4.15	4.98	5.81
16C	3	0.830	1.66	2.49	3.32	4.13	4.98	5.79	0.830	1.66	2.49	3.32	4.15	4.98	5.79
16C	4	0.830	1.65	2.49	3.31	4.14	5.01	5.81	0.830	1.65	2.52	3.32	4.15	4.99	5.81
16C	5	0.830	1.64	2.47	3.30	4.13	4.98	5.76	0.830	1.64	2.47	3.30	4.13	4.96	5.76
16C	6	0.830	1.66	2.49	3.32	4.15	4.98	5.81	0.830	1.66	2.49	3.32	4.15	4.98	5.81
16C	7	0.830	1.64	2.49	3.30	4.15	4.98	5.86	0.830	1.66	2.52	3.32	4.15	4.98	5.86
16C	8	0.830	1.66	2.52	3.32	4.15	5.01	5.86	0.830	1.66	2.52	3.32	4.15	5.01	5.86
16C	9	0.830	1.66	2.52	3.35	4.18	5.03	5.88	0.830	1.66	2.52	3.35	4.18	5.03	5.88
16C	10	0.830	1.66	2.49	3.32	4.13	4.98	5.86	0.830	1.66	2.49	3.32	4.15	4.98	5.86
15C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15C	2	0.855	1.71	2.59	3.44	4.30	5.18	6.01	0.855	1.71	2.54	3.49	4.27	5.18	5.98
15C	3	0.855	1.71	2.59	3.42	4.27	5.15	5.93	0.855	1.71	2.54	3.44	4.27	5.15	6.06
15C	4	0.855	1.71	2.59	3.44	4.32	5.20	6.08	0.879	1.71	2.56	3.44	4.32	5.20	6.03
15C	5	0.855	1.69	2.59	3.42	4.35	5.15	6.01	0.855	1.69	2.54	3.42	4.22	5.15	6.01
15C	6	0.855	1.71	2.59	3.44	4.32	5.18	6.03	0.855	1.71	2.56	3.44	4.30	5.18	6.03
15C	7	0.855	1.71	2.59	3.44	4.32	5.18	6.13	0.855	1.71	2.54	3.49	4.30	5.18	6.13
15C	8	0.855	1.71	2.59	3.42	4.30	5.18	5.96	0.855	1.71	2.56	3.44	4.30	5.18	6.01

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
15C	9	0.855	1.69	2.59	3.42	4.27	5.18	6.15	0.855	1.69	2.54	3.42	4.25	5.18	6.13
15C	10	0.879	1.71	2.61	3.44	4.32	5.20	6.08	0.879	1.73	2.61	3.47	4.32	5.20	6.10
14C	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14C	2	0.928	1.81	2.73	3.66	4.57	5.49	6.49	0.928	1.83	2.73	3.64	4.57	5.49	6.49
14C	3	0.928	1.81	2.76	3.66	4.57	5.49	6.54	0.928	1.83	2.73	3.66	4.54	5.49	6.52
14C	4	0.928	1.83	2.76	3.66	4.57	5.49	6.47	0.928	1.83	2.73	3.66	4.54	5.52	6.47
14C	5	0.928	1.83	2.76	3.66	4.64	5.49	6.47	0.928	1.83	2.73	3.66	4.54	5.52	6.47
14C	6	0.928	1.83	2.78	3.69	4.61	5.54	6.52	0.928	1.86	2.81	3.69	5.64	5.57	6.52
14C	7	0.928	1.83	2.76	3.66	4.57	5.52	6.47	0.928	1.83	2.73	3.66	4.59	5.52	6.47
14C	8	0.928	1.83	2.78	3.66	4.59	5.54	6.49	0.928	1.83	2.73	3.66	4.64	5.54	6.49
20B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20B	2	0.708	1.42	2.15	2.87	3.52	4.27	4.98	0.708	1.42	2.15	2.83	3.56	4.27	4.98
20B	3	0.708	1.42	2.15	2.83	3.52	4.25	5.01	0.708	1.42	2.10	2.86	3.56	4.25	5.01
20B	4	0.708	1.40	2.14	2.82	3.55	4.25	4.99	0.708	1.40	2.11	2.83	3.55	4.25	4.99
20B	5	0.708	1.39	2.15	2.83	3.52	4.25	4.96	0.708	1.39	2.12	2.76	3.49	4.25	4.96
20B	6	0.708	1.39	2.15	2.81	3.52	4.25	4.91	0.708	1.39	2.12	2.83	3.56	4.25	4.93
20B	7	0.708	1.42	2.15	2.86	3.56	4.27	5.01	0.708	1.42	2.12	2.83	3.56	4.27	5.01
20B	8	0.708	1.39	2.12	2.83	3.49	4.21	4.91	0.708	1.39	2.14	2.80	3.49	4.21	4.91
20B	9	0.708	1.39	2.15	2.81	3.52	4.27	4.93	0.708	1.42	2.12	2.86	3.56	4.25	4.96
20B	10	0.708	1.40	2.15	2.83	3.52	4.26	4.97	0.708	1.40	2.12	2.83	3.56	4.26	4.97
19B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19B	2	0.720	1.43	2.18	2.87	3.56	4.35	5.02	0.720	1.43	2.20	2.88	3.64	4.32	5.02
19B	3	0.720	1.43	2.17	2.87	3.63	4.33	5.09	0.720	1.43	2.17	2.87	3.63	4.33	5.09
19B	4	0.720	1.43	2.17	2.87	3.63	4.32	5.03	0.720	1.43	2.17	2.88	3.63	4.32	5.09
19B	5	0.720	1.43	2.17	2.86	3.61	4.33	4.98	0.720	1.43	2.16	2.87	3.63	4.33	4.98
19B	6	0.720	1.43	2.17	2.86	3.63	4.33	5.02	0.720	1.43	2.19	2.87	3.63	4.33	5.02
19B	7	0.720	1.43	2.17	2.87	3.59	4.32	5.02	0.720	1.43	2.19	2.87	3.63	4.32	5.02
19B	8	0.720	1.43	2.17	2.87	3.61	4.32	5.07	0.720	1.43	2.17	2.87	3.63	4.32	5.07
19B	9	0.732	1.44	2.17	2.86	3.61	4.32	5.03	0.732	1.44	2.20	2.88	3.61	4.32	5.03
19B	10	0.720	1.43	2.19	2.87	3.63	4.33	4.99	0.720	1.43	2.19	2.87	3.63	4.33	4.99
19B	11	0.732	1.44	2.17	2.88	3.64	4.35	5.05	0.732	1.44	2.17	2.88	3.64	4.35	5.08
18B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18B	2	0.745	1.47	2.25	2.95	3.74	4.44	5.21	0.745	1.47	2.21	2.95	3.74	4.44	5.21
18B	3	0.732	1.47	2.25	2.94	3.74	4.42	5.21	0.745	1.47	2.22	2.93	3.74	4.43	5.29
18B	4	0.745	1.47	2.22	2.94	3.69	4.44	5.20	0.745	1.47	2.20	2.94	3.71	4.43	5.21
18B	5	0.732	1.47	2.25	2.95	3.71	4.44	5.23	0.732	1.47	2.22	2.95	3.74	4.44	5.23
18B	6	0.732	1.47	2.25	2.98	3.71	4.44	5.23	0.732	1.47	2.20	2.95	3.74	4.44	5.23
18B	7	0.732	1.49	2.25	2.98	3.74	4.47	5.20	0.732	1.49	2.25	2.95	3.74	4.47	5.20
18B	8	0.732	1.47	2.25	2.98	3.69	4.44	5.27	0.732	1.47	2.22	2.93	3.66	4.44	5.27
18B	9	0.732	1.47	2.25	2.95	3.69	4.44	5.30	0.732	1.47	2.22	2.95	3.69	4.44	5.30
17B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17B	2	0.781	1.56	2.39	3.13	3.86	4.71	5.47	0.781	1.56	2.37	3.15	3.91	4.71	5.47
17B	3	0.781	1.54	2.39	3.15	3.96	4.74	5.49	0.781	1.56	2.30	3.15	3.83	4.74	5.49
17B	4	0.781	1.54	2.39	3.13	3.86	4.69	5.54	0.794	1.55	2.37	3.08	3.87	4.68	5.44
17B	5	0.781	1.56	2.37	3.13	3.93	4.74	5.57	0.781	1.56	2.37	3.15	3.96	4.74	5.49
17B	6	0.794	1.58	2.38	3.14	3.97	4.74	5.52	0.794	1.58	2.37	3.15	3.96	4.75	5.52
17B	7	0.781	1.56	2.37	3.15	3.93	4.74	5.52	0.781	1.56	2.37	3.15	3.96	4.74	5.49
17B	8	0.781	1.56	2.37	3.13	3.93	4.71	5.49	0.781	1.56	2.37	3.15	3.93	4.71	5.49
17B	9	0.781	1.56	2.39	3.13	3.96	4.74	5.52	0.781	1.56	2.37	3.13	3.96	4.74	5.57
17B	10	0.781	1.56	2.39	3.15	3.91	4.71	5.49	0.781	1.56	2.37	3.15	3.93	4.71	5.49
16B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—

		Box 1							Box 2						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
16B	2	0.842	1.66	2.54	3.33	4.16	5.03	5.90	0.842	1.66	2.55	3.35	4.19	5.03	5.89
16B	3	0.855	1.69	2.54	3.32	4.25	5.08	5.93	0.855	1.69	2.54	3.37	4.22	5.08	5.93
16B	4	0.842	1.67	2.53	3.35	4.18	5.04	5.90	0.842	1.67	2.55	3.36	4.20	5.04	5.93
16B	5	0.842	1.67	2.53	3.35	4.19	5.04	5.95	0.842	1.67	2.58	3.37	4.22	5.05	5.95
16B	6	0.830	1.66	2.49	3.35	4.18	5.03	5.81	0.830	1.66	2.56	3.37	4.18	5.03	5.93
16B	7	0.842	1.66	2.50	3.35	4.18	5.04	5.84	0.842	1.66	2.49	3.36	4.18	5.04	5.77
16B	8	0.830	1.66	2.49	3.32	4.15	5.03	5.88	0.830	1.66	2.47	3.35	4.15	5.03	5.91
16B	9	0.830	1.66	2.49	3.35	4.18	5.03	5.81	0.830	1.66	2.49	3.35	4.18	5.03	5.86
16B	10	0.830	1.66	2.52	3.35	4.18	5.03	5.88	0.830	1.66	2.49	3.37	4.18	5.03	5.86
15B	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15B	2	0.855	1.71	2.61	3.44	4.31	5.20	6.09	0.855	1.71	2.63	3.46	4.31	5.20	6.10
15B	3	0.867	1.67	2.49	3.47	4.35	5.20	6.03	0.867	1.67	2.49	3.48	4.33	5.20	6.08
15B	4	0.879	1.73	2.64	3.47	4.35	5.23	6.13	0.879	1.73	2.64	3.47	4.35	5.23	6.13
15B	5	0.855	1.71	2.49	3.44	4.32	5.20	6.10	0.855	1.71	2.49	3.44	4.32	5.20	6.08
15B	6	0.855	1.71	2.52	3.44	4.30	5.20	6.08	0.879	1.71	2.52	3.44	4.32	5.20	6.08
15B	7	0.855	1.71	2.61	3.44	4.32	5.20	6.08	0.855	1.71	2.66	3.44	4.32	5.20	6.08
15B	8	0.879	1.71	2.61	3.47	4.32	5.20	6.15	0.879	1.73	2.66	3.47	4.32	5.20	6.13
15B	9	0.879	1.71	2.61	3.44	4.32	5.20	6.08	0.879	1.71	2.71	3.47	4.32	5.20	6.08
15B	10	0.879	1.73	2.61	3.47	4.35	5.20	6.10	0.879	1.73	2.61	3.47	4.35	5.20	6.10
20D	1[A]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20D	2	0.806	1.59	2.42	3.17	3.96	4.81	5.59	0.806	1.59	2.39	3.17	4.05	4.81	5.59
20D	3	0.806	1.56	2.37	3.15	3.93	4.76	5.62	0.806	1.56	2.39	3.15	3.93	4.83	5.52
20D	4	0.806	1.59	2.37	3.17	3.93	4.81	5.62	0.806	1.59	2.37	3.15	3.91	4.81	5.57
20D	5	0.806	1.56	2.37	3.17	3.93	4.81	5.62	0.806	1.56	2.37	3.15	3.91	4.83	5.62
20D	6	0.806	1.59	2.37	3.17	3.93	4.81	5.59	0.806	1.59	2.37	3.22	4.05	4.81	5.59
20D	7	0.806	1.56	2.37	3.15	3.93	4.81	5.62	0.806	1.56	2.37	3.15	3.91	4.83	5.62
20D	8	0.806	1.56	2.37	3.15	3.93	4.81	5.62	0.806	1.56	2.34	3.20	3.91	4.83	5.64
20D	9	0.781	1.56	2.34	3.17	3.91	4.83	5.62	0.781	1.56	2.34	3.13	3.91	4.83	5.66
19D	1	0.830	1.61	2.44	3.27	4.03	4.96	5.74	0.830	1.61	2.42	3.27	4.15	4.96	5.74
19D	2	0.806	1.59	2.42	3.25	4.03	4.96	5.69	0.806	1.61	2.39	3.20	4.00	4.96	5.79
19D	3	0.860	1.61	2.44	3.25	4.03	4.96	5.74	0.830	1.61	2.44	3.27	4.15	4.96	5.74
19D	4	0.806	1.61	2.44	3.25	4.00	4.96	5.69	0.830	1.61	2.42	3.27	4.00	4.96	5.79
19D	5	0.830	1.64	2.47	3.27	4.13	4.96	5.76	0.830	1.64	2.44	3.27	4.15	4.96	5.81
19D	6	0.830	1.61	2.47	3.27	4.10	4.96	5.76	0.830	1.64	2.44	3.27	4.13	4.96	5.76
19D	7	0.830	1.61	2.47	3.25	4.10	4.96	5.71	0.830	1.61	2.44	3.27	4.15	4.93	5.74
19D	8	0.830	1.61	2.44	3.25	4.05	4.96	5.71	0.830	1.61	2.42	3.27	4.15	4.96	5.74
18D	1	0.855	1.66	2.52	3.37	4.20	5.15	5.98	0.855	1.66	2.49	3.35	4.15	5.15	5.88
18D	2	0.855	1.69	2.52	3.39	4.20	5.15	5.96	0.855	1.69	2.52	3.35	4.15	5.15	5.93
18D	3	0.855	1.69	2.52	3.37	4.20	5.15	5.96	0.855	1.69	2.52	3.35	4.13	5.15	5.88
18D	4	0.855	1.69	2.54	3.39	4.22	5.15	5.93	0.855	1.69	2.52	3.39	4.15	5.15	5.93
18D	5	0.855	1.69	2.51	3.37	4.18	5.13	5.88	0.855	1.69	2.52	3.35	4.15	5.13	5.88
18D	6	0.855	1.69	2.54	3.37	4.22	5.15	5.93	0.855	1.69	2.52	3.37	4.15	5.13	5.96
18D	7	0.855	1.69	2.54	3.39	4.22	5.15	5.96	0.855	1.69	2.54	3.39	4.27	5.15	5.96
18D	8	0.855	1.69	2.52	3.37	4.18	5.15	5.96	0.855	1.69	2.52	3.35	4.13	5.15	5.98
17D	1	0.879	1.76	2.64	3.54	4.40	5.35	6.25	0.879	1.76	2.64	3.54	4.42	5.35	6.25
17D	2	0.879	1.73	2.64	3.56	4.42	5.35	6.27	0.879	1.76	2.61	3.56	4.42	5.35	6.30
17D	3	0.879	1.76	2.64	3.54	4.42	5.35	6.27	0.879	1.76	2.64	3.54	4.44	5.35	6.27
17D	4	0.879	1.73	2.61	3.49	4.37	5.35	6.25	0.879	1.73	2.61	3.47	4.37	5.35	6.27
17D	5	0.879	1.76	2.66	3.54	4.40	5.35	6.25	0.879	1.76	2.64	3.54	4.44	5.35	6.27
17D	6	0.879	1.73	2.64	3.52	4.37	5.27	6.27	0.879	1.76	2.61	3.52	4.37	5.27	6.27
17D	7	0.879	1.73	2.61	3.49	4.37	5.27	6.25	0.879	1.73	2.61	3.54	4.37	5.27	6.27

		Box 1							**Box 2**						
Cable	**Run**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
17D	8	0.879	1.73	2.61	3.49	4.37	5.25	6.25	0.879	1.73	2.61	3.52	4.37	5.25	6.25
16D	1	0.928	1.83	2.77	3.70	4.71	5.68	6.86	0.928	1.83	2.77	3.66	4.71	5.69	6.95
16D	2	0.928	1.83	2.76	3.69	4.61	5.76	6.84	0.928	1.83	2.76	3.69	4.61	5.76	—
16D	3	0.952	1.86	2.83	3.76	4.71	5.71	6.71	0.952	1.86	2.76	3.66	4.69	5.71	6.71
16D	4	0.928	1.86	2.78	3.71	4.66	5.71	6.52	0.928	1.86	2.78	3.69	4.66	5.71	6.64
16D	5	0.952	1.86	2.81	3.76	4.69	5.69	6.67	0.952	1.86	2.78	3.71	4.69	5.69	6.67
16D	6	0.952	1.86	2.78	3.74	4.69	5.71	6.52	0.952	1.86	2.78	3.69	4.69	5.71	6.67
16D	7	0.952	1.88	2.81	3.76	4.71	5.71	6.54	0.952	1.88	2.81	3.71	4.71	5.71	6.71
16D	8[B]	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15D	1	1.00	1.95	3.00	3.94	4.92	5.98	6.97	0.989	1.95	2.94	3.87	4.91	5.99	7.02
15D	2	0.977	1.93	2.95	3.96	4.91	6.06	7.03	0.977	1.93	2.93	3.88	4.91	6.06	7.03
15D	3	0.977	1.95	2.95	3.93	4.91	6.01	6.79	0.977	1.95	2.93	3.88	4.91	6.01	6.86
15D	4	1.00	1.95	2.95	3.96	4.91	6.01	6.89	1.00	1.95	2.93	3.91	4.91	5.98	6.86
15D	5	1.00	1.95	2.98	3.98	4.93	6.01	6.93	1.00	1.95	2.98	3.96	4.93	6.01	6.98
15D	6	1.00	1.95	2.98	3.98	4.93	6.01	6.91	1.00	1.95	2.93	3.98	4.93	6.01	6.91
15D	7	1.00	1.95	3.00	3.98	4.93	5.98	6.98	1.00	1.95	2.98	3.98	4.93	5.98	7.01
15D	8	0.977	1.95	2.98	4.00	4.93	6.01	7.03	1.03	1.95	2.98	3.98	4.93	6.01	7.03
14D	1	1.04	2.05	3.11	4.14	5.19	6.45	7.47	1.04	2.05	3.04	4.08	5.19	6.45	7.50
14D	2	1.05	2.05	3.08	4.20	5.20	6.27	7.20	1.05	2.05	3.08	4.08	5.20	6.25	7.23
14D	3	1.05	2.08	3.10	4.20	5.20	6.35	7.25	1.05	2.08	3.10	4.10	5.23	6.35	7.30
14D	4	1.05	2.08	3.13	4.20	5.20	6.37	7.28	1.05	2.08	3.10	4.13	5.23	6.37	7.25
14D	5	1.05	2.08	3.10	4.13	5.13	6.25	7.25	1.05	2.08	3.10	4.10	5.23	6.25	7.50
14D	6	1.05	2.10	3.20	4.22	5.25	6.37	7.45	1.05	2.10	3.13	4.15	5.27	6.37	7.47
14D	7	1.08	2.10	3.17	4.22	5.23	6.40	7.45	1.08	2.12	3.15	4.22	5.37	6.40	7.47
14D	8	1.05	2.08	3.15	4.20	5.18	6.30	7.30	1.05	2.08	3.13	4.13	5.20	6.30	7.30
13D	1	1.07	2.12	3.22	4.35	5.40	6.59	7.72	1.07	2.12	3.27	4.42	5.40	6.59	7.72
13D	2	1.10	2.15	3.27	4.35	5.42	6.54	7.54	1.10	2.15	3.25	4.37	5.40	6.54	7.69
13D	3	1.10	2.20	3.30	4.30	5.44	6.59	7.59	1.10	2.20	3.32	4.37	5.44	6.62	7.69
13D	4	1.10	2.17	3.27	4.35	5.44	6.57	7.59	1.10	2.17	3.25	4.32	5.42	6.57	7.62
13D	5	1.10	2.17	3.30	4.40	5.44	6.57	7.59	1.10	2.17	3.32	4.35	5.42	6.57	7.67
13D	6	1.10	2.17	3.30	4.40	5.44	6.57	7.72	1.10	2.17	3.27	4.32	5.42	6.57	7.72
13D	7	1.10	2.17	3.30	4.35	5.44	6.57	7.59	1.10	2.17	3.25	4.35	5.44	6.57	7.67
13D	8	1.10	2.15	3.27	4.35	5.42	6.57	7.69	1.10	2.15	3.32	4.32	5.42	6.52	7.62

[A] Baseline run.
[B] Unreadable data.

Table 10. Phase 2 averaged mode frequencies (Hz).

Cable	1	2	3	4	5	6	7
20A	0.781	1.54	2.32	3.10	3.91	4.69	5.44
19A	0.830	1.64	2.47	3.30	4.13	4.98	5.79
18A	0.855	1.69	2.54	3.37	4.27	5.13	6.03
17A	0.903	1.78	2.71	3.59	4.52	5.42	6.42
16A	0.928	1.86	2.83	3.71	4.61	5.64	6.59
15A	0.977	1.95	2.93	3.91	4.86	5.88	6.84
14A	1.05	2.05	3.13	4.15	5.18	6.30	7.37
13A	1.07	2.15	3.22	4.30	5.37	6.54	7.57
12A	1.17	2.32	3.54	4.69	5.81	7.08	8.23
20C	0.732	1.47	2.22	2.95	3.69	4.40	5.18
19C	0.708	1.42	2.15	2.86	3.56	4.27	5.01
18C	0.757	1.49	2.27	3.00	3.78	4.52	5.27
17C	0.781	1.56	2.34	3.13	3.88	4.69	5.52
16C	0.830	1.66	2.49	3.32	4.15	4.98	5.86
15C	0.855	1.71	2.59	3.44	4.32	5.18	6.01
14C	0.928	1.83	2.73	3.66	4.57	5.49	6.47
20B	0.708	1.42	2.15	2.83	3.56	4.25	5.01
19B	0.720	1.43	2.17	2.87	3.63	4.32	5.02
18B	0.732	1.47	2.25	2.95	3.74	4.44	5.21
17B	0.781	1.56	2.37	3.15	3.96	4.74	5.49
16B	0.842	1.66	2.49	3.35	4.18	5.03	5.93
15B	0.879	1.71	2.61	3.44	4.32	5.20	6.08
20D	0.806	1.56	2.37	3.15	3.93	4.81	5.62
19D	0.830	1.61	2.44	3.27	4.13	4.96	5.74
18D	0.855	1.69	2.52	3.37	4.20	5.15	5.96
17D	0.879	1.76	2.61	3.54	4.37	5.35	6.27
16D	0.952	1.86	2.78	3.69	4.71	5.71	6.71
15D	1.00	1.95	2.98	3.98	4.93	6.01	7.03
14D	1.05	2.08	3.10	4.20	5.20	6.37	7.47
13D	1.10	2.17	3.27	4.35	5.44	6.57	7.72

Table 11. Phase 2 theoretical frequencies of the first mode (Hz).

Cable	Frequency	Cable	Frequency	Cable	Frequency	Cable	Frequency
20A	0.761	20B	0.638	20C	0.637	20D	0.760
19A	0.796	19B	0.658	19C	0.657	19D	0.795
18A	0.848	18B	0.710	18C	0.710	18D	0.848
17A	0.880	17B	0.746	17C	0.745	17D	0.881
16A	0.939	16B	0.799	16C	0.799	16D	0.942
15A	0.984	15B	0.843	15C	0.843	15D	0.987
14A	1.052	14B	0.904	14C	0.904	14D	1.056
13A	1.099	13B	0.949	13C	0.949	13D	1.104
12A	1.189	12B	1.024	12C	1.025	12D	1.194
11A	1.244	11B	1.078	11C	1.079	11D	1.250
10A	1.361	10B	1.175	10C	1.176	10D	1.367
9A	1.434	9B	1.246	9C	1.246	9D	1.440
8A	1.567	8B	1.358	8C	1.360	8D	1.573
7A	1.687	7B	1.473	7C	1.475	7D	1.690
6A	1.880	6B	1.636	6C	1.638	6D	1.882
5A	2.025	5B	1.772	5C	1.773	5D	2.026
4A	2.332	4B	2.029	4C	2.030	4D	2.332
3A	2.531	3B	2.217	3C	2.216	3D	2.530
2A	3.017	2B	2.615	2C	2.611	2D	3.012
1A	3.326	1B	2.905	1C	2.894	1D	3.320

APPENDIX B. MODE FREQUENCY PLOTS

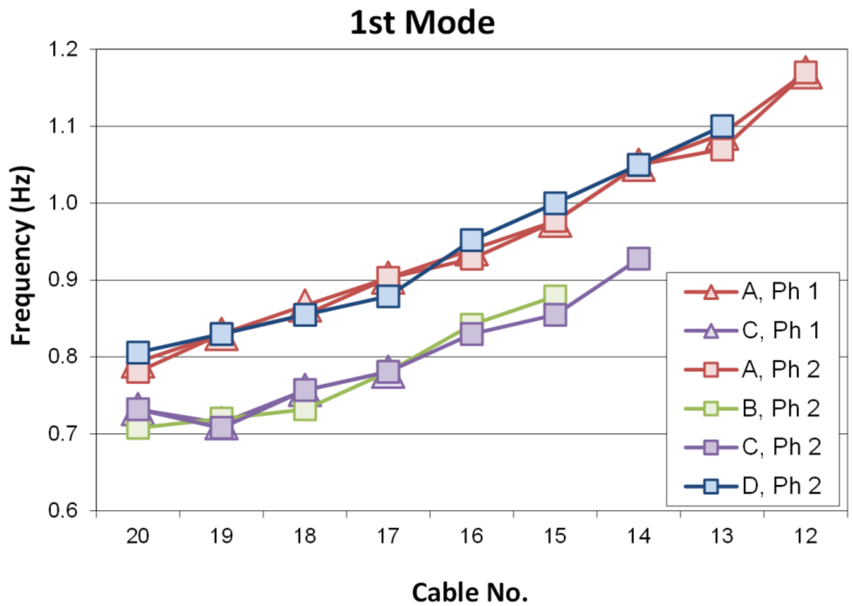


Figure 59. Graph. Comparison of first mode frequencies.

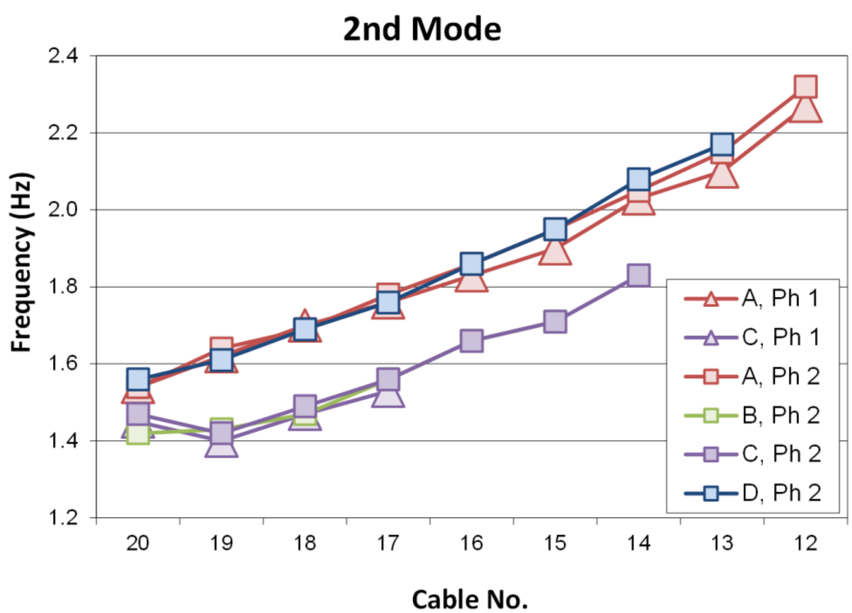


Figure 60. Graph. Comparison of second mode frequencies.

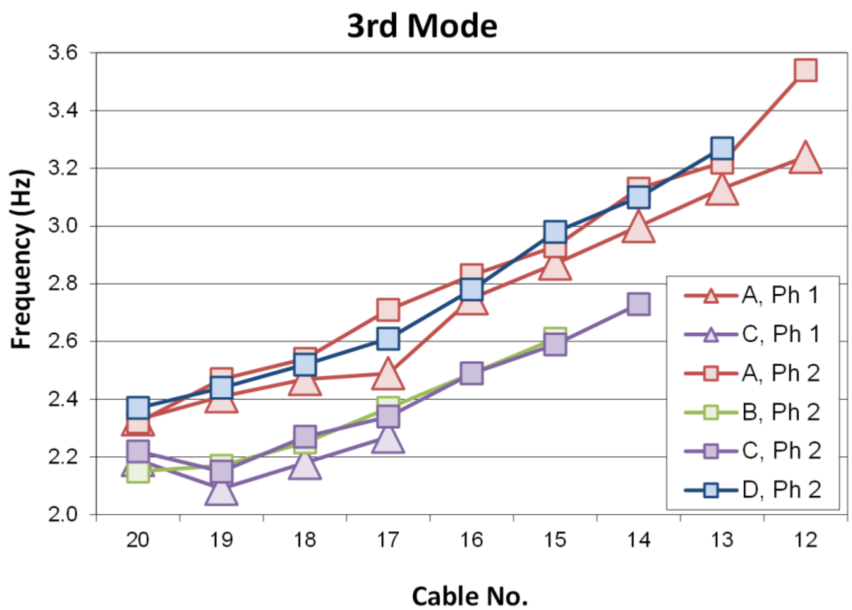


Figure 61. Graph. Comparison of third mode frequencies.

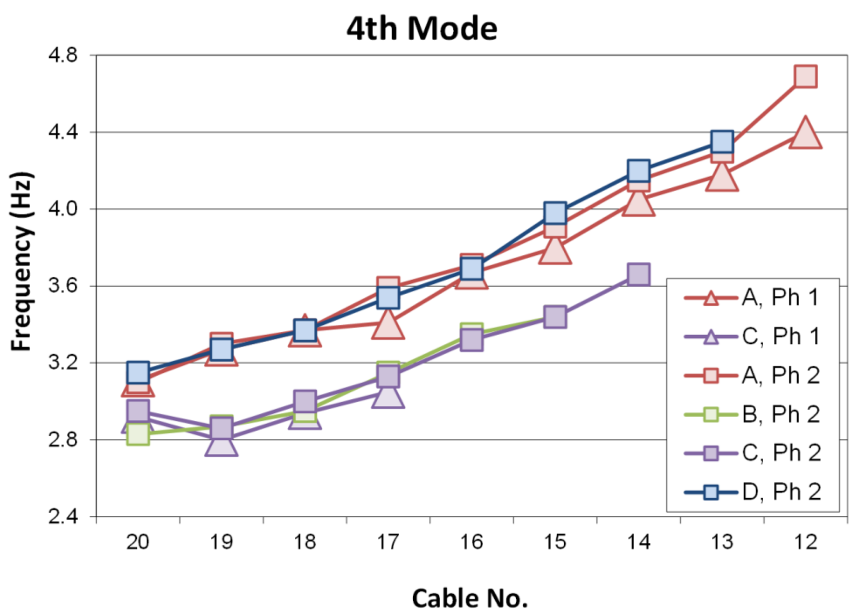


Figure 62. Graph. Comparison of fourth mode frequencies.

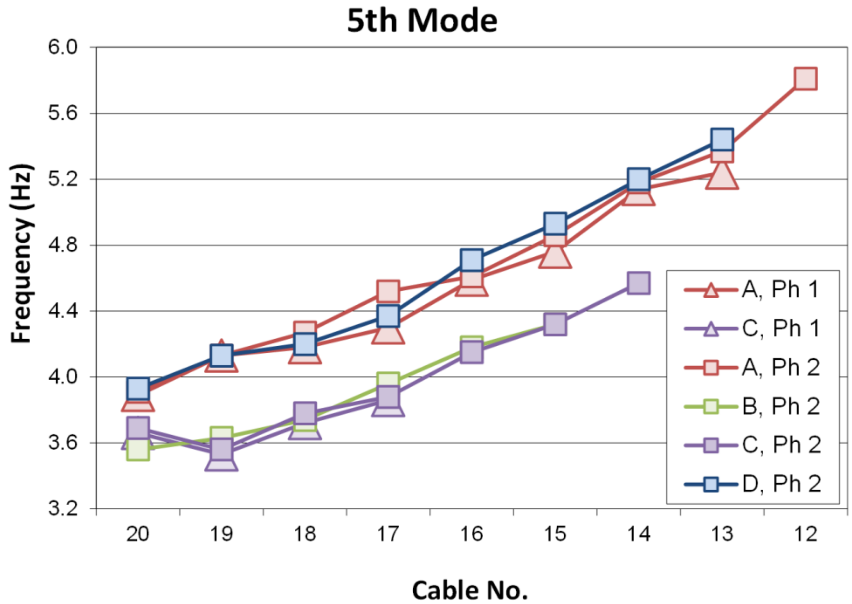


Figure 63. Graph. Comparison of fifth mode frequencies.

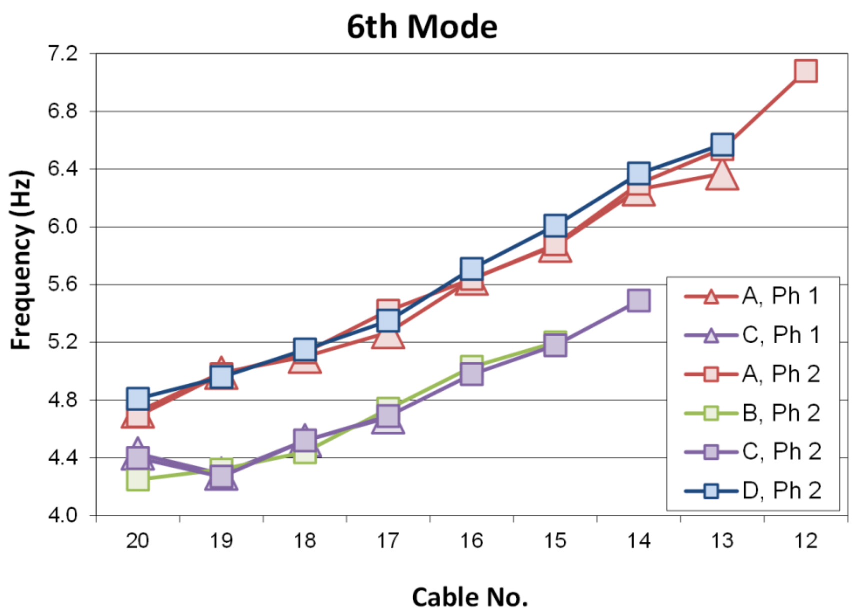


Figure 64. Graph. Comparison of sixth mode frequencies.

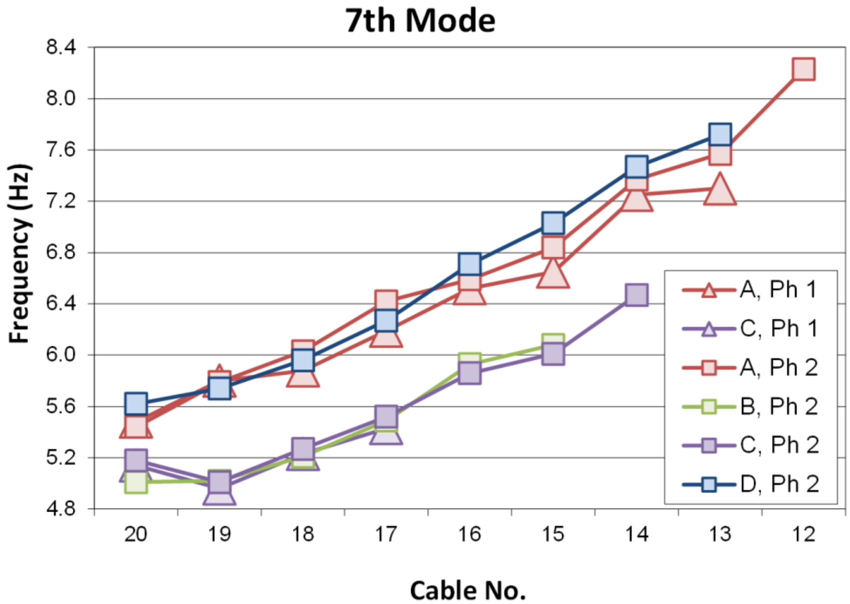


Figure 65. Graph. Comparison of seventh mode frequencies.

APPENDIX C. DAMPING RATIO TABLES

Table 12. Phase 1, box 1, first mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1[A]	—	—	—	—	—	—	—	—
20A	2	0.63	0.85	25	250	0.230	0.9917	0.230	0.9917
20A	3	0.70	0.86	50	210	0.210	0.9961	0.210	0.9960
20A	4	0.71	0.86	50	200	0.282	0.9986	0.282	0.9986
20A	5	0.71	0.88	40	200	0.212	0.9914	0.211	0.9913
20A	6	0.71	0.88	30	200	0.225	0.9945	0.225	0.9945
20A	7	0.71	0.88	30	200	0.294	0.9956	0.294	0.9956
20A	8	0.71	0.88	30	150	0.228	0.9929	0.228	0.9928
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	0.67	0.95	20	120	0.227	0.9770	0.226	0.9773
19A	3	0.75	0.89	20	250	0.190	0.9969	0.191	0.9968
19A	4	0.60	1.00	50	200	0.203	0.9954	0.204	0.9955
19A	5	0.60	1.00	50	250	0.209	0.9975	0.209	0.9975
19A	6	0.60	1.00	50	250	0.182	0.9980	0.182	0.9980
19A	7	0.60	1.00	50	200	0.195	0.9964	0.195	0.9965
19A	8	0.70	0.95	30	180	0.204	0.9962	0.205	0.9962
19A	9	0.60	1.00	20	120	0.220	0.9910	0.219	0.9912
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	0.62	1.02	40	160	0.324	0.9975	0.323	0.9975
18A	3	0.62	1.02	40	160	0.295	0.9967	0.295	0.9967
18A	4	0.62	1.02	40	155	0.263	0.9884	0.261	0.9884
18A	5[B]	—	—	—	—	—	—	—	—
18A	6	0.62	1.02	40	200	0.322	0.9954	0.321	0.9953
18A	7	0.62	1.02	50	200	0.355	0.9958	0.354	0.9957
18A	8	0.62	1.02	60	230	0.289	0.9996	0.289	0.9996
18A	9	0.62	1.02	50	230	0.279	0.9989	0.279	0.9989
18A	10	0.62	1.02	60	220	0.247	0.9995	0.247	0.9995
18A	11	0.62	1.02	60	170	0.248	0.9982	0.248	0.9982
18A	12	0.62	1.02	70	220	0.254	0.9981	0.255	0.9982
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	0.58	1.06	50	160	0.124	0.9643	0.124	0.9652
17A	3	0.72	1.02	30	230	0.125	0.9883	0.126	0.9882
17A	4[A]	—	—	—	—	—	—	—	—
17A	5	0.62	1.02	75	180	0.085	0.9336	0.085	0.9368
17A	6	0.62	1.02	40	200	0.093	0.9852	0.094	0.9850
17A	7	0.62	1.02	40	140	0.106	0.8977	0.106	0.8989
17A	8	0.62	1.02	40	180	0.133	0.9910	0.133	0.9908
17A	9	0.74	1.02	25	230	0.152	0.9955	0.152	0.9954

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	1[A]	—	—	—	—	—	—	—	—
16A	2	0.78	1.06	30	180	0.191	0.9903	0.191	0.9904
16A	3	0.72	1.06	50	180	0.213	0.9948	0.213	0.9947
16A	4	0.78	1.06	35	150	0.279	0.9989	0.280	0.9990
16A	5	0.78	1.06	30	180	0.226	0.9937	0.226	0.9937
16A	6	0.78	1.06	50	200	0.214	0.9925	0.214	0.9926
16A	7	0.78	1.06	30	200	0.249	0.9979	0.249	0.9979
16A	8	0.78	1.06	30	180	0.247	0.9972	0.247	0.9972
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	0.76	1.12	55	250	0.198	0.9983	0.198	0.9983
15A	3	0.76	1.12	50	250	0.156	0.9928	0.156	0.9928
15A	4	0.76	1.12	60	250	0.201	0.9980	0.201	0.9980
15A	5	0.76	1.12	50	250	0.172	0.9985	0.172	0.9985
15A	6	0.76	1.12	40	230	0.206	0.9958	0.206	0.9958
15A	7	0.76	1.12	50	250	0.179	0.9979	0.179	0.9978
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	0.62	1.18	40	190	0.250	0.9912	0.251	0.9909
14A	3	0.62	1.18	40	180	0.251	0.9974	0.251	0.9975
14A	4	0.62	1.18	50	210	0.250	0.9987	0.250	0.9986
14A	5	0.62	1.18	50	200	0.246	0.9946	0.246	0.9948
14A	6	0.62	1.18	50	185	0.257	0.9995	0.257	0.9996
14A	7[B]	—	—	—	—	—	—	—	—
14A	8	0.62	1.18	50	240	0.236	0.9990	0.236	0.9990
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	0.62	1.22	70	100	0.398	0.9970	0.395	0.9968
13A	3	0.62	1.22	45	100	0.375	0.9982	0.373	0.9982
13A	4	0.62	1.22	45	90	0.381	0.9973	0.378	0.9974
13A	5	0.72	1.22	65	130	0.381	0.9982	0.379	0.9981
13A	6	0.72	1.22	45	90	0.387	0.9972	0.384	0.9972
13A	7	0.72	1.22	45	110	0.396	0.9977	0.395	0.9977
12A	1[A]	—	—	—	—	—	—	—	—
12A	2	0.76	1.32	55	120	0.507	0.9598	0.504	0.9604
12A	3[B]	—	—	—	—	—	—	—	—
12A	4	0.76	1.32	90	180	0.203	0.9805	0.202	0.9802
12A	5	0.76	1.32	65	100	0.413	0.9941	0.417	0.9940
12A	6	0.76	1.32	65	110	0.407	0.9937	0.408	0.9936
12A	7	0.76	1.32	75	120	0.368	0.9984	0.369	0.9983
12A	8	0.76	1.32	80	160	0.420	0.9959	0.420	0.9958
12A	9	0.76	1.32	85	160	0.370	0.9905	0.368	0.9901
12A	10	0.76	1.32	55	95	0.396	0.9949	0.400	0.9944
20C	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20C	2	0.62	0.82	85	290	0.124	0.9961	0.124	0.9961
20C	3	0.62	0.82	110	370	0.121	0.9973	0.121	0.9973
20C	4	0.62	0.82	85	330	0.156	0.9972	0.156	0.9972
20C	5	0.62	0.82	100	350	0.167	0.9951	0.167	0.9950
20C	6[B]	—	—	—	—	—	—	—	—
20C	7	0.62	0.82	80	300	0.189	0.9990	0.189	0.9990
20C	8	0.62	0.82	80	250	0.143	0.9973	0.143	0.9973
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	0.56	0.86	110	350	0.119	0.9981	0.119	0.9981
19C	3	0.56	0.86	110	350	0.153	0.9997	0.153	0.9996
19C	4	0.56	0.86	85	250	0.150	0.9969	0.150	0.9969
19C	5	0.56	0.86	100	350	0.132	0.9976	0.132	0.9975
19C	6	0.56	0.86	75	450	0.115	0.9837	0.116	0.9934
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	0.58	0.88	80	220	0.099	0.9921	0.098	0.9924
18C	3	0.58	0.88	90	450	0.092	0.9950	0.092	0.9951
18C	4	0.58	0.88	100	260	0.112	0.9990	0.112	0.9991
18C	5	0.58	0.88	90	230	0.142	0.9987	0.142	0.9988
18C	6	0.58	0.88	110	320	0.084	0.9959	0.084	0.9960
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	0.62	0.88	90	250	0.128	0.9984	0.128	0.9984
17C	3	0.62	0.88	80	300	0.134	0.9994	0.134	0.9994
17C	4	0.62	0.88	80	250	0.139	0.9991	0.139	0.9991
17C	5	0.62	0.88	95	250	0.136	0.9993	0.136	0.9993

[A] Baseline run.

[B] Unreadable data.

Table 13. Phase 1, box 2, first mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1[A]	—	—	—	—	—	—	—	—
20A	2	0.63	0.85	25	250	0.230	0.9911	0.230	0.9911
20A	3	0.70	0.90	50	210	0.210	0.9971	0.210	0.9970
20A	4	0.71	0.86	50	200	0.284	0.9988	0.285	0.9988
20A	5	0.71	0.88	40	200	0.213	0.9913	0.212	0.9911
20A	6	0.71	0.88	40	150	0.250	0.9988	0.250	0.9987
20A	7	0.71	0.88	30	200	0.297	0.9966	0.297	0.9966
20A	8	0.71	0.88	30	150	0.230	0.9937	0.230	0.9937
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	0.67	0.95	20	120	0.232	0.9784	0.232	0.9780
19A	3	0.75	0.89	20	250	0.194	0.9964	0.194	0.9964
19A	4	0.60	1.00	50	200	0.205	0.9954	0.205	0.9954
19A	5	0.60	1.00	50	250	0.208	0.9961	0.208	0.9961
19A	6	0.60	1.00	50	250	0.185	0.9980	0.185	0.9980
19A	7	0.60	1.00	50	200	0.198	0.9958	0.199	0.9958
19A	8	0.70	0.95	30	180	0.209	0.9958	0.210	0.9958
19A	9	0.60	1.00	20	120	0.225	0.9892	0.225	0.9895
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	0.62	1.02	40	160	0.334	0.9969	0.334	0.9969
18A	3	0.62	1.02	30	160	0.308	0.9967	0.308	0.9967
18A	4	0.62	1.02	30	155	0.280	0.9888	0.279	0.9889
18A	5[B]	—	—	—	—	—	—	—	—
18A	6	0.62	1.02	40	200	0.326	0.9946	0.325	0.9945
18A	7	0.62	1.02	50	200	0.360	0.9944	0.359	0.9942
18A	8	0.62	1.02	60	230	0.293	0.9991	0.293	0.9991
18A	9	0.62	1.02	50	230	0.283	0.9989	0.283	0.9989
18A	10	0.62	1.02	60	220	0.253	0.9991	0.253	0.9991
18A	11	0.62	1.02	60	170	0.256	0.9983	0.256	0.9983
18A	12	0.62	1.02	70	220	0.263	0.9985	0.264	0.9986
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	0.58	1.06	50	160	0.122	0.9537	0.122	0.9550
17A	3[B]	—	—	—	—	—	—	—	—
17A	4[A]	—	—	—	—	—	—	—	—
17A	5	0.62	1.02	75	170	0.086	0.8311	0.088	0.8383
17A	6	0.62	1.02	40	200	0.095	0.9845	0.096	0.9844
17A	7	0.62	1.02	40	140	0.114	0.8809	0.115	0.8832
17A	8	0.62	1.02	30	160	0.150	0.9956	0.150	0.9955
17A	9	0.74	1.02	25	230	0.150	0.9947	0.149	0.9945
16A	1[A]	—	—	—	—	—	—	—	—
16A	2	0.78	1.02	30	180	0.196	0.9908	0.196	0.9909

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	3	0.72	1.06	50	180	0.218	0.9950	0.217	0.9949
16A	4	0.78	1.06	30	150	0.287	0.9987	0.287	0.9988
16A	5	0.78	1.06	30	180	0.231	0.9945	0.232	0.9945
16A	6	0.72	1.06	50	180	0.231	0.9959	0.231	0.9960
16A	7	0.78	1.06	20	160	0.263	0.9982	0.263	0.9982
16A	8	0.78	1.06	30	180	0.252	0.9974	0.251	0.9974
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	0.76	1.12	50	250	0.202	0.9983	0.202	0.9983
15A	3	0.76	1.12	50	250	0.160	0.9932	0.160	0.9933
15A	4	0.76	1.12	60	250	0.206	0.9982	0.206	0.9982
15A	5	0.76	1.12	40	250	0.180	0.9975	0.180	0.9975
15A	6	0.76	1.12	35	230	0.214	0.9949	0.213	0.9950
15A	7	0.76	1.12	45	250	0.185	0.9977	0.185	0.9977
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	0.62	1.18	35	190	0.252	0.9894	0.253	0.9890
14A	3	0.62	1.18	35	180	0.260	0.9966	0.260	0.9967
14A	4	0.62	1.18	50	210	0.256	0.9987	0.256	0.9987
14A	5	0.62	1.18	45	200	0.256	0.9938	0.256	0.9940
14A	6	0.62	1.18	50	185	0.264	0.9995	0.263	0.9995
14A	7[B]	—	—	—	—	—	—	—	—
14A	8	0.62	1.18	50	240	0.240	0.9989	0.240	0.9989
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	0.62	1.22	70	100	0.408	0.9973	0.406	0.9971
13A	3	0.62	1.22	40	100	0.385	0.9979	0.384	0.9978
13A	4	0.62	1.22	40	90	0.393	0.9976	0.393	0.9976
13A	5	0.72	1.22	65	130	0.384	0.9982	0.383	0.9982
13A	6	0.72	1.22	40	100	0.380	0.9966	0.378	0.9966
13A	7	0.72	1.22	45	110	0.399	0.9979	0.399	0.9978
12A	1[A]	—	—	—	—	—	—	—	—
12A	2	0.76	1.32	60	120	0.488	0.9431	0.483	0.9442
12A	3[B]	—	—	—	—	—	—	—	—
12A	4	0.76	1.32	90	180	0.205	0.9795	0.204	0.9790
12A	5	0.76	1.32	60	120	0.356	0.9898	0.357	0.9897
12A	6	0.76	1.32	65	110	0.407	0.9928	0.410	0.9928
12A	7	0.76	1.32	75	120	0.363	0.9977	0.364	0.9976
12A	8	0.76	1.32	80	160	0.424	0.9954	0.423	0.9953
12A	9	0.76	1.32	85	120	0.351	0.9933	0.348	0.9925
12A	10	0.76	1.32	65	95	0.375	0.9949	0.377	0.9946
20C	1[A]	—	—	—	—	—	—	—	—
20C	2	0.62	0.82	85	290	0.124	0.9966	0.124	0.9966
20C	3	0.62	0.82	110	370	0.121	0.9976	0.121	0.9976

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
20C	4	0.62	0.82	85	330	0.157	0.9974	0.157	0.9974
20C	5	0.62	0.82	100	350	0.168	0.9947	0.168	0.9947
20C	6	0.62	0.82	85	170	0.154	0.9932	0.153	0.9931
20C	7	0.62	0.82	80	300	0.189	0.9991	0.189	0.9990
20C	8	0.62	0.82	85	250	0.142	0.9977	0.142	0.9976
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	0.56	0.86	110	350	0.121	0.9982	0.121	0.9982
19C	3	0.56	0.86	110	350	0.155	0.9996	0.155	0.9996
19C	4	0.56	0.86	80	250	0.153	0.9969	0.153	0.9970
19C	5	0.56	0.86	85	350	0.138	0.9964	0.138	0.9963
19C	6	0.56	0.86	70	450	0.117	0.9977	0.117	0.9977
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	0.58	0.88	80	250	0.095	0.9911	0.094	0.9912
18C	3	0.58	0.88	80	450	0.095	0.9942	0.095	0.9941
18C	4	0.58	0.88	95	380	0.098	0.9914	0.098	0.9915
18C	5	0.58	0.88	85	250	0.138	0.9957	0.138	0.9958
18C	6	0.58	0.88	100	330	0.086	0.9955	0.086	0.9954
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	0.62	0.88	80	250	0.134	0.9980	0.134	0.9979
17C	3	0.62	0.88	70	300	0.139	0.9991	0.139	0.9991
17C	4	0.62	0.88	75	250	0.143	0.9990	0.143	0.9990
17C	5	0.62	0.88	90	250	0.140	0.9992	0.140	0.9991

[A] Baseline run.
[B] Unreadable data.

Table 14. Phase 1, box 1, second mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1[A]	—	—	—	—	—	—	—	—
20A	2	1.41	1.70	30	150	0.176	0.9921	0.177	0.9920
20A	3	1.41	1.65	30	120	0.174	0.9927	0.174	0.9927
20A	4	1.41	1.65	30	120	0.181	0.9951	0.181	0.9952
20A	5	1.41	1.65	30	120	0.180	0.9873	0.180	0.9874
20A	6	1.41	1.65	40	150	0.167	0.9949	0.168	0.9950
20A	7	1.41	1.65	30	120	0.160	0.9851	0.160	0.9852
20A	8	1.41	1.65	20	140	0.164	0.9961	0.164	0.9962
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	1.40	1.82	30	120	0.154	0.9763	0.154	0.9760
19A	3	1.55	1.75	30	120	0.255	0.9908	0.256	0.9909
19A	4	1.40	1.85	40	140	0.141	0.9521	0.142	0.9522
19A	5	1.40	1.85	30	150	0.181	0.9838	0.180	0.9840
19A	6	1.45	1.80	50	150	0.230	0.9915	0.231	0.9916
19A	7	1.45	1.80	50	150	0.225	0.9923	0.225	0.9925
19A	8	1.45	1.80	20	100	0.238	0.9940	0.237	0.9940
19A	9	1.45	1.80	20	100	0.219	0.9936	0.220	0.9942
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	1.42	1.86	40	150	0.299	0.9972	0.298	0.9973
18A	3	1.42	1.86	30	120	0.279	0.9939	0.278	0.9939
18A	4	1.42	1.86	35	150	0.221	0.9919	0.222	0.9920
18A	5[B]	—	—	—	—	—	—	—	—
18A	6	1.42	1.86	40	150	0.243	0.9932	0.243	0.9931
18A	7	1.32	1.86	50	150	0.228	0.9930	0.228	0.9930
18A	8	1.32	1.86	55	150	0.298	0.9963	0.298	0.9963
18A	9	1.32	1.86	50	130	0.301	0.9942	0.301	0.9943
18A	10	1.42	1.86	60	130	0.278	0.9970	0.277	0.9968
18A	11	1.32	1.86	55	120	0.254	0.9941	0.253	0.9941
18A	12	1.42	1.86	65	150	0.279	0.9945	0.278	0.9945
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	1.24	1.98	55	150	0.201	0.9946	0.202	0.9947
17A	3	1.58	1.92	40	150	0.186	0.9964	0.186	0.9964
17A	4[A]	—	—	—	—	—	—	—	—
17A	5	1.38	1.92	75	200	0.106	0.9816	0.106	0.9817
17A	6	1.38	1.92	30	120	0.167	0.9873	0.167	0.9874
17A	7	1.38	1.98	35	150	0.163	0.9901	0.163	0.9902
17A	8	1.44	1.98	30	140	0.207	0.9919	0.207	0.9919
17A	9	1.58	1.92	20	130	0.207	0.9925	0.207	0.9924
16A	1[A]	—	—	—	—	—	—	—	—
16A	2	1.66	1.92	25	80	0.263	0.9881	0.262	0.9879

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	3	1.56	2.06	50	90	0.215	0.9893	0.215	0.9893
16A	4	1.66	1.98	30	80	0.372	0.9871	0.371	0.9875
16A	5	1.72	1.92	20	100	0.271	0.9939	0.272	0.9938
16A	6	1.52	2.06	45	160	0.256	0.9941	0.255	0.9942
16A	7	1.66	2.06	20	80	0.425	0.9887	0.423	0.9884
16A	8	1.66	1.98	20	80	0.378	0.9932	0.378	0.9932
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	1.76	2.18	50	100	0.361	0.9954	0.360	0.9957
15A	3	1.48	2.18	50	150	0.173	0.9924	0.173	0.9923
15A	4	1.48	2.18	50	100	0.377	0.9916	0.375	0.9915
15A	5	1.62	2.18	40	120	0.320	0.9944	0.320	0.9943
15A	6	1.62	2.18	30	90	0.414	0.9893	0.413	0.9891
15A	7	1.68	2.18	40	120	0.330	0.9936	0.331	0.9935
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	1.62	2.26	35	80	0.477	0.9986	0.478	0.9985
14A	3	1.62	2.26	35	100	0.377	0.9965	0.378	0.9965
14A	4	1.62	2.26	50	90	0.403	0.9993	0.404	0.9993
14A	5	1.62	2.26	45	90	0.409	0.9969	0.410	0.9969
14A	6	1.62	2.26	50	110	0.322	0.9951	0.323	0.9951
14A	7[B]	—	—	—	—	—	—	—	—
14A	8	1.62	2.26	50	120	0.320	0.9976	0.321	0.9976
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	1.46	2.38	70	90	0.384	0.9955	0.383	0.9960
13A	3	1.62	2.28	40	70	0.534	0.9936	0.534	0.9936
13A	4	1.62	2.28	40	70	0.478	0.9929	0.481	0.9929
13A	5	1.62	2.38	60	90	0.559	0.9915	0.556	0.9915
13A	6	1.62	2.38	45	80	0.367	0.9923	0.370	0.9924
13A	7	1.62	2.28	45	75	0.503	0.9943	0.500	0.9944
12A	1[A]	—	—	—	—	—	—	—	—
12A	2	1.66	2.52	65	80	0.504	0.9853	0.506	0.9865
12A	3	1.66	2.52	75	110	0.247	0.9783	0.248	0.9777
12A	4[B]	—	—	—	—	—	—	—	—
12A	5	1.66	2.52	60	90	0.512	0.9956	0.514	0.9953
12A	6	1.86	2.52	65	95	0.454	0.9919	0.452	0.9923
12A	7	1.86	2.52	75	100	0.472	0.9920	0.469	0.9921
12A	8	1.66	2.52	80	105	0.561	0.9908	0.561	0.9906
12A	9	1.66	2.52	85	110	0.370	0.9727	0.370	0.9727
12A	10	1.66	2.52	65	95	0.463	0.9930	0.463	0.9931
20C	1[A]	—	—	—	—	—	—	—	—
20C	2	1.26	1.58	80	180	0.158	0.9903	0.158	0.9901
20C	3	1.26	1.58	105	135	0.305	0.9980	0.306	0.9980

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20C	4	1.26	1.58	80	120	0.299	0.9962	0.300	0.9967
20C	5	1.26	1.58	100	140	0.348	0.9978	0.349	0.9980
20C	6[B]	—	—	—	—	—	—	—	—
20C	7	1.26	1.58	70	140	0.236	0.9937	0.236	0.9935
20C	8	1.26	1.58	80	160	0.183	0.9916	0.184	0.9916
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	1.22	1.62	110	200	0.181	0.9907	0.181	0.9907
19C	3	1.22	1.62	110	210	0.211	0.9961	0.210	0.9961
19C	4	1.22	1.62	80	210	0.170	0.9948	0.170	0.9948
19C	5	1.22	1.62	85	190	0.196	0.9930	0.196	0.9929
19C	6	1.16	1.62	70	170	0.210	0.9931	0.211	0.9933
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	1.22	1.66	70	130	0.339	0.9991	0.339	0.9991
18C	3	1.22	1.66	80	140	0.373	0.9998	0.373	0.9997
18C	4	1.22	1.66	90	150	0.358	0.9994	0.359	0.9995
18C	5	1.22	1.66	80	150	0.347	0.9998	0.347	0.9998
18C	6	1.22	1.66	100	160	0.333	0.9966	0.333	0.9967
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	1.32	1.68	80	200	0.247	0.9953	0.248	0.9953
17C	3	1.32	1.68	70	200	0.215	0.9937	0.214	0.9938
17C	4	1.32	1.68	70	200	0.244	0.9961	0.244	0.9961
17C	5	1.32	1.68	90	250	0.216	0.9966	0.215	0.9966

[A] Baseline run.
[B] Unreadable data.

Table 15. Phase 1, box 2, second mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1[A]	—	—	—	—	—	—	—	—
20A	2	1.41	1.70	30	150	0.178	0.9919	0.178	0.9919
20A	3	1.41	1.65	30	120	0.175	0.9927	0.175	0.9928
20A	4	1.41	1.65	30	120	0.181	0.9945	0.181	0.9946
20A	5	1.41	1.65	30	120	0.184	0.9883	0.184	0.9884
20A	6	1.41	1.65	40	150	0.166	0.9955	0.166	0.9955
20A	7	1.41	1.65	30	120	0.160	0.9845	0.161	0.9846
20A	8	1.41	1.65	20	140	0.164	0.9961	0.164	0.9962
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	1.40	1.82	30	120	0.154	0.9755	0.154	0.9752
19A	3	1.55	1.75	30	120	0.261	0.9938	0.261	0.9939
19A	4	1.40	1.85	40	140	0.143	0.9611	0.143	0.9612
19A	5	1.40	1.85	30	150	0.180	0.9844	0.180	0.9846
19A	6	1.45	1.80	50	150	0.229	0.9925	0.229	0.9926
19A	7	1.45	1.80	50	150	0.225	0.9932	0.225	0.9934
19A	8	1.45	1.80	20	100	0.239	0.9964	0.238	0.9964
19A	9	1.45	1.80	20	100	0.224	0.9927	0.225	0.9932
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	1.42	1.86	40	150	0.300	0.9976	0.300	0.9976
18A	3	1.42	1.86	30	120	0.280	0.9952	0.279	0.9952
18A	4	1.42	1.86	35	150	0.230	0.9914	0.230	0.9915
18A	5[B]	—	—	—	—	—	—	—	—
18A	6	1.42	1.86	40	150	0.247	0.9943	0.247	0.9942
18A	7	1.32	1.86	55	160	0.223	0.9952	0.223	0.9951
18A	8	1.32	1.86	55	160	0.291	0.9969	0.292	0.9968
18A	9	1.32	1.86	50	130	0.301	0.9950	0.300	0.9950
18A	10	1.42	1.86	60	130	0.280	0.9973	0.279	0.9971
18A	11	1.32	1.86	55	120	0.258	0.9949	0.258	0.9949
18A	12	1.42	1.86	65	150	0.280	0.9954	0.280	0.9955
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	1.24	1.98	50	150	0.204	0.9927	0.204	0.9929
17A	3[B]	—	—	—	—	—	—	—	—
17A	4[A]	—	—	—	—	—	—	—	—
17A	5	1.38	1.92	75	150	0.137	0.9873	0.137	0.9878
17A	6	1.38	1.92	35	120	0.161	0.9858	0.161	0.9861
17A	7	1.38	1.98	35	130	0.176	0.9924	0.176	0.9924
17A	8	1.44	1.98	30	140	0.208	0.9925	0.208	0.9925
17A	9	1.58	1.92	15	130	0.211	0.9918	0.211	0.9919
16A	1[A]	—	—	—	—	—	—	—	—
16A	2	1.66	1.92	30	80	0.250	0.9878	0.249	0.9875

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	3	1.56	2.06	45	90	0.231	0.9861	0.231	0.9861
16A	4	1.66	1.98	30	80	0.372	0.9839	0.371	0.9844
16A	5	1.72	1.92	20	100	0.274	0.9945	0.274	0.9944
16A	6	1.52	2.06	45	140	0.258	0.9919	0.259	0.9918
16A	7	1.66	2.06	20	80	0.429	0.9910	0.427	0.9907
16A	8	1.66	1.98	20	80	0.381	0.9927	0.382	0.9926
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	1.76	2.18	50	120	0.312	0.9898	0.312	0.9901
15A	3	1.48	2.18	50	150	0.172	0.9940	0.172	0.9940
15A	4	1.62	2.18	50	100	0.378	0.9912	0.380	0.9913
15A	5	1.62	2.18	40	120	0.319	0.9951	0.319	0.9950
15A	6	1.62	2.18	30	100	0.399	0.9891	0.399	0.9893
15A	7	1.68	2.18	40	120	0.327	0.9939	0.328	0.9937
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	1.62	2.26	35	80	0.481	0.9980	0.481	0.9979
14A	3	1.62	2.26	35	100	0.377	0.9967	0.378	0.9966
14A	4	1.62	2.26	50	90	0.400	0.9993	0.400	0.9992
14A	5	1.62	2.26	45	90	0.407	0.9965	0.408	0.9964
14A	6	1.62	2.26	50	110	0.321	0.9956	0.322	0.9956
14A	7[B]	—	—	—	—	—	—	—	—
14A	8	1.62	2.26	50	120	0.318	0.9978	0.318	0.9977
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	1.46	2.38	70	90	0.381	0.9908	0.379	0.9909
13A	3	1.62	2.28	45	75	0.448	0.9935	0.449	0.9934
13A	4	1.62	2.28	40	70	0.469	0.9906	0.474	0.9902
13A	5	1.62	2.38	65	90	0.499	0.9918	0.499	0.9915
13A	6	1.62	2.28	45	80	0.371	0.9953	0.373	0.9953
13A	7	1.62	2.28	45	80	0.467	0.9930	0.466	0.9932
12A	1[A]	—	—	—	—	—	—	—	—
12A	2	1.66	2.52	65	80	0.495	0.9770	0.497	0.9785
12A	3	1.66	2.52	75	110	0.247	0.9794	0.247	0.9787
12A	4[B]	—	—	—	—	—	—	—	—
12A	5	1.66	2.52	60	90	0.510	0.9958	0.512	0.9955
12A	6	1.86	2.52	65	95	0.450	0.9919	0.448	0.9924
12A	7	1.86	2.52	75	100	0.463	0.9917	0.460	0.9917
12A	8	1.66	2.52	80	105	0.559	0.9900	0.558	0.9897
12A	9	1.66	2.52	85	110	0.374	0.9754	0.374	0.9754
12A	10	1.66	2.52	65	95	0.462	0.9940	0.461	0.9941
20C	1[A]	—	—	—	—	—	—	—	—
20C	2	1.26	1.58	80	180	0.157	0.9913	0.158	0.9911
20C	3	1.26	1.58	105	135	0.307	0.9994	0.307	0.9993

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20C	4	1.26	1.58	80	115	0.312	0.9978	0.311	0.9977
20C	5	1.26	1.58	100	140	0.354	0.9968	0.355	0.9971
20C	6	1.26	1.58	80	115	0.334	0.9984	0.333	0.9984
20C	7	1.26	1.58	70	140	0.237	0.9921	0.236	0.9920
20C	8	1.26	1.58	80	160	0.180	0.9904	0.181	0.9903
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	1.22	1.62	105	240	0.174	0.9957	0.175	0.9958
19C	3	1.22	1.62	110	240	0.194	0.9955	0.194	0.9955
19C	4	1.22	1.62	80	210	0.170	0.9951	0.170	0.9951
19C	5	1.16	1.62	85	210	0.186	0.9932	0.185	0.9933
19C	6	1.16	1.62	65	180	0.203	0.9927	0.203	0.9927
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	1.22	1.66	70	130	0.348	0.9985	0.348	0.9985
18C	3	1.22	1.66	80	140	0.387	0.9993	0.387	0.9993
18C	4	1.22	1.66	90	150	0.373	0.9995	0.374	0.9995
18C	5	1.22	1.66	80	150	0.358	0.9996	0.358	0.9996
18C	6	1.22	1.66	100	160	0.341	0.9978	0.340	0.9977
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	1.32	1.68	80	200	0.248	0.9947	0.248	0.9947
17C	3	1.32	1.68	70	200	0.215	0.9934	0.215	0.9934
17C	4	1.32	1.68	70	200	0.244	0.9956	0.245	0.9956
17C	5	1.32	1.68	90	250	0.217	0.9964	0.216	0.9965

[A] Baseline run.
[B] Unreadable data.

Table 16. Phase 1 summary of average damping values.

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
20A	1	0.242	0.258	0.227	0.9949	160.7
19A	1	0.205	0.212	0.199	0.9933	160.0
18A	1	0.292	0.305	0.278	0.9967	144.5
17A	1	0.118	0.129	0.107	0.9535	140.0
16A	1	0.235	0.249	0.222	0.9954	141.8
15A	1	0.188	0.198	0.178	0.9968	197.9
14A	1	0.252	0.256	0.247	0.9964	155.4
13A	1	0.389	0.394	0.384	0.9976	52.9
12A	1	0.378	0.414	0.343	0.9871	57.5
20C	1	0.151	0.162	0.139	0.9968	213.8
19C	1	0.135	0.145	0.126	0.9965	256.5
18C	1	0.104	0.116	0.092	0.9949	223.0
17C	1	0.137	0.140	0.134	0.9989	180.0
20A	2	0.172	0.176	0.168	0.9919	101.4
19A	2	0.206	0.224	0.188	0.9852	95.0
18A	2	0.269	0.280	0.257	0.9949	92.8
17A	2	0.179	0.195	0.164	0.9905	102.7
16A	2	0.313	0.350	0.275	0.9902	64.3
15A	2	0.323	0.366	0.281	0.9925	72.5
14A	2	0.384	0.415	0.353	0.9973	54.2
13A	2	0.455	0.491	0.419	0.9929	29.2
12A	2	0.447	0.489	0.404	0.9872	26.9
20C	2	0.262	0.300	0.224	0.9949	57.7
19C	2	0.190	0.199	0.180	0.9940	116.0
18C	2	0.356	0.366	0.345	0.9989	62.0
17C	2	0.231	0.242	0.219	0.9952	135.0

[A]Max and min values are for the 90 percent confidence interval on the mean.

Table 17. Phase 2, box 1, first mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1	0.40	1.00	92	115	1.46	0.9978	1.47	0.9975
20A	2	0.40	1.00	65	90	1.66	0.9968	1.67	0.9971
20A	3	0.40	1.00	54	80	1.52	0.9962	1.51	0.9966
20A	4	0.40	1.00	50	75	1.39	0.9979	1.40	0.9975
20A	5	0.40	1.00	51	75	1.51	0.9963	1.53	0.9962
20A	6	0.40	1.00	51	75	1.48	0.9960	1.50	0.9957
20A	7	0.40	1.00	55	80	1.53	0.9961	1.53	0.9964
20A	8	0.40	1.00	55	80	1.59	0.9955	1.62	0.9954
20A	9	0.40	1.00	51	75	1.39	0.9977	1.42	0.9976
20A	10	0.40	1.00	46	70	1.41	0.9975	1.39	0.9976
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	0.40	1.00	49	75	1.35	0.9985	1.35	0.9983
19A	3	0.40	1.00	52	80	1.33	0.9981	1.33	0.9976
19A	4	0.40	1.00	47	75	1.40	0.9980	1.40	0.9981
19A	5	0.40	1.00	317	340	1.33	0.9982	1.35	0.9984
19A	6	0.40	1.00	72	100	1.62	0.9964	1.63	0.9965
19A	7	0.40	1.00	64	100	1.47	0.9976	1.47	0.9975
19A	8	0.40	1.00	43	70	1.51	0.9969	1.51	0.9971
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	0.40	1.10	56	75	1.91	0.9919	1.89	0.9917
18A	3	0.40	1.10	58	80	1.88	0.9945	1.86	0.9932
18A	4	0.40	1.10	57	80	1.85	0.9931	1.81	0.9915
18A	5	0.40	1.10	68	90	1.70	0.9979	1.71	0.9984
18A	6	0.40	1.10	126	150	1.93	0.9967	1.92	0.9960
18A	7	0.40	1.10	78	100	1.94	0.9962	1.91	0.9960
18A	8	0.40	1.10	56	80	1.77	0.9925	1.79	0.9938
18A	9	0.40	1.10	63	85	1.78	0.9936	1.80	0.9935
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	0.40	1.10	63	95	1.57	0.9955	1.55	0.9953
17A	3	0.40	1.10	46	80	1.59	0.9962	1.57	0.9958
17A	4	0.40	1.10	50	90	1.57	0.9967	1.57	0.9968
17A	5	0.40	1.10	44	75	1.54	0.9965	1.56	0.9971
17A	6	0.40	1.10	44	75	1.50	0.9949	1.52	0.9951
17A	7	0.40	1.10	54	90	1.44	0.9954	1.43	0.9948
17A	8	0.40	1.10	103	135	1.51	0.9940	1.50	0.9939
17A	9	0.40	1.10	59	90	1.56	0.9973	1.55	0.9971
17A	10	0.40	1.10	81	110	1.49	0.9938	1.48	0.9935
16A	1[A]	—	—	—	—	—	—	—	—
16A	2[A]	—	—	—	—	—	—	—	—
16A	3	0.40	1.10	47	75	1.66	0.9987	1.67	0.9989

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
16A	4	0.40	1.10	36	65	1.69	0.9981	1.70	0.9982
16A	5	0.40	1.10	35	65	1.69	0.9971	1.68	0.9969
16A	6	0.40	1.10	30	60	1.70	0.9976	1.70	0.9973
16A	7	0.40	1.20	37	67	1.69	0.9973	1.70	0.9977
16A	8	0.40	1.10	47	77	1.67	0.9972	1.68	0.9974
16A	9	0.40	1.10	32	62	1.70	0.9974	1.71	0.9979
16A	10	0.40	1.10	34	65	1.66	0.9980	1.67	0.9982
16A	11	0.40	1.20	44	75	1.68	0.9980	1.69	0.9983
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	0.50	1.20	40	65	1.86	0.9974	1.87	0.9979
15A	3	0.50	1.20	35	60	1.88	0.9983	1.86	0.9981
15A	4	0.50	1.20	31	56	1.79	0.9954	1.77	0.9941
15A	5	0.50	1.20	35	60	1.89	0.9985	1.87	0.9981
15A	6	0.50	1.20	61	86	1.87	0.9979	1.85	0.9975
15A	7	0.50	1.20	36	61	1.85	0.9977	1.84	0.9973
15A	8	0.50	1.20	52	77	1.86	0.9980	1.84	0.9977
15A	9	0.50	1.20	36	61	1.79	0.9967	1.81	0.9974
15A	10	0.50	1.20	60	85	1.86	0.9978	1.84	0.9973
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	0.50	1.20	57	71	1.93	0.9947	1.98	0.9964
14A	3	0.50	1.30	29	55	1.83	0.9978	1.85	0.9979
14A	4	0.50	1.30	33	58	1.84	0.9985	1.82	0.9983
14A	5	0.50	1.30	30	55	1.78	0.9984	1.77	0.9982
14A	6	0.50	1.30	66	90	1.80	0.9987	1.79	0.9984
14A	7	0.50	1.30	32	57	1.85	0.9985	1.84	0.9984
14A	8	0.50	1.30	34	60	1.77	0.9982	1.78	0.9984
14A	9	0.50	1.30	29	54	1.79	0.9990	1.78	0.9989
14A	10	0.50	1.30	39	64	1.79	0.9985	1.78	0.9983
14A	11	0.50	1.30	30	55	1.78	0.9987	1.77	0.9987
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	0.50	1.30	74	97	1.78	0.9965	1.76	0.9960
13A	3	0.50	1.30	50	72	1.75	0.9975	1.77	0.9979
13A	4	0.50	1.30	37	60	1.78	0.9960	1.79	0.9970
13A	5	0.50	1.30	51	71	1.80	0.9965	1.78	0.9953
13A	6	0.50	1.30	54	75	1.79	0.9955	1.81	0.9966
13A	7	0.50	1.30	58	78	1.81	0.9954	1.79	0.9943
13A	8	0.50	1.30	51	67	1.82	0.9958	1.83	0.9963
13A	9	0.50	1.30	56	72	1.84	0.9966	1.81	0.9958
13A	10	0.50	1.30	50	66	1.80	0.9979	1.77	0.9973
13A	11	0.50	1.30	48	69	1.70	0.9956	1.73	0.9961
12A	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
12A	2	0.60	1.40	203	222	1.91	0.9964	1.94	0.9967
12A	3	0.60	1.40	41	60	1.93	0.9969	1.95	0.9971
12A	4	0.60	1.40	58	78	1.92	0.9971	1.90	0.9965
12A	5	0.60	1.40	39	59	1.94	0.9969	1.96	0.9970
12A	6	0.60	1.40	43	63	1.91	0.9958	1.93	0.9966
12A	7	0.60	1.40	49	64	1.91	0.9944	1.94	0.9955
12A	8	0.60	1.40	49	68	1.93	0.9963	1.91	0.9960
12A	9	0.60	1.40	50	70	1.97	0.9981	1.99	0.9984
12A	10	0.60	1.40	46	66	1.95	0.9984	1.96	0.9987
12A	11	0.60	1.40	63	82	1.92	0.9979	1.91	0.9973
20C	1[A]	—	—	—	—	—	—	—	—
20C	2[B]	—	—	—	—	—	—	—	—
20C	3[B]	—	—	—	—	—	—	—	—
20C	4[B]	—	—	—	—	—	—	—	—
20C	5	0.40	0.90	85	105	1.35	0.9988	1.37	0.9989
20C	6	0.40	0.90	74	98	1.34	0.9977	1.33	0.9974
20C	7	0.40	0.90	55	77	1.45	0.9975	1.45	0.9979
20C	8	0.40	0.90	55	80	1.39	0.9981	1.39	0.9985
20C	9	0.40	0.90	54	78	1.38	0.9972	1.38	0.9968
20C	10	0.40	0.90	64	85	1.45	0.9977	1.45	0.9978
20C	11	0.40	0.90	59	87	1.42	0.9969	1.44	0.9966
20C	12	0.40	0.90	52	75	1.33	0.9974	1.35	0.9980
20C	13	0.40	0.90	46	68	1.44	0.9981	1.42	0.9982
20C	14	0.40	0.90	58	80	1.35	0.9981	1.33	0.9979
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	0.40	0.90	132	185	1.50	0.9949	1.51	0.9949
19C	3	0.40	0.90	58	130	1.52	0.9973	1.52	0.9973
19C	4	0.40	0.90	58	95	1.59	0.9912	1.62	0.9914
19C	5	0.40	0.90	55	115	1.47	0.9933	1.48	0.9931
19C	6	0.40	0.90	64	92	1.44	0.9956	1.44	0.9950
19C	7	0.40	0.90	64	120	1.53	0.9943	1.54	0.9943
19C	8	0.40	0.90	62	90	1.36	0.9952	1.36	0.9946
19C	9	0.40	0.90	68	130	1.42	0.9935	1.42	0.9932
19C	10	0.40	0.90	96	125	1.41	0.9940	1.44	0.9937
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	0.40	0.90	154	185	1.75	0.9971	1.74	0.9969
18C	3	0.40	0.90	117	160	1.58	0.9948	1.57	0.9941
18C	4	0.40	0.90	42	80	1.65	0.9949	1.64	0.9947
18C	5	0.40	0.90	40	72	1.79	0.9943	1.77	0.9942
18C	6	0.40	0.90	51	95	1.62	0.9969	1.61	0.9965
18C	7	0.40	0.90	51	95	1.64	0.9971	1.63	0.9966

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
18C	8	0.40	0.90	56	95	1.65	0.9954	1.66	0.9959
18C	9	0.40	0.90	38	75	1.65	0.9945	1.66	0.9948
18C	10	0.40	0.90	43	80	1.63	0.9946	1.62	0.9939
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	0.40	1.00	128	163	1.71	0.9985	1.70	0.9978
17C	3	0.40	1.00	41	76	1.67	0.9970	1.66	0.9964
17C	4	0.40	1.00	38	75	1.61	0.9984	1.60	0.9982
17C	5	0.40	1.00	38	73	1.60	0.9960	1.61	0.9965
17C	6	0.40	1.00	39	74	1.68	0.9951	1.67	0.9944
17C	7	0.40	1.00	36	73	1.63	0.9947	1.64	0.9950
17C	8	0.40	1.00	38	73	1.66	0.9980	1.64	0.9978
17C	9	0.40	1.00	45	82	1.65	0.9964	1.64	0.9957
16C	1[A]	—	—	—	—	—	—	—	—
16C	2	0.40	1.00	42	75	1.96	0.9943	1.98	0.9955
16C	3	0.40	1.00	59	90	1.96	0.9961	1.98	0.9967
16C	4	0.40	1.00	47	77	2.07	0.9961	2.06	0.9958
16C	5	0.40	1.00	42	70	2.00	0.9930	2.02	0.9939
16C	6	0.40	1.00	43	75	2.08	0.9950	2.11	0.9957
16C	7	0.40	1.10	52	78	2.03	0.9954	2.00	0.9946
16C	8	0.40	1.00	41	69	1.97	0.9959	1.95	0.9949
16C	9	0.40	1.00	45	73	1.99	0.9943	2.01	0.9952
16C	10	0.40	1.00	52	79	2.00	0.9967	1.98	0.9958
15C	1[A]	—	—	—	—	—	—	—	—
15C	2	0.40	1.10	47	75	1.84	0.9984	1.82	0.9981
15C	3	0.40	1.10	45	73	1.76	0.9979	1.78	0.9980
15C	4	0.40	1.10	46	75	1.80	0.9968	1.80	0.9971
15C	5	0.40	1.10	66	95	1.76	0.9968	1.75	0.9970
15C	6	0.40	1.10	51	80	1.80	0.9969	1.82	0.9973
15C	7	0.40	1.10	52	85	1.82	0.9938	1.84	0.9943
15C	8	0.40	1.10	47	77	1.81	0.9969	1.80	0.9969
15C	9	0.40	1.10	41	70	1.79	0.9975	1.80	0.9975
15C	10	0.40	1.10	52	85	1.76	0.9945	1.75	0.9942
14C	1[A]	—	—	—	—	—	—	—	—
14C	2	0.40	1.10	58	95	1.93	0.9962	1.94	0.9966
14C	3	0.40	1.10	55	90	2.10	0.9973	2.09	0.9972
14C	4	0.40	1.10	44	83	2.19	0.9975	2.20	0.9975
14C	5	0.40	1.10	48	80	1.99	0.9964	1.99	0.9964
14C	6	0.40	1.10	76	115	2.04	0.9967	2.03	0.9967
14C	7	0.40	1.10	47	83	2.04	0.9969	2.06	0.9975
14C	8	0.40	1.10	59	95	1.98	0.9973	1.99	0.9973
20B	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
20B	2	0.40	0.90	71	101	1.45	0.9975	1.45	0.9970
20B	3	0.40	0.90	49	80	1.30	0.9981	1.29	0.9982
20B	4	0.40	0.90	64	95	1.24	0.9984	1.24	0.9987
20B	5	0.40	0.90	50	80	1.34	0.9974	1.32	0.9975
20B	6	0.40	0.90	55	85	1.30	0.9976	1.30	0.9972
20B	7	0.40	0.90	48	78	1.32	0.9973	1.32	0.9977
20B	8	0.40	0.90	52	80	1.30	0.9979	1.32	0.9977
20B	9	0.40	0.90	54	85	1.36	0.9978	1.34	0.9980
20B	10	0.40	0.90	63	93	1.36	0.9971	1.37	0.9965
19B	1[A]	—	—	—	—	—	—	—	—
19B	2	0.40	0.90	58	88	1.24	0.9987	1.24	0.9989
19B	3	0.40	0.90	52	82	1.21	0.9987	1.22	0.9985
19B	4	0.40	0.90	72	105	1.20	0.9989	1.21	0.9988
19B	5	0.40	0.90	64	95	1.19	0.9989	1.19	0.9987
19B	6	0.40	0.90	74	105	1.18	0.9986	1.19	0.9983
19B	7	0.40	0.90	59	90	1.20	0.9986	1.21	0.9984
19B	8	0.40	0.90	72	105	1.15	0.9987	1.16	0.9986
19B	9	0.40	0.90	67	100	1.20	0.9984	1.19	0.9985
19B	10	0.40	0.90	72	105	1.19	0.9984	1.18	0.9986
19B	11	0.40	0.90	52	85	1.17	0.9985	1.18	0.9983
18B	1[A]	—	—	—	—	—	—	—	—
18B	2	0.40	0.90	58	83	1.62	0.9965	1.65	0.9968
18B	3	0.40	0.90	76	101	1.73	0.9966	1.76	0.9964
18B	4	0.40	0.90	58	83	1.67	0.9967	1.66	0.9969
18B	5	0.40	0.90	61	86	1.61	0.9972	1.64	0.9975
18B	6	0.40	0.90	51	90	1.75	0.9958	1.73	0.9953
18B	7	0.40	0.90	52	75	1.67	0.9974	1.67	0.9970
18B	8	0.40	0.90	58	78	1.77	0.9969	1.81	0.9970
18B	9	0.40	0.90	51	90	1.84	0.9982	1.83	0.9982
17B	1[A]	—	—	—	—	—	—	—	—
17B	2	0.40	1.00	61	86	1.55	0.9975	1.53	0.9978
17B	3	0.40	1.00	51	76	1.49	0.9975	1.47	0.9977
17B	4	0.40	1.00	58	83	1.48	0.9977	1.50	0.9973
17B	5	0.40	1.00	51	76	1.48	0.9984	1.49	0.9982
17B	6	0.40	1.00	72	97	1.43	0.9990	1.41	0.9991
17B	7	0.40	1.00	53	78	1.48	0.9981	1.50	0.9980
17B	8	0.40	1.00	61	86	1.45	0.9981	1.43	0.9983
17B	9	0.40	1.00	56	79	1.42	0.9987	1.42	0.9985
17B	10	0.40	1.00	66	91	1.54	0.9960	1.52	0.9966
16B	1[A]	—	—	—	—	—	—	—	—
16B	2	0.50	1.00	71	96	1.72	0.9984	1.72	0.9982

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16B	3	0.50	1.00	61	86	1.63	0.9985	1.63	0.9984
16B	4	0.50	1.00	96	121	1.60	0.9991	1.58	0.9991
16B	5	0.50	1.00	86	111	1.69	0.9981	1.67	0.9982
16B	6	0.50	1.00	58	85	1.66	0.9981	1.66	0.9978
16B	7	0.50	1.00	79	104	1.69	0.9980	1.68	0.9982
16B	8	0.50	1.00	51	76	1.63	0.9988	1.64	0.9988
16B	9	0.50	1.00	54	80	1.66	0.9982	1.64	0.9984
16B	10	0.50	1.00	88	113	1.65	0.9981	1.63	0.9983
15B	1[A]	—	—	—	—	—	—	—	—
15B	2	0.50	1.00	106	126	1.78	0.9975	1.78	0.9972
15B	3	0.50	1.00	81	101	1.73	0.9977	1.76	0.9976
15B	4	0.50	1.00	65	85	1.72	0.9976	1.72	0.9972
15B	5	0.50	1.00	83	103	1.74	0.9979	1.73	0.9982
15B	6	0.50	1.10	64	84	1.78	0.9983	1.79	0.9981
15B	7	0.50	1.10	57	77	1.71	0.9984	1.69	0.9985
15B	8	0.50	1.10	63	85	1.72	0.9980	1.72	0.9984
15B	9	0.50	1.10	67	87	1.63	0.9983	1.63	0.9986
15B	10	0.50	1.10	78	98	1.64	0.9985	1.64	0.9987
20D	1[A]	—	—	—	—	—	—	—	—
20D	2	0.40	1.00	71	101	1.34	0.9981	1.35	0.9979
20D	3	0.40	1.00	51	76	1.30	0.9985	1.29	0.9986
20D	4	0.40	1.00	39	65	1.25	0.9985	1.24	0.9986
20D	5	0.40	1.00	42	67	1.27	0.9983	1.28	0.9982
20D	6	0.40	1.00	34	60	1.28	0.9990	1.29	0.9989
20D	7	0.40	1.00	39	65	1.23	0.9984	1.24	0.9984
20D	8	0.40	1.00	39	65	1.22	0.9985	1.23	0.9985
20D	9	0.40	1.00	35	65	1.24	0.9966	1.23	0.9968
19D	1	0.40	1.10	76	135	1.26	0.9986	1.25	0.9986
19D	2	0.40	1.10	48	100	1.26	0.9983	1.26	0.9984
19D	3	0.40	1.10	39	90	1.23	0.9988	1.22	0.9987
19D	4	0.40	1.10	39	85	1.29	0.9987	1.28	0.9984
19D	5	0.40	1.10	37	90	1.25	0.9989	1.24	0.9988
19D	6	0.40	1.10	41	90	1.24	0.9986	1.24	0.9987
19D	7	0.40	1.10	40	95	1.17	0.9983	1.17	0.9982
19D	8	0.40	1.10	29	80	1.23	0.9983	1.22	0.9982
18D	1	0.40	1.10	49	70	1.50	0.9977	1.52	0.9975
18D	2	0.40	1.10	46	66	1.54	0.9987	1.53	0.9987
18D	3	0.40	1.10	46	66	1.48	0.9989	1.48	0.9990
18D	4	0.40	1.10	36	60	1.44	0.9983	1.46	0.9985
18D	5	0.40	1.10	44	65	1.57	0.9971	1.59	0.9971
18D	6	0.40	1.10	36	56	1.49	0.9990	1.48	0.9991

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
18D	7	0.40	1.10	36	56	1.43	0.9977	1.45	0.9977
18D	8	0.40	1.10	48	70	1.52	0.9979	1.51	0.9981
17D	1	0.40	1.10	99	119	1.66	0.9985	1.68	0.9982
17D	2	0.40	1.10	56	76	1.67	0.9985	1.65	0.9986
17D	3	0.40	1.10	64	84	1.56	0.9985	1.58	0.9983
17D	4	0.40	1.10	49	70	1.59	0.9987	1.61	0.9984
17D	5	0.40	1.10	40	60	1.60	0.9996	1.59	0.9997
17D	6	0.40	1.10	44	64	1.66	0.9989	1.66	0.9991
17D	7	0.40	1.10	39	60	1.57	0.9984	1.56	0.9987
17D	8	0.40	1.10	49	70	1.66	0.9983	1.68	0.9978
16D	1	0.40	1.20	195	225	1.69	0.9975	1.70	0.9977
16D	2	0.50	1.20	54	85	1.63	0.9965	1.65	0.9972
16D	3	0.50	1.20	43	80	1.54	0.9977	1.54	0.9978
16D	4	0.50	1.20	50	85	1.57	0.9993	1.56	0.9992
16D	5	0.50	1.20	45	80	1.58	0.9994	1.58	0.9993
16D	6	0.50	1.20	50	85	1.55	0.9987	1.56	0.9988
16D	7	0.50	1.20	45	75	1.61	0.9994	1.62	0.9994
16D	8[B]	—	—	—	—	—	—	—	—
15D	1	0.50	1.20	139	170	1.62	0.9991	1.62	0.9991
15D	2	0.50	1.20	53	85	1.62	0.9989	1.61	0.9987
15D	3	0.60	1.30	48	75	1.63	0.9995	1.62	0.9995
15D	4	0.50	1.20	36	75	1.52	0.9992	1.52	0.9991
15D	5	0.60	1.30	34	60	1.60	0.9998	1.60	0.9998
15D	6	0.50	1.20	32	60	1.68	0.9995	1.69	0.9995
15D	7	0.60	1.20	37	72	1.57	0.9988	1.56	0.9986
15D	8	0.60	1.20	32	65	1.62	0.9992	1.62	0.9992
14D	1	0.50	1.30	121	146	1.96	0.9994	1.95	0.9992
14D	2	0.50	1.30	49	75	1.83	0.9992	1.82	0.9992
14D	3	0.50	1.30	36	61	1.88	0.9997	1.88	0.9996
14D	4	0.50	1.30	32	57	1.83	0.9987	1.85	0.9990
14D	5	0.50	1.30	36	61	1.83	0.9982	1.84	0.9987
14D	6	0.60	1.30	39	65	1.83	0.9970	1.85	0.9975
14D	7	0.60	1.30	35	60	1.88	0.9987	1.89	0.9988
14D	8	0.60	1.30	40	65	1.93	0.9990	1.93	0.9989

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
13D	1	0.60	1.30	65	85	2.17	0.9995	2.17	0.9994
13D	2	0.60	1.30	35	55	2.07	0.9991	2.05	0.9990
13D	3	0.60	1.30	38	60	2.04	0.9978	2.02	0.9974
13D	4	0.60	1.30	70	90	2.11	0.9993	2.12	0.9995
13D	5	0.60	1.30	52	72	2.10	0.9988	2.12	0.9992
13D	6	0.60	1.30	52	72	2.01	0.9998	2.01	0.9998
13D	7	0.60	1.30	38	60	2.04	0.9996	2.02	0.9995
13D	8	0.60	1.30	40	60	2.10	0.9989	2.10	0.9989

[A] Baseline run.
[B] Unreadable data.

Table 18. Phase 2, box 2, first mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1	0.40	1.00	92	115	1.62	0.9962	1.63	0.9957
20A	2	0.40	1.00	64	84	1.70	0.9949	1.74	0.9946
20A	3	0.40	1.00	54	75	1.51	0.9971	1.51	0.9975
20A	4	0.40	1.00	50	75	1.48	0.9960	1.51	0.9959
20A	5	0.40	1.00	51	71	1.53	0.9976	1.52	0.9982
20A	6	0.40	1.00	51	71	1.47	0.9974	1.46	0.9979
20A	7	0.40	1.00	55	75	1.52	0.9978	1.51	0.9979
20A	8	0.40	1.00	55	75	1.57	0.9969	1.61	0.9967
20A	9	0.40	1.00	51	71	1.41	0.9984	1.41	0.9987
20A	10	0.40	1.00	46	66	1.41	0.9987	1.41	0.9984
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	0.40	1.00	49	74	1.41	0.9981	1.42	0.9978
19A	3	0.40	1.00	52	75	1.33	0.9989	1.33	0.9980
19A	4	0.40	1.00	47	72	1.45	0.9978	1.46	0.9976
19A	5	0.40	1.00	317	340	1.43	0.9977	1.46	0.9978
19A	6	0.40	1.00	72	92	1.61	0.9953	1.60	0.9960
19A	7	0.40	1.00	64	84	1.57	0.9968	1.57	0.9975
19A	8	0.40	1.00	43	63	1.52	0.9975	1.52	0.9978
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	0.50	1.10	56	75	2.61	0.9914	2.55	0.9908
18A	3	0.50	1.10	59	80	2.52	0.9930	2.47	0.9921
18A	4	0.50	1.10	57	77	2.58	0.9952	2.64	0.9964
18A	5	0.50	1.10	68	88	2.28	0.9954	2.26	0.9953
18A	6	0.50	1.10	126	141	2.16	0.9936	2.23	0.9934
18A	7	0.50	1.10	78	102	2.38	0.9932	2.36	0.9919
18A	8	0.50	1.10	56	78	2.48	0.9951	2.43	0.9940
18A	9	0.50	1.10	63	83	2.47	0.9926	2.42	0.9924
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	0.40	1.10	63	80	1.68	0.9977	1.70	0.9975
17A	3	0.40	1.10	46	66	1.74	0.9954	1.72	0.9960
17A	4	0.40	1.10	50	70	1.75	0.9962	1.72	0.9968
17A	5	0.40	1.10	44	60	1.71	0.9975	1.69	0.9982
17A	6	0.40	1.10	44	60	1.72	0.9968	1.71	0.9972
17A	7	0.40	1.10	54	74	1.71	0.9977	1.74	0.9974
17A	8	0.40	1.10	103	120	1.75	0.9985	1.76	0.9982
17A	9	0.40	1.10	59	77	1.72	0.9975	1.70	0.9977
17A	10	0.40	1.10	81	97	1.83	0.9983	1.84	0.9978
16A	1[A]	—	—	—	—	—	—	—	—
16A	2[A]	—	—	—	—	—	—	—	—
16A	3	0.40	1.10	47	67	1.94	0.9963	1.93	0.9970

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	4	0.40	1.10	36	54	1.91	0.9977	1.95	0.9972
16A	5	0.40	1.10	35	53	1.99	0.9958	1.95	0.9965
16A	6	0.40	1.10	30	48	1.98	0.9965	2.02	0.9959
16A	7	0.40	1.20	37	55	1.99	0.9964	1.96	0.9966
16A	8	0.40	1.10	47	65	1.93	0.9974	1.92	0.9977
16A	9	0.40	1.10	32	52	1.92	0.9970	1.91	0.9973
16A	10	0.40	1.10	34	53	1.86	0.9977	1.89	0.9973
16A	11	0.40	1.20	44	62	1.89	0.9974	1.91	0.9971
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	0.50	1.20	40	56	2.13	0.9953	2.08	0.9960
15A	3	0.50	1.20	35	51	2.02	0.9970	2.06	0.9971
15A	4	0.50	1.20	31	44	2.07	0.9968	2.12	0.9966
15A	5	0.50	1.20	35	50	2.06	0.9978	2.07	0.9974
15A	6	0.50	1.20	61	76	2.03	0.9969	2.02	0.9972
15A	7	0.50	1.20	36	51	2.01	0.9979	2.05	0.9977
15A	8	0.50	1.20	52	67	2.03	0.9982	2.04	0.9978
15A	9	0.50	1.20	36	51	2.01	0.9978	2.01	0.9973
15A	10	0.50	1.20	60	75	2.00	0.9974	2.01	0.9972
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	0.50	1.30	58	70	3.10	0.9972	3.18	0.9978
14A	3	0.50	1.30	30	46	2.10	0.9982	2.13	0.9980
14A	4	0.50	1.30	33	48	2.08	0.9990	2.05	0.9988
14A	5	0.50	1.30	30	46	2.11	0.9978	2.08	0.9978
14A	6	0.50	1.30	66	82	2.10	0.9986	2.11	0.9985
14A	7	0.50	1.30	32	47	2.08	0.9990	2.08	0.9990
14A	8	0.50	1.30	34	50	2.02	0.9993	2.04	0.9992
14A	9	0.50	1.30	29	47	2.07	0.9989	2.06	0.9990
14A	10	0.50	1.30	39	57	2.09	0.9983	2.07	0.9987
14A	11	0.50	1.30	30	48	2.06	0.9984	2.04	0.9989
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	0.50	1.30	74	89	2.09	0.9981	2.10	0.9974
13A	3	0.50	1.30	50	65	2.07	0.9973	2.06	0.9977
13A	4	0.50	1.30	37	52	2.07	0.9975	2.04	0.9978
13A	5	0.50	1.30	51	64	2.15	0.9977	2.20	0.9964
13A	6	0.50	1.30	54	67	2.16	0.9977	2.12	0.9977
13A	7	0.50	1.30	58	70	2.04	0.9969	2.10	0.9975
13A	8	0.50	1.30	51	63	2.46	0.9979	2.52	0.9981
13A	9	0.50	1.30	56	68	2.46	0.9954	2.38	0.9959
13A	10	0.50	1.30	50	62	2.41	0.9959	2.33	0.9951
13A	11	0.50	1.30	49	62	2.14	0.9964	2.14	0.9970
12A	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
12A	2	0.60	1.40	204	215	2.35	0.9964	2.41	0.9964
12A	3	0.60	1.40	41	53	2.32	0.9981	2.36	0.9977
12A	4	0.60	1.40	58	70	2.27	0.9987	2.31	0.9984
12A	5	0.60	1.40	39	51	2.29	0.9982	2.30	0.9977
12A	6	0.60	1.40	43	55	2.34	0.9980	2.30	0.9983
12A	7	0.60	1.40	49	64	2.66	0.9966	2.68	0.9971
12A	8	0.60	1.40	49	61	2.37	0.9966	2.32	0.9973
12A	9	0.60	1.40	51	64	2.33	0.9980	2.32	0.9982
12A	10	0.60	1.40	46	59	2.19	0.9989	2.20	0.9983
12A	11	0.60	1.40	63	77	2.34	0.9973	2.33	0.9973
20C	1[A]	—	—	—	—	—	—	—	—
20C	2[B]	—	—	—	—	—	—	—	—
20C	3[B]	—	—	—	—	—	—	—	—
20C	4[B]	—	—	—	—	—	—	—	—
20C	5	0.40	0.90	85	105	1.39	0.9988	1.41	0.9990
20C	6	0.40	0.90	74	98	1.41	0.9970	1.40	0.9967
20C	7	0.40	0.90	55	77	1.51	0.9969	1.51	0.9976
20C	8	0.40	0.90	55	80	1.43	0.9980	1.43	0.9984
20C	9	0.40	0.90	54	78	1.40	0.9965	1.43	0.9971
20C	10	0.40	0.90	64	85	1.50	0.9979	1.51	0.9976
20C	11	0.40	0.90	59	87	1.48	0.9956	1.51	0.9949
20C	12	0.40	0.90	52	75	1.37	0.9970	1.40	0.9976
20C	13	0.40	0.90	46	68	1.49	0.9978	1.47	0.9979
20C	14	0.40	0.90	58	80	1.40	0.9977	1.37	0.9972
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	0.40	0.90	132	157	1.54	0.9966	1.57	0.9964
19C	3	0.40	0.90	58	83	1.39	0.9979	1.37	0.9982
19C	4	0.40	0.90	58	83	1.46	0.9960	1.43	0.9967
19C	5	0.40	0.90	55	80	1.34	0.9981	1.36	0.9981
19C	6	0.40	0.90	64	89	1.46	0.9967	1.44	0.9971
19C	7	0.40	0.90	64	89	1.35	0.9975	1.37	0.9972
19C	8	0.40	0.90	62	87	1.37	0.9970	1.35	0.9974
19C	9	0.40	0.90	68	93	1.46	0.9975	1.49	0.9971
19C	10	0.40	0.90	96	121	1.40	0.9957	1.43	0.9956
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	0.40	0.90	154	169	1.93	0.9972	1.93	0.9977
18C	3	0.40	0.90	117	137	1.69	0.9976	1.72	0.9975
18C	4	0.40	0.90	42	62	1.83	0.9964	1.82	0.9956
18C	5	0.40	0.90	40	57	1.99	0.9960	1.94	0.9971
18C	6	0.40	0.90	51	71	1.69	0.9980	1.71	0.9980
18C	7	0.40	0.90	52	72	1.70	0.9973	1.72	0.9973

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
18C	8	0.40	0.90	56	76	1.69	0.9980	1.66	0.9978
18C	9	0.40	0.90	38	58	1.81	0.9957	1.81	0.9961
18C	10	0.40	0.90	43	63	1.82	0.9961	1.81	0.9967
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	0.40	1.00	128	146	1.93	0.9966	1.93	0.9966
17C	3	0.40	1.00	41	61	1.83	0.9967	1.82	0.9971
17C	4	0.40	1.00	38	56	1.74	0.9975	1.74	0.9976
17C	5	0.40	1.00	38	55	1.76	0.9977	1.77	0.9972
17C	6	0.40	1.00	39	56	1.94	0.9968	1.93	0.9973
17C	7	0.40	1.00	36	54	1.76	0.9982	1.79	0.9981
17C	8	0.40	1.00	38	58	1.81	0.9976	1.84	0.9975
17C	9	0.40	1.00	45	63	1.79	0.9970	1.78	0.9978
16C	1[A]	—	—	—	—	—	—	—	—
16C	2	0.40	1.00	42	60	2.17	0.9967	2.12	0.9972
16C	3	0.40	1.00	59	76	2.08	0.9970	2.08	0.9977
16C	4	0.40	1.00	47	63	2.23	0.9951	2.23	0.9959
16C	5	0.40	1.00	42	57	2.15	0.9980	2.16	0.9974
16C	6	0.40	1.00	43	58	2.21	0.9970	2.22	0.9976
16C	7	0.40	1.10	52	67	2.40	0.9946	2.41	0.9939
16C	8	0.40	1.00	41	56	2.17	0.9970	2.22	0.9970
16C	9	0.40	1.00	45	60	2.13	0.9985	2.14	0.9979
16C	10	0.40	1.00	52	67	2.21	0.9963	2.20	0.9968
15C	1[A]	—	—	—	—	—	—	—	—
15C	2	0.40	1.10	47	64	1.95	0.9979	1.96	0.9973
15C	3	0.40	1.10	45	62	1.91	0.9965	1.96	0.9963
15C	4	0.40	1.10	46	63	1.98	0.9953	1.92	0.9952
15C	5	0.40	1.10	66	83	2.07	0.9963	2.07	0.9964
15C	6	0.40	1.10	51	68	1.99	0.9947	1.97	0.9954
15C	7	0.40	1.10	52	68	1.87	0.9958	1.93	0.9954
15C	8	0.40	1.10	47	65	1.95	0.9956	2.00	0.9954
15C	9	0.40	1.10	41	58	1.88	0.9964	1.93	0.9964
15C	10	0.40	1.10	52	69	2.00	0.9963	1.95	0.9964
14C	1[A]	—	—	—	—	—	—	—	—
14C	2	0.40	1.10	58	75	2.04	0.9971	2.06	0.9964
14C	3	0.40	1.10	55	71	2.10	0.9973	2.09	0.9976
14C	4	0.40	1.10	44	60	2.00	0.9955	1.95	0.9963
14C	5	0.40	1.10	48	65	1.96	0.9970	1.97	0.9962
14C	6	0.40	1.10	76	92	2.00	0.9973	2.00	0.9979
14C	7	0.40	1.10	47	64	2.06	0.9975	2.07	0.9971
14C	8	0.40	1.10	59	76	1.94	0.9977	1.95	0.9968
20B	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
20B	2	0.60	0.90	71	101	1.58	0.9934	1.59	0.9935
20B	3	0.40	0.90	49	80	1.37	0.9969	1.35	0.9971
20B	4	0.40	0.90	64	95	1.29	0.9974	1.29	0.9980
20B	5	0.40	0.90	50	80	1.40	0.9963	1.38	0.9966
20B	6	0.40	0.90	55	85	1.36	0.9963	1.36	0.9956
20B	7	0.40	0.90	48	78	1.40	0.9954	1.39	0.9962
20B	8	0.40	0.90	52	80	1.37	0.9966	1.39	0.9965
20B	9	0.40	0.90	54	85	1.43	0.9961	1.40	0.9966
20B	10	0.40	0.90	63	93	1.44	0.9956	1.45	0.9942
19B	1[A]	—	—	—	—	—	—	—	—
19B	2	0.40	0.90	58	88	1.29	0.9982	1.29	0.9984
19B	3	0.40	0.90	52	82	1.26	0.9987	1.26	0.9984
19B	4	0.40	0.90	72	105	1.24	0.9985	1.26	0.9983
19B	5	0.40	0.90	64	95	1.24	0.9984	1.24	0.9982
19B	6	0.40	0.90	74	105	1.23	0.9981	1.24	0.9976
19B	7	0.40	0.90	59	90	1.25	0.9982	1.25	0.9980
19B	8	0.40	0.90	72	105	1.18	0.9981	1.20	0.9980
19B	9	0.40	0.90	67	100	1.24	0.9981	1.23	0.9981
19B	10	0.40	0.90	72	105	1.24	0.9979	1.22	0.9981
19B	11	0.40	0.90	52	85	1.21	0.9982	1.21	0.9984
18B	1[A]	—	—	—	—	—	—	—	—
18B	2	0.40	0.90	59	83	1.77	0.9955	1.80	0.9956
18B	3	0.40	0.90	76	96	1.67	0.9978	1.71	0.9975
18B	4	0.40	0.90	58	78	1.63	0.9980	1.62	0.9982
18B	5	0.40	0.90	61	84	1.63	0.9970	1.67	0.9972
18B	6	0.40	0.90	51	71	1.82	0.9965	1.82	0.9962
18B	7	0.40	0.90	52	72	1.69	0.9978	1.65	0.9977
18B	8	0.40	0.90	58	76	1.81	0.9972	1.86	0.9962
18B	9	0.40	0.90	51	71	1.81	0.9966	1.76	0.9970
17B	1[A]	—	—	—	—	—	—	—	—
17B	2	0.40	1.00	61	86	1.62	0.9969	1.59	0.9971
17B	3	0.40	1.00	51	76	1.51	0.9967	1.51	0.9966
17B	4	0.40	1.00	58	83	1.56	0.9969	1.58	0.9965
17B	5	0.40	1.00	51	76	1.53	0.9976	1.55	0.9976
17B	6	0.40	1.00	72	97	1.48	0.9985	1.46	0.9988
17B	7	0.40	1.00	53	78	1.54	0.9974	1.56	0.9973
17B	8	0.40	1.00	61	86	1.50	0.9978	1.47	0.9979
17B	9	0.40	1.00	56	79	1.45	0.9986	1.46	0.9984
17B	10	0.40	1.00	66	91	1.62	0.9944	1.59	0.9952
16B	1[A]	—	—	—	—	—	—	—	—
16B	2	0.50	1.00	71	96	1.85	0.9968	1.82	0.9970

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
16B	3	0.50	1.00	61	86	1.73	0.9973	1.73	0.9969
16B	4	0.50	1.00	96	121	1.65	0.9978	1.66	0.9984
16B	5	0.50	1.00	86	111	1.80	0.9965	1.79	0.9968
16B	6	0.50	1.00	58	85	1.79	0.9968	1.80	0.9961
16B	7	0.50	1.00	79	104	1.81	0.9962	1.78	0.9969
16B	8	0.50	1.00	51	76	1.71	0.9976	1.74	0.9979
16B	9	0.50	1.00	54	80	1.78	0.9962	1.75	0.9963
16B	10	0.50	1.00	88	113	1.76	0.9961	1.73	0.9968
15B	1[A]	—	—	—	—	—	—	—	—
15B	2	0.50	1.10	106	126	1.93	0.9965	1.94	0.9958
15B	3	0.50	1.10	81	101	1.94	0.9956	1.93	0.9961
15B	4	0.50	1.10	65	85	1.90	0.9953	1.93	0.9949
15B	5	0.50	1.10	83	103	1.91	0.9964	1.90	0.9967
15B	6	0.50	1.10	64	84	1.96	0.9968	1.96	0.9965
15B	7	0.50	1.10	57	77	1.87	0.9968	1.84	0.9970
15B	8	0.50	1.10	63	85	1.85	0.9965	1.88	0.9963
15B	9	0.50	1.10	67	87	1.75	0.9974	1.75	0.9981
15B	10	0.50	1.10	78	98	1.76	0.9979	1.76	0.9980
20D	1[A]	—	—	—	—	—	—	—	—
20D	2	0.40	1.00	71	96	1.35	0.9991	1.35	0.9987
20D	3	0.40	1.00	51	76	1.38	0.9988	1.37	0.9989
20D	4	0.40	1.00	39	65	1.33	0.9981	1.31	0.9984
20D	5	0.40	1.00	42	67	1.35	0.9978	1.35	0.9975
20D	6	0.40	1.00	34	60	1.35	0.9990	1.37	0.9987
20D	7	0.40	1.00	39	65	1.32	0.9986	1.33	0.9988
20D	8	0.40	1.00	39	65	1.30	0.9988	1.31	0.9988
20D	9	0.40	1.00	35	60	1.24	0.9980	1.24	0.9985
19D	1	0.40	1.10	76	106	1.32	0.9995	1.33	0.9993
19D	2	0.40	1.10	48	68	1.33	0.9999	1.33	0.9999
19D	3	0.40	1.10	39	70	1.29	0.9988	1.29	0.9984
19D	4	0.40	1.10	39	65	1.38	0.9979	1.37	0.9982
19D	5	0.40	1.10	37	67	1.32	0.9977	1.30	0.9980
19D	6	0.40	1.10	41	71	1.34	0.9983	1.35	0.9981
19D	7	0.40	1.10	40	70	1.24	0.9985	1.25	0.9985
19D	8	0.40	1.10	29	60	1.30	0.9979	1.30	0.9977
18D	1	0.40	1.10	49	69	1.57	0.9969	1.60	0.9971
18D	2	0.40	1.10	46	66	1.65	0.9975	1.65	0.9980
18D	3	0.40	1.10	46	66	1.61	0.9975	1.60	0.9979
18D	4	0.40	1.10	36	60	1.54	0.9972	1.57	0.9973
18D	5	0.40	1.10	44	64	1.68	0.9969	1.71	0.9964
18D	6	0.40	1.10	36	56	1.60	0.9984	1.58	0.9985

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
18D	7	0.40	1.10	36	56	1.51	0.9977	1.55	0.9976
18D	8	0.40	1.10	48	68	1.59	0.9983	1.57	0.9985
17D	1	0.40	1.10	99	119	1.82	0.9972	1.85	0.9968
17D	2	0.40	1.10	56	76	1.84	0.9975	1.82	0.9977
17D	3	0.40	1.10	64	84	1.71	0.9977	1.70	0.9978
17D	4	0.40	1.10	49	70	1.72	0.9978	1.75	0.9976
17D	5	0.40	1.10	40	60	1.73	0.9991	1.71	0.9995
17D	6	0.40	1.10	44	64	1.86	0.9975	1.85	0.9977
17D	7	0.40	1.10	39	60	1.72	0.9970	1.71	0.9975
17D	8	0.40	1.10	49	70	1.83	0.9974	1.86	0.9965
16D	1	0.50	1.20	195	215	1.98	0.9946	1.95	0.9961
16D	2	0.50	1.20	54	75	1.91	0.9939	1.89	0.9945
16D	3	0.50	1.20	43	65	1.74	0.9981	1.74	0.9981
16D	4	0.50	1.20	50	75	1.77	0.9968	1.79	0.9967
16D	5	0.50	1.20	45	70	1.67	0.9989	1.68	0.9985
16D	6	0.50	1.20	50	75	1.75	0.9971	1.72	0.9978
16D	7	0.50	1.20	45	70	1.79	0.9965	1.79	0.9966
16D	8[B]	—	—	—	—	—	—	—	—
15D	1	0.50	1.20	139	159	1.77	0.9986	1.76	0.9987
15D	2	0.50	1.20	53	73	1.95	0.9981	1.93	0.9982
15D	3	0.60	1.30	48	68	1.87	0.9982	1.85	0.9983
15D	4	0.50	1.20	36	61	1.87	0.9987	1.88	0.9988
15D	5	0.60	1.30	34	54	1.79	0.9988	1.78	0.9989
15D	6	0.50	1.20	32	52	1.86	0.9984	1.88	0.9981
15D	7	0.60	1.20	37	57	1.78	0.9988	1.78	0.9987
15D	8	0.60	1.20	32	55	1.95	0.9978	1.97	0.9971
14D	1	0.50	1.30	121	136	2.27	0.9971	2.24	0.9973
14D	2	0.50	1.30	49	69	2.21	0.9970	2.20	0.9970
14D	3	0.50	1.30	36	56	2.14	0.9988	2.15	0.9980
14D	4	0.50	1.30	32	52	2.19	0.9976	2.21	0.9974
14D	5	0.50	1.30	36	54	2.22	0.9973	2.24	0.9966
14D	6	0.60	1.30	39	57	2.15	0.9975	2.18	0.9967
14D	7	0.60	1.30	35	53	2.12	0.9986	2.15	0.9980
14D	8	0.60	1.30	40	58	2.16	0.9965	2.15	0.9972

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
13D	1	0.60	1.30	65	80	2.46	0.9959	2.47	0.9953
13D	2	0.60	1.30	35	50	2.19	0.9990	2.18	0.9988
13D	3	0.60	1.30	38	53	2.32	0.9978	2.32	0.9980
13D	4	0.60	1.30	70	88	2.63	0.9959	2.59	0.9964
13D	5	0.60	1.30	52	67	2.36	0.9981	2.38	0.9978
13D	6	0.60	1.30	52	67	2.26	0.9990	2.26	0.9991
13D	7	0.60	1.30	38	55	2.27	0.9991	2.27	0.9987
13D	8	0.60	1.30	40	55	2.23	0.9992	2.26	0.9990

[A] Baseline run.

[B] Unreadable data.

Table 19. Phase 2, box 1, second mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1	1.10	1.80	91	106	1.62	0.9964	1.60	0.9971
20A	2	1.10	1.80	63	78	1.73	0.9867	1.69	0.9873
20A	3	1.20	1.90	45	70	1.17	0.9930	1.18	0.9933
20A	4	1.20	1.80	52	67	1.53	0.9939	1.52	0.9949
20A	5	1.20	1.80	51	66	1.77	0.9885	1.73	0.9897
20A	6	1.20	1.80	50	65	1.45	0.9975	1.46	0.9969
20A	7	1.20	1.80	51	75	1.50	0.9955	1.49	0.9953
20A	8	1.20	1.80	54	69	1.47	0.9922	1.45	0.9924
20A	9	1.20	1.80	52	67	1.24	0.9931	1.22	0.9937
20A	10	1.20	1.80	47	62	1.17	0.9905	1.15	0.9907
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	1.20	1.90	50	70	1.84	0.9969	1.84	0.9969
19A	3	1.20	1.90	53	70	1.77	0.9987	1.76	0.9986
19A	4	1.20	1.90	46	70	1.63	0.9991	1.63	0.9992
19A	5	1.20	1.90	316	340	1.70	0.9943	1.70	0.9943
19A	6	1.20	1.90	71	95	1.79	0.9941	1.78	0.9935
19A	7	1.20	1.90	62	80	1.77	0.9974	1.78	0.9973
19A	8	1.20	1.90	42	60	1.75	0.9969	1.75	0.9968
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	1.20	2.00	57	73	1.29	0.9975	1.28	0.9977
18A	3	1.20	2.00	60	75	1.43	0.9964	1.45	0.9972
18A	4	1.40	2.00	60	75	1.46	0.9966	1.47	0.9966
18A	5	1.30	2.00	68	88	1.62	0.9991	1.61	0.9990
18A	6	1.20	2.00	126	141	1.53	0.9969	1.52	0.9971
18A	7	1.20	2.00	78	95	1.62	0.9973	1.60	0.9971
18A	8	1.20	2.00	54	70	1.59	0.9986	1.60	0.9984
18A	9	1.20	2.00	63	80	1.57	0.9984	1.58	0.9985
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	1.30	2.00	64	80	1.75	0.9971	1.75	0.9968
17A	3	1.30	2.10	47	62	1.62	0.9988	1.62	0.9988
17A	4	1.20	2.20	49	65	1.84	0.9981	1.85	0.9980
17A	5	1.40	2.10	43	58	1.85	0.9988	1.85	0.9985
17A	6	1.40	2.10	44	59	1.67	0.9881	1.67	0.9881
17A	7	1.40	2.20	54	69	1.57	0.9946	1.60	0.9943
17A	8	1.60	2.10	102	117	1.59	0.9949	1.58	0.9948
17A	9	1.40	2.10	60	75	1.84	0.9912	1.83	0.9916
17A	10	1.50	2.00	78	93	1.67	0.9951	1.66	0.9952
16A	1[A]	—	—	—	—	—	—	—	—
16A	2[A]	—	—	—	—	—	—	—	—
16A	3	1.40	2.20	46	61	1.74	0.9968	1.73	0.9966

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
16A	4	1.40	2.10	36	51	1.86	0.9984	1.85	0.9984
16A	5	1.40	2.10	34	49	1.77	0.9968	1.76	0.9967
16A	6	1.50	2.20	30	45	1.67	0.9936	1.70	0.9934
16A	7	1.40	2.10	38	53	1.60	0.9911	1.57	0.9914
16A	8	1.50	2.10	38	60	1.13	0.9651	1.13	0.9627
16A	9	1.40	2.20	31	56	1.64	0.9873	1.65	0.9877
16A	10	1.50	2.10	35	50	1.57	0.9903	1.54	0.9910
16A	11	1.50	2.10	45	60	1.56	0.9843	1.52	0.9844
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	1.50	2.20	39	54	2.10	0.9983	2.11	0.9983
15A	3	1.50	2.20	35	50	2.17	0.9977	2.17	0.9980
15A	4	1.50	2.20	31	46	2.01	0.9980	2.00	0.9981
15A	5	1.50	2.20	35	50	2.22	0.9967	2.22	0.9967
15A	6	1.50	2.20	61	76	2.22	0.9973	2.23	0.9974
15A	7	1.50	2.20	36	51	2.70	0.9802	2.66	0.9884
15A	8	1.50	2.20	52	67	2.19	0.9979	2.20	0.9980
15A	9	1.50	2.20	37	52	2.15	0.9971	2.18	0.9973
15A	10	1.50	2.20	60	75	2.10	0.9985	2.11	0.9985
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	1.50	2.30	57	77	1.96	0.9970	1.95	0.9969
14A	3	1.60	2.40	30	36	2.40	0.9959	2.36	0.9949
14A	4	1.70	2.40	34	40	2.39	0.9924	2.47	0.9945
14A	5	1.70	2.40	33	53	1.64	0.9979	1.64	0.9977
14A	6	1.50	2.40	66	76	1.72	0.9954	1.76	0.9963
14A	7	1.50	2.40	33	41	1.92	0.9954	1.97	0.9944
14A	8	1.60	2.40	34	42	2.17	0.9933	2.14	0.9931
14A	9	1.60	2.40	33	45	1.46	0.9934	1.48	0.9934
14A	10	1.60	2.40	40	48	2.25	0.9936	2.17	0.9926
14A	11	1.60	2.40	32	42	2.00	0.9958	2.00	0.9957
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	1.80	2.50	76	82	2.54	0.9932	2.46	0.9925
13A	3	1.80	2.40	50	56	2.87	0.9984	2.86	0.9985
13A	4	1.80	2.50	37	43	2.69	0.9967	2.72	0.9970
13A	5	1.70	2.40	52	59	2.05	0.9907	2.13	0.9913
13A	6	1.70	2.40	54	61	2.25	0.9970	2.26	0.9965
13A	7	1.70	2.40	59	67	2.09	0.9969	2.13	0.9973
13A	8	1.60	2.40	52	60	2.13	0.9991	2.15	0.9992
13A	9	1.60	2.40	58	63	2.10	0.9992	2.11	0.9992
13A	10	1.70	2.40	51	59	2.14	0.9993	2.15	0.9993
13A	11	1.60	2.40	48	56	2.26	0.9957	2.23	0.9946
12A	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
12A	2	1.80	2.60	204	211	1.94	0.9953	1.92	0.9953
12A	3	1.80	2.60	40	46	2.48	0.9949	2.51	0.9957
12A	4	1.80	2.60	58	65	2.36	0.9948	2.41	0.9952
12A	5	1.80	2.60	39	45	2.72	0.9808	2.72	0.9808
12A	6	2.10	2.60	43	49	2.58	0.9828	2.52	0.9782
12A	7	2.10	2.60	48	52	3.64	0.9975	3.71	0.9987
12A	8	1.80	2.60	49	54	2.93	0.9967	2.88	0.9967
12A	9	1.80	2.60	51	56	2.90	0.9788	2.87	0.9741
12A	10	1.80	2.60	46	53	2.67	0.9938	2.67	0.9940
12A	11	1.80	2.60	63	68	2.85	0.9920	2.91	0.9932
20C	1[A]	—	—	—	—	—	—	—	—
20C	2[B]	—	—	—	—	—	—	—	—
20C	3[B]	—	—	—	—	—	—	—	—
20C	4[B]	—	—	—	—	—	—	—	—
20C	5	1.10	1.70	84	105	1.41	0.9990	1.40	0.9990
20C	6	1.10	1.70	74	90	1.48	0.9993	1.47	0.9995
20C	7	1.10	1.70	54	70	1.63	0.9967	1.60	0.9973
20C	8	1.10	1.70	55	70	1.57	0.9974	1.55	0.9975
20C	9	1.10	1.70	54	70	1.76	0.9984	1.76	0.9984
20C	10	1.10	1.70	64	80	1.83	0.9983	1.82	0.9983
20C	11	1.10	1.70	60	75	1.82	0.9945	1.80	0.9952
20C	12	1.10	1.70	53	70	1.69	0.9945	1.70	0.9948
20C	13	1.10	1.70	47	65	1.78	0.9967	1.78	0.9963
20C	14	1.10	1.70	58	75	1.56	0.9983	1.56	0.9983
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	1.10	1.70	130	150	1.33	0.9961	1.33	0.9958
19C	3	1.10	1.70	59	74	1.36	0.9894	1.39	0.9884
19C	4	1.10	1.70	58	73	1.60	0.9954	1.62	0.9949
19C	5	1.10	1.70	56	71	1.59	0.9917	1.60	0.9914
19C	6	1.10	1.70	63	78	1.60	0.9930	1.62	0.9926
19C	7	1.10	1.70	65	85	1.73	0.9915	1.72	0.9915
19C	8	1.10	1.70	63	78	1.66	0.9947	1.67	0.9949
19C	9	1.10	1.70	62	85	1.60	0.9852	1.58	0.9858
19C	10	1.10	1.70	96	111	1.70	0.9881	1.72	0.9869
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	1.20	1.70	154	170	1.74	0.9933	1.77	0.9925
18C	3	1.20	1.70	117	140	1.64	0.9981	1.63	0.9980
18C	4	1.20	1.70	43	65	1.78	0.9957	1.79	0.9959
18C	5	1.20	1.70	40	60	1.80	0.9904	1.78	0.9900
18C	6	1.20	1.70	51	71	1.53	0.9965	1.51	0.9966
18C	7	1.20	1.70	53	73	1.46	0.9984	1.46	0.9984

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
18C	8	1.20	1.70	57	77	1.58	0.9986	1.59	0.9986
18C	9	1.20	1.70	38	58	1.56	0.9950	1.57	0.9951
18C	10	1.20	1.70	43	63	1.61	0.9970	1.62	0.9972
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	1.20	1.80	127	142	2.09	0.9933	2.10	0.9932
17C	3	1.20	1.80	39	54	2.06	0.9973	2.06	0.9976
17C	4	1.20	1.80	38	55	1.88	0.9980	1.86	0.9983
17C	5	1.20	1.80	38	55	2.14	0.9968	2.13	0.9968
17C	6	1.30	1.80	40	55	1.93	0.9954	1.96	0.9950
17C	7	1.30	1.80	37	57	2.06	0.9971	2.06	0.9970
17C	8	1.30	1.80	39	54	2.09	0.9952	2.09	0.9952
17C	9	1.30	1.80	46	65	2.00	0.9954	2.00	0.9949
16C	1[A]	—	—	—	—	—	—	—	—
16C	2	1.20	1.90	43	60	2.03	0.9979	2.01	0.9981
16C	3	1.20	1.90	60	75	2.03	0.9936	2.00	0.9933
16C	4	1.20	1.90	48	65	2.00	0.9967	2.00	0.9966
16C	5	1.20	1.90	42	57	2.19	0.9979	2.16	0.9970
16C	6	1.20	1.90	44	58	2.52	0.9950	2.50	0.9947
16C	7	1.20	1.90	52	67	2.21	0.9974	2.21	0.9971
16C	8	1.20	1.90	40	53	2.25	0.9938	2.24	0.9942
16C	9	1.30	1.90	46	65	1.79	0.9819	1.83	0.9847
16C	10	1.20	1.90	52	67	2.09	0.9953	2.08	0.9961
15C	1[A]	—	—	—	—	—	—	—	—
15C	2	1.20	2.00	47	62	2.10	0.9965	2.09	0.9962
15C	3	1.20	2.00	46	61	2.32	0.9977	2.31	0.9979
15C	4	1.40	2.00	46	61	2.30	0.9968	2.30	0.9971
15C	5	1.20	2.00	67	82	2.29	0.9938	2.33	0.9949
15C	6	1.40	2.00	52	67	2.53	0.9935	2.55	0.9930
15C	7	1.40	2.00	53	66	2.30	0.9967	2.27	0.9951
15C	8	1.40	2.00	48	61	2.44	0.9947	2.47	0.9953
15C	9	1.40	2.00	42	58	2.33	0.9958	2.34	0.9962
15C	10	1.40	2.00	53	63	2.51	0.9930	2.49	0.9925
14C	1[A]	—	—	—	—	—	—	—	—
14C	2	1.40	2.10	59	79	1.91	0.9948	1.93	0.9955
14C	3	1.40	2.10	57	67	2.04	0.9963	2.02	0.9964
14C	4	1.40	2.10	44	64	1.92	0.9958	1.93	0.9963
14C	5	1.40	2.10	49	64	2.15	0.9931	2.15	0.9936
14C	6	1.40	2.10	78	95	1.85	0.9901	1.83	0.9903
14C	7	1.40	2.10	48	63	2.12	0.9951	2.15	0.9946
14C	8	1.60	2.10	60	75	1.76	0.9948	1.73	0.9967
20B	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20B	2	1.10	1.60	71	91	1.32	0.9970	1.34	0.9966
20B	3	1.10	1.60	50	75	1.47	0.9985	1.46	0.9984
20B	4	1.10	1.60	66	91	1.67	0.9986	1.67	0.9986
20B	5	1.10	1.60	51	81	1.60	0.9980	1.59	0.9975
20B	6	1.10	1.60	56	81	1.46	0.9995	1.47	0.9994
20B	7	1.10	1.60	48	68	1.44	0.9972	1.43	0.9974
20B	8	1.10	1.60	54	84	1.67	0.9986	1.67	0.9984
20B	9	1.10	1.60	55	80	1.61	0.9997	1.61	0.9997
20B	10	1.10	1.60	64	89	1.40	0.9993	1.40	0.9994
19B	1[A]	—	—	—	—	—	—	—	—
19B	2	1.10	1.60	58	88	1.34	0.9973	1.34	0.9974
19B	3	1.20	1.70	53	83	1.20	0.9975	1.20	0.9976
19B	4	1.20	1.70	74	99	1.21	0.9940	1.22	0.9935
19B	5	1.20	1.70	65	95	1.38	0.9988	1.38	0.9988
19B	6	1.20	1.70	76	101	1.34	0.9983	1.34	0.9982
19B	7	1.20	1.70	61	86	1.46	0.9973	1.45	0.9969
19B	8	1.20	1.70	74	99	1.39	0.9968	1.40	0.9973
19B	9	1.20	1.70	69	89	1.52	0.9979	1.52	0.9979
19B	10	1.10	1.70	73	98	1.46	0.9946	1.47	0.9952
19B	11	1.10	1.70	53	73	1.39	0.9983	1.38	0.9982
18B	1[A]	—	—	—	—	—	—	—	—
18B	2	1.20	1.70	59	74	2.22	0.9984	2.21	0.9985
18B	3	1.20	1.70	78	93	2.40	0.9955	2.38	0.9955
18B	4	1.20	1.70	58	70	2.39	0.9970	2.38	0.9968
18B	5	1.30	1.70	63	85	2.21	0.9950	2.18	0.9934
18B	6	1.20	1.70	51	66	2.10	0.9930	2.15	0.9933
18B	7	1.20	1.70	52	72	2.25	0.9977	2.27	0.9972
18B	8	1.10	1.70	57	77	2.25	0.9988	2.25	0.9987
18B	9	1.10	1.70	52	67	2.17	0.9972	2.18	0.9967
17B	1[A]	—	—	—	—	—	—	—	—
17B	2	1.20	1.80	62	82	1.96	0.9982	1.95	0.9982
17B	3	1.20	1.80	49	74	1.60	0.9966	1.61	0.9969
17B	4	1.20	1.80	59	79	2.04	0.9987	2.05	0.9986
17B	5	1.20	1.80	52	77	1.55	0.9913	1.54	0.9913
17B	6	1.20	1.80	73	93	1.62	0.9956	1.62	0.9960
17B	7	1.30	1.80	52	72	1.69	0.9956	1.67	0.9956
17B	8	1.30	1.80	62	92	1.51	0.9953	1.50	0.9950
17B	9	1.30	1.80	54	74	1.36	0.9956	1.35	0.9957
17B	10	1.20	1.80	66	91	1.81	0.9988	1.81	0.9987
16B	1[A]	—	—	—	—	—	—	—	—
16B	2	1.40	1.90	70	85	2.21	0.9991	2.21	0.9992

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16B	3	1.30	1.90	61	74	2.16	0.9989	2.16	0.9990
16B	4	1.30	1.90	97	117	1.97	0.9988	1.96	0.9986
16B	5	1.20	1.90	86	101	2.00	0.9957	2.00	0.9956
16B	6	1.20	1.90	55	73	1.96	0.9977	1.96	0.9979
16B	7	1.30	1.90	79	99	1.99	0.9985	2.00	0.9987
16B	8	1.30	1.90	52	70	2.08	0.9986	2.07	0.9986
16B	9	1.30	1.90	55	73	2.02	0.9991	2.01	0.9991
16B	10	1.30	1.90	88	103	1.96	0.9991	1.95	0.9994
15B	1[A]	—	—	—	—	—	—	—	—
15B	2	1.40	1.90	107	127	2.06	0.9960	2.05	0.9961
15B	3	1.30	1.90	80	93	1.96	0.9904	1.92	0.9917
15B	4	1.30	1.90	66	85	2.18	0.9940	2.17	0.9934
15B	5	1.30	2.10	82	102	1.94	0.9951	1.95	0.9954
15B	6	1.40	1.90	65	85	2.05	0.9915	2.04	0.9907
15B	7	1.40	2.00	57	77	2.08	0.9912	2.06	0.9903
15B	8	1.40	1.90	65	76	2.17	0.9846	2.24	0.9822
15B	9	1.40	1.90	69	84	2.14	0.9945	2.15	0.9946
15B	10	1.40	2.00	79	99	1.87	0.9952	1.86	0.9945
20D	1[A]	—	—	—	—	—	—	—	—
20D	2	1.20	1.90	71	86	1.60	0.9990	1.61	0.9989
20D	3	1.20	1.80	52	77	1.80	0.9996	1.80	0.9996
20D	4	1.20	1.80	39	64	1.67	0.9994	1.68	0.9994
20D	5	1.20	1.80	43	58	1.71	0.9983	1.70	0.9984
20D	6	1.20	1.80	34	54	1.71	0.9972	1.72	0.9970
20D	7	1.20	1.80	40	60	1.79	0.9982	1.79	0.9982
20D	8	1.20	1.80	40	65	1.77	0.9992	1.76	0.9993
20D	9	1.20	1.80	36	53	1.76	0.9978	1.75	0.9978
19D	1	1.20	1.90	76	96	1.61	0.9955	1.62	0.9956
19D	2	1.10	1.90	48	68	1.52	0.9994	1.52	0.9994
19D	3	1.20	1.90	40	60	1.52	0.9985	1.51	0.9986
19D	4	1.20	1.90	40	65	1.54	0.9982	1.54	0.9982
19D	5	1.30	1.90	38	58	1.48	0.9928	1.45	0.9944
19D	6	1.30	1.90	40	65	1.47	0.9951	1.47	0.9947
19D	7	1.20	1.90	39	59	1.61	0.9983	1.61	0.9985
19D	8	1.20	1.90	30	55	1.66	0.9989	1.65	0.9991
18D	1	1.20	2.00	50	70	1.72	0.9995	1.72	0.9995
18D	2	1.20	2.00	47	73	1.67	0.9967	1.67	0.9966
18D	3	1.20	2.00	45	65	1.67	0.9996	1.67	0.9996
18D	4	1.20	2.00	37	57	1.68	0.9989	1.68	0.9988
18D	5	1.20	2.00	44	64	1.62	0.9981	1.62	0.9981
18D	6	1.20	2.00	37	53	1.52	0.9955	1.50	0.9947

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
18D	7	1.30	2.00	37	57	1.58	0.9987	1.59	0.9987
18D	8	1.20	2.00	48	68	1.68	0.9995	1.68	0.9995
17D	1	1.20	2.00	100	115	1.77	0.9981	1.76	0.9983
17D	2	1.30	2.00	56	71	1.84	0.9990	1.86	0.9984
17D	3	1.30	2.00	64	79	2.08	0.9944	2.05	0.9952
17D	4	1.30	2.00	50	65	1.82	0.9968	1.81	0.9967
17D	5	1.30	2.00	41	53	2.07	0.9985	2.09	0.9987
17D	6	1.40	2.10	44	59	2.18	0.9972	2.20	0.9967
17D	7	1.40	2.10	39	54	2.14	0.9902	2.13	0.9902
17D	8	1.40	2.10	50	63	2.21	0.9954	2.22	0.9951
16D	1	1.40	2.10	195	203	1.98	0.9969	1.98	0.9969
16D	2	1.40	2.20	54	64	1.87	0.9985	1.88	0.9986
16D	3	1.40	2.20	43	58	1.95	0.9968	1.95	0.9968
16D	4	1.40	2.20	51	61	1.95	0.9983	1.96	0.9987
16D	5	1.40	2.20	45	58	2.11	0.9969	2.10	0.9969
16D	6	1.40	2.20	49	64	2.00	0.9963	2.01	0.9964
16D	7	1.40	2.20	45	58	2.02	0.9986	2.02	0.9986
16D	8[B]	—	—	—	—	—	—	—	—
15D	1	1.40	2.20	139	152	2.04	0.9967	2.06	0.9967
15D	2	1.40	2.20	53	68	1.68	0.9981	1.67	0.9981
15D	3	1.40	2.20	47	60	2.19	0.9981	2.19	0.9982
15D	4	1.40	2.20	37	50	2.01	0.9972	2.01	0.9975
15D	5	1.40	2.20	32	47	2.33	0.9886	2.34	0.9887
15D	6	1.40	2.20	31	42	2.07	0.9912	2.04	0.9923
15D	7	1.40	2.30	36	48	1.90	0.9950	1.92	0.9961
15D	8	1.40	2.30	31	41	2.05	0.9930	2.07	0.9938
14D	1	1.60	2.40	121	132	2.70	0.9948	2.70	0.9952
14D	2	1.60	2.40	50	63	2.41	0.9960	2.38	0.9945
14D	3	1.60	2.40	37	47	2.07	0.9959	2.05	0.9956
14D	4	1.60	2.40	33	45	1.98	0.9941	1.99	0.9941
14D	5	1.60	2.40	36	46	2.05	0.9956	2.07	0.9943
14D	6	1.60	2.40	39	50	1.61	0.9930	1.57	0.9934
14D	7	1.80	2.40	32	48	1.51	0.9787	1.50	0.9773
14D	8	1.70	2.40	41	53	2.29	0.9921	2.35	0.9883

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
13D	1	1.60	2.40	66	77	2.17	0.9895	2.13	0.9883
13D	2	1.70	2.50	35	45	2.17	0.9856	2.14	0.9848
13D	3	1.60	2.50	37	45	3.02	0.9940	3.02	0.9948
13D	4	1.60	2.50	69	80	2.67	0.9919	2.70	0.9914
13D	5	1.70	2.50	52	59	3.34	0.9967	3.33	0.9962
13D	6	1.70	2.50	52	60	2.52	0.9899	2.53	0.9897
13D	7	1.70	2.50	39	48	2.33	0.9833	2.31	0.9826
13D	8	1.70	2.50	41	51	2.32	0.9921	2.35	0.9923

[A] Baseline run.

[B] Unreadable data.

Table 20. Phase 2, box 2, second mode damping data.

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
20A	1	1.10	1.80	91	106	1.67	0.9985	1.66	0.9988
20A	2	1.10	1.90	64	76	1.77	0.9962	1.75	0.9971
20A	3	1.20	1.90	45	70	1.24	0.9944	1.25	0.9944
20A	4	1.20	1.90	52	67	1.59	0.9954	1.58	0.9955
20A	5	1.20	1.90	51	66	1.74	0.9951	1.76	0.9936
20A	6	1.20	1.90	50	65	1.58	0.9982	1.59	0.9978
20A	7	1.20	1.90	51	75	1.66	0.9927	1.66	0.9921
20A	8	1.20	1.90	54	69	1.56	0.9956	1.57	0.9956
20A	9	1.20	1.90	52	67	1.35	0.9970	1.34	0.9968
20A	10	1.20	1.90	47	62	1.31	0.9941	1.29	0.9956
19A	1[A]	—	—	—	—	—	—	—	—
19A	2	1.20	1.90	50	67	1.73	0.9953	1.72	0.9949
19A	3	1.20	1.90	53	70	1.63	0.9983	1.62	0.9984
19A	4	1.20	1.90	46	70	1.76	0.9959	1.76	0.9910
19A	5	1.20	1.90	316	334	1.47	0.9966	1.47	0.9964
19A	6	1.20	1.90	71	86	1.77	0.9955	1.79	0.9956
19A	7	1.20	1.90	62	80	1.76	0.9973	1.75	0.9975
19A	8	1.20	1.90	42	60	1.67	0.9984	1.68	0.9982
18A	1[A]	—	—	—	—	—	—	—	—
18A	2	1.20	2.00	57	73	1.74	0.9965	1.75	0.9966
18A	3	1.20	2.00	60	75	1.91	0.9993	1.91	0.9993
18A	4	1.20	2.00	60	75	1.93	0.9982	1.94	0.9984
18A	5	1.20	2.00	68	88	1.85	0.9981	1.86	0.9983
18A	6	1.20	2.00	126	141	1.77	0.9979	1.78	0.9981
18A	7	1.20	2.00	78	95	1.86	0.9942	1.86	0.9941
18A	8	1.20	2.00	54	69	1.81	0.9987	1.82	0.9987
18A	9	1.20	2.00	63	78	1.91	0.9956	1.96	0.9919
17A	1[A]	—	—	—	—	—	—	—	—
17A	2	1.30	2.00	64	77	2.07	0.9984	2.05	0.9991
17A	3	1.30	2.10	47	60	1.93	0.9953	1.94	0.9951
17A	4	1.20	2.20	49	62	1.92	0.9977	1.94	0.9977
17A	5	1.40	2.10	43	58	2.08	0.9954	2.07	0.9956
17A	6	1.40	2.10	44	59	2.01	0.9929	2.01	0.9936
17A	7	1.40	2.20	54	69	1.90	0.9935	1.89	0.9925
17A	8	1.60	2.10	102	117	1.82	0.9940	1.86	0.9929
17A	9	1.40	2.10	60	71	2.04	0.9904	2.08	0.9903
17A	10	1.50	2.00	78	93	1.98	0.9979	1.97	0.9977
16A	1[A]	—	—	—	—	—	—	—	—
16A	2[A]	—	—	—	—	—	—	—	—
16A	3	1.40	2.20	46	61	1.79	0.9974	1.79	0.9973

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16A	4	1.40	2.10	36	51	1.94	0.9986	1.93	0.9989
16A	5	1.40	2.10	34	49	1.76	0.9973	1.76	0.9973
16A	6	1.50	2.20	30	45	1.79	0.9932	1.83	0.9908
16A	7	1.40	2.10	38	53	1.71	0.9952	1.69	0.9956
16A	8	1.50	2.10	38	60	1.17	0.9794	1.17	0.9779
16A	9	1.40	2.20	31	51	1.58	0.9910	1.59	0.9900
16A	10	1.50	2.10	35	50	1.61	0.9961	1.59	0.9969
16A	11	1.50	2.10	45	60	1.57	0.9940	1.54	0.9951
15A	1[A]	—	—	—	—	—	—	—	—
15A	2	1.50	2.20	39	54	2.17	0.9984	2.16	0.9984
15A	3	1.50	2.20	35	48	2.24	0.9965	2.22	0.9974
15A	4	1.50	2.20	31	46	2.16	0.9982	2.16	0.9983
15A	5	1.50	2.20	35	48	2.32	0.9974	2.30	0.9976
15A	6	1.50	2.20	61	74	2.34	0.9980	2.32	0.9980
15A	7	1.50	2.20	36	48	2.32	0.9927	2.36	0.9912
15A	8	1.50	2.20	52	65	2.38	0.9977	2.37	0.9978
15A	9	1.50	2.20	37	52	2.46	0.9988	2.46	0.9988
15A	10	1.50	2.20	60	75	2.36	0.9979	2.35	0.9980
14A	1[A]	—	—	—	—	—	—	—	—
14A	2	1.50	2.30	57	70	2.31	0.9934	2.33	0.9928
14A	3	1.60	2.40	30	45	1.79	0.9986	1.79	0.9987
14A	4	1.70	2.40	34	47	1.75	0.9974	1.76	0.9973
14A	5	1.70	2.40	33	53	1.80	0.9944	1.83	0.9902
14A	6	1.50	2.40	66	84	1.80	0.9994	1.80	0.9994
14A	7	1.50	2.40	33	48	1.88	0.9947	1.88	0.9952
14A	8	1.60	2.40	34	49	1.98	0.9978	1.96	0.9982
14A	9	1.60	2.40	33	46	1.99	0.9985	1.99	0.9986
14A	10	1.60	2.40	40	52	1.90	0.9985	1.90	0.9984
14A	11	1.60	2.40	32	43	1.85	0.9991	1.85	0.9989
13A	1[A]	—	—	—	—	—	—	—	—
13A	2	1.80	2.50	76	82	2.60	0.9983	2.59	0.9982
13A	3	1.80	2.40	50	56	2.58	0.9982	2.58	0.9981
13A	4	1.80	2.50	37	43	2.56	0.9964	2.45	0.9944
13A	5	1.70	2.40	52	59	2.29	0.9948	2.35	0.9960
13A	6	1.70	2.40	54	61	2.39	0.9978	2.40	0.9981
13A	7	1.70	2.40	59	67	2.17	0.9978	2.17	0.9978
13A	8	1.60	2.40	52	60	2.25	0.9983	2.26	0.9986
13A	9	1.60	2.40	58	64	2.06	0.9962	2.04	0.9958
13A	10	1.70	2.40	51	59	2.28	0.9965	2.25	0.9961
13A	11	1.60	2.40	48	56	2.52	0.9980	2.50	0.9976
12A	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	Run	Low (Hz)	High (Hz)	Start (s)	End (s)	Damping (percent)	Correlation	Damping (percent)	Correlation
12A	2	1.80	2.60	204	211	2.10	0.9982	2.09	0.9983
12A	3	1.80	2.60	40	46	2.68	0.9953	2.71	0.9961
12A	4	1.80	2.60	58	65	2.49	0.9953	2.53	0.9956
12A	5	1.80	2.60	39	45	2.47	0.9874	2.48	0.9851
12A	6	2.10	2.60	43	49	2.57	0.9949	2.55	0.9931
12A	7	2.10	2.60	48	60	1.56	0.9877	1.52	0.9880
12A	8	1.80	2.60	49	59	1.72	0.9933	1.75	0.9928
12A	9	1.80	2.60	51	61	2.17	0.9910	2.11	0.9891
12A	10	1.80	2.60	46	56	1.95	0.9975	1.97	0.9976
12A	11	1.80	2.60	63	73	1.75	0.9940	1.72	0.9939
20C	1[A]	—	—	—	—	—	—	—	—
20C	2[B]	—	—	—	—	—	—	—	—
20C	3[B]	—	—	—	—	—	—	—	—
20C	4[B]	—	—	—	—	—	—	—	—
20C	5	1.10	1.70	84	105	1.59	0.9983	1.59	0.9983
20C	6	1.10	1.70	74	90	1.61	0.9987	1.60	0.9989
20C	7	1.10	1.70	54	70	1.73	0.9977	1.71	0.9984
20C	8	1.10	1.70	55	70	1.74	0.9984	1.72	0.9988
20C	9	1.10	1.70	54	70	1.89	0.9992	1.88	0.9992
20C	10	1.10	1.70	64	80	1.92	0.9985	1.92	0.9983
20C	11	1.10	1.70	60	75	1.85	0.9956	1.83	0.9965
20C	12	1.10	1.70	53	70	1.77	0.9971	1.78	0.9972
20C	13	1.10	1.70	47	65	1.90	0.9960	1.90	0.9957
20C	14	1.10	1.70	58	75	1.67	0.9996	1.66	0.9995
19C	1[A]	—	—	—	—	—	—	—	—
19C	2	1.10	1.70	130	150	1.62	0.9986	1.61	0.9987
19C	3	1.10	1.70	59	74	1.65	0.9941	1.68	0.9927
19C	4	1.10	1.70	58	73	1.81	0.9959	1.82	0.9957
19C	5	1.10	1.70	56	71	1.83	0.9963	1.85	0.9960
19C	6	1.10	1.70	63	78	1.83	0.9946	1.85	0.9946
19C	7	1.10	1.70	65	78	1.66	0.9927	1.68	0.9927
19C	8	1.10	1.70	63	78	1.91	0.9950	1.92	0.9953
19C	9	1.10	1.70	62	77	1.56	0.9965	1.56	0.9972
19C	10	1.10	1.70	96	111	1.82	0.9944	1.85	0.9930
18C	1[A]	—	—	—	—	—	—	—	—
18C	2	1.20	1.80	154	170	1.89	0.9939	1.92	0.9919
18C	3	1.20	1.80	117	140	1.81	0.9944	1.80	0.9941
18C	4	1.20	1.80	43	65	1.96	0.9918	1.95	0.9921
18C	5	1.20	1.80	40	60	2.01	0.9912	2.01	0.9910
18C	6	1.20	1.80	51	71	1.61	0.9963	1.60	0.9966
18C	7	1.20	1.80	53	73	1.66	0.9864	1.72	0.9808

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
18C	8	1.20	1.80	57	77	1.67	0.9986	1.68	0.9984
18C	9	1.20	1.80	38	58	1.73	0.9935	1.74	0.9934
18C	10	1.20	1.80	43	63	1.76	0.9966	1.77	0.9965
17C	1[A]	—	—	—	—	—	—	—	—
17C	2	1.20	1.80	127	137	2.09	0.9934	2.11	0.9941
17C	3	1.20	1.80	39	54	2.23	0.9992	2.23	0.9993
17C	4	1.20	1.80	38	55	2.05	0.9980	2.03	0.9983
17C	5	1.20	1.80	38	53	2.27	0.9970	2.29	0.9967
17C	6	1.20	1.80	40	55	2.19	0.9981	2.19	0.9979
17C	7	1.20	1.80	37	52	2.12	0.9991	2.13	0.9983
17C	8	1.20	1.80	39	54	2.26	0.9942	2.27	0.9947
17C	9	1.20	1.80	46	61	2.13	0.9936	2.18	0.9909
16C	1[A]	—	—	—	—	—	—	—	—
16C	2	1.20	1.90	43	60	2.25	0.9973	2.24	0.9972
16C	3	1.20	1.90	60	73	2.43	0.9979	2.45	0.9982
16C	4	1.20	1.90	48	63	2.32	0.9978	2.30	0.9978
16C	5	1.20	1.90	42	57	2.40	0.9982	2.37	0.9978
16C	6	1.20	1.90	44	58	2.67	0.9983	2.64	0.9982
16C	7	1.20	1.90	52	65	2.48	0.9962	2.46	0.9964
16C	8	1.20	1.90	40	53	2.31	0.9958	2.32	0.9960
16C	9	1.30	1.90	46	65	2.20	0.9748	2.26	0.9730
16C	10	1.20	1.90	52	67	2.31	0.9982	2.34	0.9979
15C	1[A]	—	—	—	—	—	—	—	—
15C	2	1.20	2.00	47	62	2.04	0.9976	2.04	0.9977
15C	3	1.20	2.00	46	61	2.18	0.9981	2.19	0.9981
15C	4	1.40	2.00	46	61	2.16	0.9978	2.18	0.9982
15C	5	1.40	2.00	67	82	2.22	0.9983	2.20	0.9982
15C	6	1.40	2.00	52	67	2.33	0.9966	2.36	0.9967
15C	7	1.40	2.00	53	66	2.12	0.9989	2.10	0.9982
15C	8	1.40	2.00	48	61	2.21	0.9986	2.22	0.9987
15C	9	1.40	2.00	42	58	2.24	0.9982	2.23	0.9979
15C	10	1.40	2.00	53	63	2.23	0.9978	2.24	0.9980
14C	1[A]	—	—	—	—	—	—	—	—
14C	2	1.40	2.10	59	79	2.03	0.9951	2.04	0.9954
14C	3	1.40	2.10	57	67	2.02	0.9986	2.00	0.9987
14C	4	1.40	2.10	44	64	1.89	0.9979	1.90	0.9985
14C	5	1.40	2.10	49	64	2.06	0.9981	2.06	0.9982
14C	6	1.40	2.10	78	95	1.73	0.9909	1.75	0.9918
14C	7	1.40	2.10	48	63	2.12	0.9964	2.12	0.9968
14C	8	1.40	2.10	60	73	1.75	0.9963	1.73	0.9976
20B	1[A]	—	—	—	—	—	—	—	—

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
20B	2	1.30	1.60	71	91	1.62	0.9506	1.59	0.9460
20B	3	1.10	1.60	50	75	1.64	0.9981	1.63	0.9979
20B	4	1.10	1.60	66	84	1.74	0.9972	1.76	0.9966
20B	5	1.10	1.60	51	81	1.86	0.9948	1.85	0.9944
20B	6	1.10	1.60	56	81	1.69	0.9995	1.70	0.9995
20B	7	1.10	1.60	48	68	1.64	0.9988	1.62	0.9989
20B	8	1.10	1.60	54	74	1.93	0.9976	1.94	0.9976
20B	9	1.10	1.60	55	75	1.83	0.9988	1.84	0.9987
20B	10	1.10	1.60	64	89	1.62	0.9987	1.63	0.9989
19B	1[A]	—	—	—	—	—	—	—	—
19B	2	1.10	1.70	58	88	1.45	0.9964	1.46	0.9962
19B	3	1.20	1.70	53	73	1.31	0.9984	1.31	0.9984
19B	4	1.20	1.70	74	99	1.32	0.9980	1.31	0.9981
19B	5	1.20	1.70	65	95	1.49	0.9993	1.49	0.9993
19B	6	1.20	1.70	76	101	1.42	0.9989	1.41	0.9988
19B	7	1.20	1.70	61	86	1.51	0.9985	1.50	0.9984
19B	8	1.20	1.70	74	94	1.53	0.9996	1.52	0.9996
19B	9	1.20	1.70	69	89	1.52	0.9992	1.52	0.9991
19B	10	1.10	1.70	73	98	1.53	0.9983	1.53	0.9983
19B	11	1.10	1.70	53	73	1.39	0.9990	1.38	0.9991
18B	1[A]	—	—	—	—	—	—	—	—
18B	2	1.20	1.70	59	74	2.27	0.9992	2.27	0.9993
18B	3	1.20	1.70	78	93	2.48	0.9973	2.47	0.9969
18B	4	1.20	1.70	58	70	2.44	0.9977	2.43	0.9975
18B	5	1.20	1.70	63	80	2.34	0.9982	2.33	0.9982
18B	6	1.20	1.70	51	66	2.28	0.9973	2.30	0.9974
18B	7	1.20	1.70	52	72	2.40	0.9958	2.38	0.9965
18B	8	1.20	1.70	57	72	2.47	0.9990	2.48	0.9990
18B	9	1.20	1.70	52	67	2.28	0.9979	2.30	0.9976
17B	1[A]	—	—	—	—	—	—	—	—
17B	2	1.20	1.80	62	79	2.00	0.9965	2.01	0.9965
17B	3	1.20	1.80	49	69	1.62	0.9971	1.61	0.9972
17B	4	1.20	1.80	59	79	1.96	0.9980	1.95	0.9986
17B	5	1.20	1.80	52	72	1.70	0.9968	1.72	0.9964
17B	6	1.20	1.80	73	93	1.63	0.9945	1.64	0.9946
17B	7	1.30	1.80	52	72	1.71	0.9972	1.70	0.9974
17B	8	1.30	1.80	62	82	1.49	0.9988	1.49	0.9988
17B	9	1.30	1.80	54	64	1.67	0.9924	1.67	0.9917
17B	10	1.20	1.80	66	86	1.89	0.9979	1.90	0.9978
16B	1[A]	—	—	—	—	—	—	—	—
16B	2	1.40	1.90	70	85	2.18	0.9991	2.18	0.9991

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
16B	3	1.30	1.90	61	74	2.15	0.9997	2.15	0.9997
16B	4	1.30	1.90	97	117	2.01	0.9987	2.01	0.9987
16B	5	1.20	1.90	86	101	1.95	0.9974	1.95	0.9971
16B	6	1.20	1.90	55	70	2.01	0.9960	2.00	0.9964
16B	7	1.30	1.90	79	99	2.02	0.9956	2.03	0.9958
16B	8	1.30	1.90	52	70	2.10	0.9982	2.09	0.9981
16B	9	1.30	1.90	55	73	2.03	0.9996	2.02	0.9995
16B	10	1.30	1.90	88	103	1.89	0.9988	1.87	0.9992
15B	1[A]	—	—	—	—	—	—	—	—
15B	2	1.40	2.00	107	120	1.88	0.9966	1.89	0.9963
15B	3	1.30	1.90	80	93	1.89	0.9984	1.87	0.9985
15B	4	1.30	1.90	66	81	2.01	0.9933	2.03	0.9934
15B	5	1.30	2.10	82	102	2.06	0.9970	2.05	0.9969
15B	6	1.40	1.90	65	85	2.11	0.9988	2.10	0.9984
15B	7	1.40	2.00	57	77	2.16	0.9948	2.15	0.9940
15B	8	1.40	2.00	65	76	2.11	0.9918	2.17	0.9887
15B	9	1.40	2.00	69	84	2.07	0.9976	2.07	0.9974
15B	10	1.40	2.00	79	99	1.92	0.9973	1.90	0.9966
20D	1[A]	—	—	—	—	—	—	—	—
20D	2	1.20	1.90	71	86	1.62	0.9990	1.62	0.9989
20D	3	1.20	1.80	52	77	1.86	0.9993	1.86	0.9993
20D	4	1.20	1.80	43	58	1.65	0.9999	1.65	0.9998
20D	5	1.20	1.80	43	58	1.69	0.9994	1.69	0.9993
20D	6	1.20	1.80	34	54	1.67	0.9992	1.68	0.9991
20D	7	1.20	1.80	40	60	1.75	0.9989	1.76	0.9987
20D	8	1.20	1.80	40	60	1.71	0.9993	1.71	0.9994
20D	9	1.20	1.80	36	53	1.74	0.9987	1.73	0.9988
19D	1	1.20	1.90	76	91	1.56	0.9976	1.54	0.9984
19D	2	1.10	1.90	48	68	1.61	0.9983	1.62	0.9982
19D	3	1.20	1.90	40	60	1.67	0.9958	1.66	0.9957
19D	4	1.20	1.90	40	60	1.64	0.9977	1.65	0.9972
19D	5	1.30	1.90	38	58	1.59	0.9942	1.61	0.9938
19D	6	1.30	1.90	40	55	1.37	0.9972	1.38	0.9966
19D	7	1.20	1.90	39	59	1.71	0.9962	1.73	0.9958
19D	8	1.20	1.90	30	50	1.73	0.9974	1.72	0.9975
18D	1	1.20	2.00	50	70	1.85	0.9985	1.85	0.9983
18D	2	1.20	2.00	47	73	1.74	0.9969	1.74	0.9968
18D	3	1.20	2.00	45	65	1.78	0.9982	1.79	0.9981
18D	4	1.20	2.00	37	57	1.83	0.9971	1.83	0.9971
18D	5	1.20	2.00	44	64	1.77	0.9981	1.78	0.9971
18D	6	1.20	2.00	37	53	1.62	0.9975	1.62	0.9975

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
18D	7	1.20	2.00	37	57	1.77	0.9924	1.81	0.9876
18D	8	1.20	2.00	48	68	1.83	0.9961	1.84	0.9965
17D	1	1.20	2.00	100	113	1.70	0.9996	1.72	0.9988
17D	2	1.30	2.00	56	71	1.99	0.9970	1.98	0.9970
17D	3	1.30	2.00	64	77	2.02	0.9961	2.05	0.9955
17D	4	1.30	2.00	50	65	1.89	0.9988	1.89	0.9989
17D	5	1.30	2.00	41	53	2.20	0.9976	2.19	0.9977
17D	6	1.40	2.10	44	57	2.11	0.9976	2.11	0.9971
17D	7	1.40	2.10	39	51	2.33	0.9936	2.31	0.9934
17D	8	1.40	2.10	50	62	2.18	0.9959	2.24	0.9940
16D	1	1.40	2.20	195	203	2.06	0.9984	2.07	0.9985
16D	2	1.40	2.20	54	64	1.82	0.9987	1.82	0.9985
16D	3	1.40	2.20	43	55	2.01	0.9980	2.00	0.9978
16D	4	1.40	2.20	51	61	1.96	0.9993	1.97	0.9995
16D	5	1.40	2.20	45	58	2.18	0.9990	2.17	0.9990
16D	6	1.40	2.20	49	64	2.23	0.9984	2.21	0.9987
16D	7	1.40	2.20	45	58	2.08	0.9991	2.07	0.9993
16D	8[B]	—	—	—	—	—	—	—	—
15D	1	1.40	2.20	139	150	2.12	0.9979	2.10	0.9980
15D	2	1.40	2.20	53	68	1.78	0.9984	1.77	0.9982
15D	3	1.40	2.20	47	60	2.22	0.9971	2.22	0.9973
15D	4	1.40	2.20	37	50	2.06	0.9964	2.05	0.9967
15D	5	1.40	2.20	32	43	1.99	0.9931	2.01	0.9935
15D	6	1.40	2.20	31	42	2.12	0.9937	2.10	0.9941
15D	7	1.40	2.20	36	48	1.90	0.9993	1.90	0.9996
15D	8	1.40	2.20	31	41	2.09	0.9912	2.11	0.9910
14D	1	1.60	2.40	121	130	2.50	0.9981	2.53	0.9975
14D	2	1.60	2.40	50	60	2.46	0.9933	2.42	0.9952
14D	3	1.60	2.40	37	47	2.21	0.9989	2.20	0.9988
14D	4	1.60	2.40	33	45	2.09	0.9974	2.09	0.9974
14D	5	1.60	2.40	36	46	2.25	0.9961	2.28	0.9947
14D	6	1.60	2.40	39	50	1.73	0.9947	1.70	0.9938
14D	7	1.60	2.40	32	42	1.86	0.9942	1.87	0.9947
14D	8	1.60	2.40	41	51	2.23	0.9907	2.17	0.9917

		Bandpass Filter		Time Filter		Positive Peaks		Negative Peaks	
Cable	**Run**	**Low (Hz)**	**High (Hz)**	**Start (s)**	**End (s)**	**Damping (percent)**	**Correlation**	**Damping (percent)**	**Correlation**
13D	1	1.60	2.40	66	77	2.12	0.9959	2.10	0.9952
13D	2	1.70	2.50	35	45	2.11	0.9933	2.09	0.9923
13D	3	1.60	2.50	37	45	2.51	0.9962	2.49	0.9966
13D	4	1.60	2.50	69	81	2.45	0.9916	2.49	0.9910
13D	5	1.60	2.50	52	59	2.86	0.9928	2.87	0.9915
13D	6	1.70	2.50	52	60	2.29	0.9979	2.34	0.9963
13D	7	1.70	2.50	39	48	2.40	0.9905	2.43	0.9903
13D	8	1.70	2.50	41	51	2.38	0.9941	2.40	0.9942

[A] Baseline run.

[B] Unreadable data.

Table 21. Phase 2 summary of average damping values for box 1.

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C20A	1	1.49	1.54	1.45	0.9968	24.5
C19A	1	1.43	1.51	1.35	0.9977	28.0
C18A	1	1.85	1.90	1.79	0.9945	22.3
C17A	1	1.53	1.56	1.50	0.9956	32.9
C16A	1	1.68	1.69	1.67	0.9977	29.9
C15A	1	1.85	1.87	1.83	0.9975	25.0
C14A	1	1.82	1.84	1.79	0.9981	24.0
C13A	1	1.79	1.81	1.76	0.9963	19.8
C12A	1	1.93	1.94	1.92	0.9968	19.1
C20C	1	1.39	1.42	1.36	0.9978	23.1
C19C	1	1.47	1.51	1.43	0.9944	47.2
C18C	1	1.66	1.70	1.62	0.9955	38.3
C17C	1	1.65	1.68	1.62	0.9968	35.8
C16C	1	2.01	2.03	1.98	0.9952	29.2
C15C	1	1.79	1.81	1.78	0.9966	29.8
C14C	1	2.04	2.10	1.98	0.9969	36.3
C20B	1	1.33	1.37	1.30	0.9977	30.1
C19B	1	1.19	1.21	1.18	0.9986	31.8
C18B	1	1.71	1.76	1.65	0.9969	27.6
C17B	1	1.48	1.51	1.45	0.9979	24.8
C16B	1	1.66	1.68	1.64	0.9984	25.3
C15B	1	1.72	1.75	1.68	0.9980	20.2
C20D	1	1.27	1.29	1.24	0.9982	26.8
C19D	1	1.24	1.26	1.22	0.9986	52.0
C18D	1	1.50	1.53	1.46	0.9982	21.0
C17D	1	1.62	1.65	1.59	0.9987	20.4
C16D	1	1.59	1.63	1.56	0.9983	33.3
C15D	1	1.61	1.64	1.58	0.9992	31.4
C14D	1	1.87	1.91	1.84	0.9987	25.3
C13D	1	2.08	2.12	2.05	0.9991	20.5
C20A	2	1.47	1.59	1.34	0.9927	16.9
C19A	2	1.75	1.80	1.70	0.9968	20.7
C18A	2	1.51	1.59	1.44	0.9976	16.4
C17A	2	1.71	1.78	1.64	0.9952	15.2
C16A	2	1.61	1.74	1.49	0.9893	16.9
C15A	2	2.20	2.33	2.08	0.9957	15.0
C14A	2	1.99	2.18	1.81	0.9950	10.8
C13A	2	2.31	2.48	2.15	0.9966	6.9
C12A	2	2.71	2.96	2.45	0.9907	5.8
C20C	2	1.65	1.74	1.57	0.9973	16.7

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C19C	2	1.57	1.66	1.49	0.9917	17.0
C18C	2	1.63	1.71	1.56	0.9959	20.1
C17C	2	2.03	2.09	1.97	0.9961	16.6
C16C	2	2.12	2.25	2.00	0.9944	15.6
C15C	2	2.35	2.43	2.27	0.9954	14.1
C14C	2	1.96	2.07	1.86	0.9943	16.0
C20B	2	1.52	1.60	1.44	0.9985	25.0
C19B	2	1.37	1.43	1.31	0.9971	25.5
C18B	2	2.25	2.31	2.18	0.9966	16.8
C17B	2	1.68	1.82	1.55	0.9962	22.8
C16B	2	2.04	2.10	1.98	0.9984	16.9
C15B	2	2.05	2.12	1.98	0.9925	17.6
C20D	2	1.73	1.77	1.68	0.9986	20.3
C19D	2	1.55	1.60	1.50	0.9971	21.9
C18D	2	1.64	1.69	1.60	0.9983	20.3
C17D	2	2.01	2.13	1.90	0.9962	14.4
C16D	2	1.98	2.04	1.93	0.9975	12.0
C15D	2	2.03	2.16	1.91	0.9947	12.8
C14D	2	2.08	2.34	1.81	0.9925	11.9
C13D	2	2.57	2.85	2.29	0.9904	9.3

[A]Max and min values are for the 90 percent confidence interval on the mean.

Table 22. Phase 2 summary of average damping values for box 2.

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C20A	1	1.52	1.58	1.47	0.9971	20.9
C19A	1	1.47	1.55	1.40	0.9974	22.3
C18A	1	2.43	2.54	2.33	0.9937	20.1
C17A	1	1.74	1.76	1.71	0.9973	17.8
C16A	1	1.94	1.96	1.91	0.9969	18.6
C15A	1	2.04	2.07	2.01	0.9972	15.0
C14A	1	2.18	2.37	1.99	0.9985	16.0
C13A	1	2.21	2.30	2.11	0.9971	13.2
C12A	1	2.35	2.42	2.27	0.9977	12.6
C20C	1	1.44	1.47	1.41	0.9973	23.1
C19C	1	1.42	1.46	1.38	0.9970	25.0
C18C	1	1.79	1.86	1.72	0.9969	19.1
C17C	1	1.82	1.87	1.77	0.9973	18.3
C16C	1	2.19	2.25	2.14	0.9967	15.7
C15C	1	1.95	1.99	1.91	0.9961	17.0
C14C	1	2.02	2.06	1.97	0.9971	16.6
C20B	1	1.40	1.45	1.35	0.9960	30.1
C19B	1	1.24	1.26	1.22	0.9982	31.8
C18B	1	1.73	1.78	1.67	0.9970	20.6
C17B	1	1.53	1.57	1.50	0.9972	24.8
C16B	1	1.76	1.80	1.73	0.9968	25.3
C15B	1	1.87	1.92	1.83	0.9966	20.2
C20D	1	1.33	1.35	1.30	0.9985	25.5
C19D	1	1.32	1.34	1.29	0.9986	28.5
C18D	1	1.59	1.63	1.56	0.9975	20.5
C17D	1	1.78	1.82	1.74	0.9977	20.4
C16D	1	1.80	1.88	1.72	0.9966	23.3
C15D	1	1.85	1.90	1.81	0.9984	21.0
C14D	1	2.18	2.21	2.15	0.9976	18.4
C13D	1	2.34	2.44	2.24	0.9980	15.6
C20A	2	1.55	1.65	1.44	0.9957	16.6
C19A	2	1.69	1.76	1.61	0.9968	18.1
C18A	2	1.85	1.90	1.80	0.9973	16.0
C17A	2	1.97	2.03	1.92	0.9951	13.9
C16A	2	1.66	1.79	1.52	0.9936	16.3
C15A	2	2.30	2.37	2.24	0.9973	13.8
C14A	2	1.91	2.00	1.81	0.9972	14.5
C13A	2	2.37	2.48	2.26	0.9972	7.0
C12A	2	2.15	2.38	1.92	0.9935	8.4
C20C	2	1.77	1.84	1.70	0.9979	16.7

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C19C	2	1.74	1.82	1.67	0.9953	15.3
C18C	2	1.79	1.88	1.70	0.9936	20.1
C17C	2	2.17	2.22	2.11	0.9966	14.6
C16C	2	2.37	2.46	2.29	0.9949	14.9
C15C	2	2.19	2.24	2.14	0.9980	14.1
C14C	2	1.94	2.06	1.83	0.9962	15.7
C20B	2	1.73	1.80	1.66	0.9927	22.6
C19B	2	1.45	1.50	1.40	0.9986	24.0
C18B	2	2.37	2.43	2.31	0.9978	15.5
C17B	2	1.74	1.85	1.64	0.9966	18.6
C16B	2	2.04	2.10	1.98	0.9981	16.6
C15B	2	2.02	2.09	1.96	0.9962	16.3
C20D	2	1.71	1.76	1.66	0.9992	18.4
C19D	2	1.61	1.68	1.53	0.9968	18.8
C18D	2	1.77	1.82	1.73	0.9969	20.3
C17D	2	2.05	2.18	1.92	0.9970	13.1
C16D	2	2.05	2.15	1.95	0.9987	11.6
C15D	2	2.03	2.13	1.94	0.9959	12.0
C14D	2	2.17	2.34	1.99	0.9954	10.3
C13D	2	2.39	2.55	2.23	0.9940	9.4

[A]Max and min values are for the 90 percent confidence interval on the mean.

Table 23. Phase 2 summary of average damping values for boxes 1 and 2 combined.

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C20A	1	1.51	1.54	1.47	0.9969	22.7
C19A	1	1.45	1.50	1.40	0.9976	25.1
C18A	1	2.14	2.28	2.00	0.9941	21.2
C17A	1	1.63	1.68	1.59	0.9964	25.3
C16A	1	1.81	1.86	1.75	0.9973	24.2
C15A	1	1.95	1.99	1.90	0.9974	20.0
C14A	1	2.00	2.11	1.89	0.9983	20.0
C13A	1	2.00	2.09	1.90	0.9967	16.5
C12A	1	2.14	2.23	2.05	0.9972	15.9
C20C	1	1.41	1.44	1.39	0.9975	23.1
C19C	1	1.44	1.47	1.42	0.9957	36.1
C18C	1	1.73	1.77	1.68	0.9962	28.7
C17C	1	1.74	1.78	1.69	0.9970	27.0
C16C	1	2.10	2.15	2.05	0.9959	22.4
C15C	1	1.87	1.91	1.84	0.9964	23.4
C14C	1	2.03	2.06	1.99	0.9970	26.4
C20B	1	1.37	1.40	1.34	0.9968	30.1
C19B	1	1.22	1.23	1.20	0.9984	31.8
C18B	1	1.72	1.75	1.68	0.9970	24.1
C17B	1	1.51	1.53	1.48	0.9976	24.8
C16B	1	1.71	1.74	1.68	0.9976	25.3
C15B	1	1.80	1.84	1.75	0.9973	20.2
C20D	1	1.30	1.32	1.27	0.9984	26.1
C19D	1	1.28	1.30	1.25	0.9986	40.3
C18D	1	1.54	1.58	1.51	0.9978	20.8
C17D	1	1.70	1.74	1.66	0.9982	20.4
C16D	1	1.70	1.76	1.63	0.9975	28.3
C15D	1	1.73	1.79	1.67	0.9988	26.2
C14D	1	2.03	2.10	1.95	0.9981	21.8
C13D	1	2.21	2.28	2.14	0.9986	18.1
C20A	2	1.51	1.58	1.43	0.9942	16.8
C19A	2	1.72	1.76	1.67	0.9968	19.4
C18A	2	1.68	1.77	1.60	0.9975	16.2
C17A	2	1.84	1.91	1.77	0.9951	14.6
C16A	2	1.64	1.72	1.55	0.9914	16.6
C15A	2	2.25	2.32	2.19	0.9965	14.4
C14A	2	1.95	2.05	1.85	0.9961	12.7
C13A	2	2.34	2.43	2.25	0.9969	7.0
C12A	2	2.43	2.62	2.23	0.9921	7.1
C20C	2	1.71	1.76	1.65	0.9976	16.7

Cable Number	Mode	Average Damping Value (percent)	Max Damping Value[A] (percent)	Min Damping Value[A] (percent)	Correlation	Average Length of Time Sample (s)
C19C	2	1.66	1.72	1.60	0.9935	16.2
C18C	2	1.71	1.77	1.65	0.9948	20.1
C17C	2	2.10	2.15	2.05	0.9963	15.6
C16C	2	2.25	2.34	2.16	0.9947	15.2
C15C	2	2.27	2.32	2.22	0.9967	14.1
C14C	2	1.95	2.02	1.89	0.9952	15.9
C20B	2	1.62	1.69	1.56	0.9956	23.8
C19B	2	1.41	1.45	1.37	0.9978	24.8
C18B	2	2.31	2.36	2.26	0.9972	16.1
C17B	2	1.71	1.79	1.63	0.9964	20.7
C16B	2	2.04	2.07	2.00	0.9983	16.7
C15B	2	2.04	2.08	1.99	0.9943	16.9
C20D	2	1.72	1.75	1.69	0.9989	19.3
C19D	2	1.58	1.62	1.54	0.9969	20.3
C18D	2	1.71	1.75	1.67	0.9976	20.3
C17D	2	2.03	2.11	1.95	0.9966	13.8
C16D	2	2.02	2.07	1.96	0.9981	11.8
C15D	2	2.03	2.11	1.96	0.9953	12.4
C14D	2	2.12	2.26	1.98	0.9940	11.1
C13D	2	2.48	2.63	2.33	0.9922	9.3

[A]Max and min values are for the 90 percent confidence interval on the mean.

APPENDIX D. DAMPING PLOTS

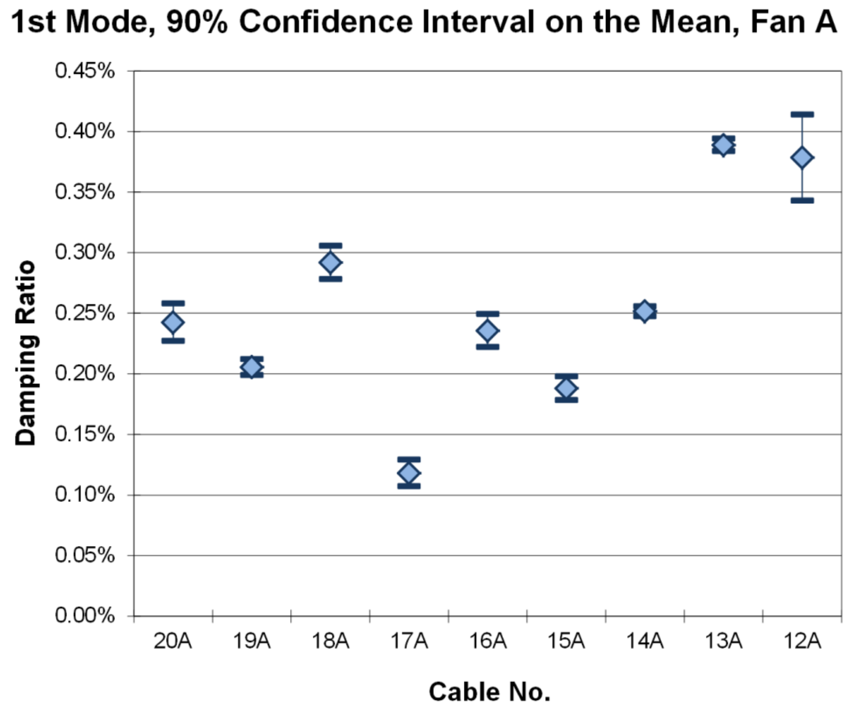


Figure 66. Graph. Phase 1, first mode 90 percent confidence interval on the mean, fan A.

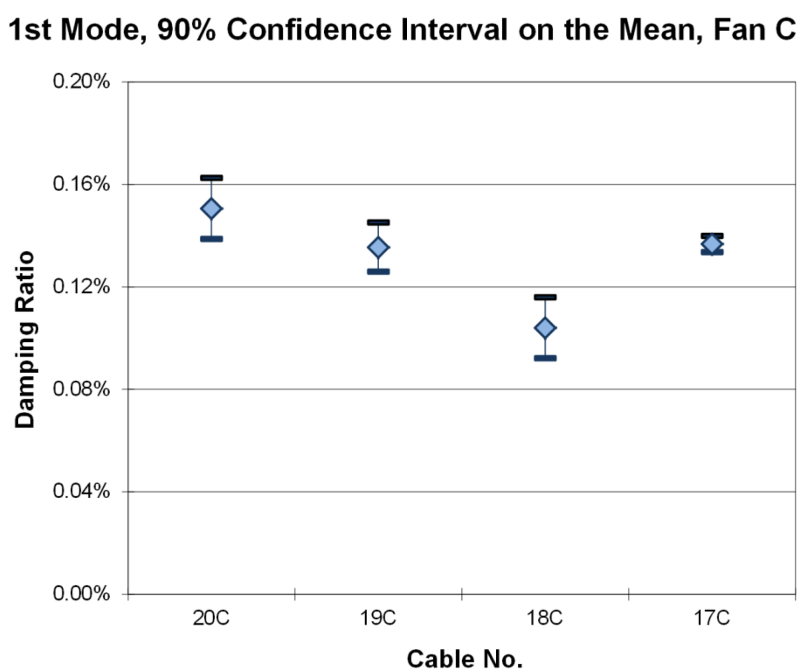


Figure 67. Graph. Phase 1, first mode 90 percent confidence interval on the mean, fan C.

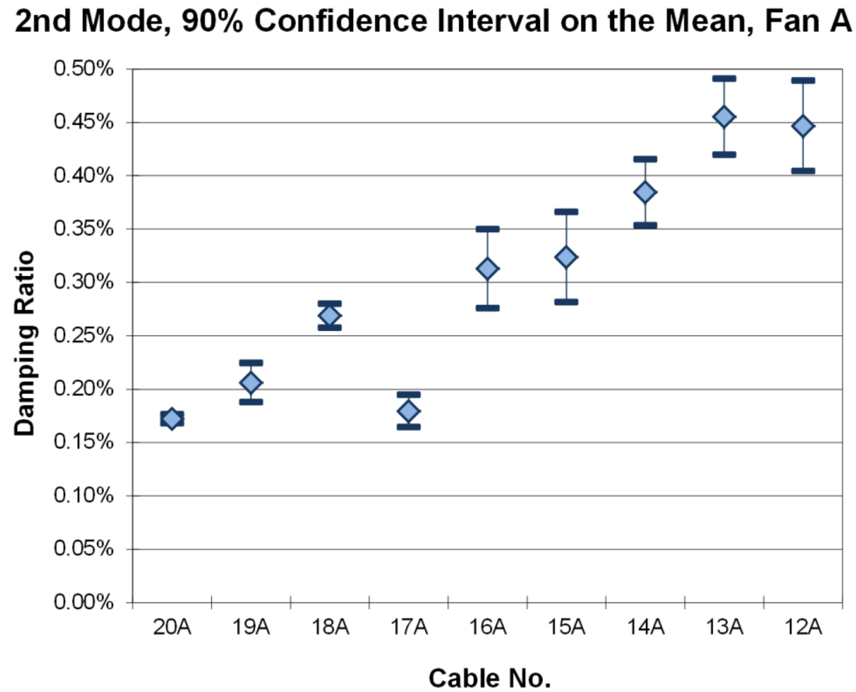


Figure 68. Graph. Phase 1, second mode 90 percent confidence interval on the mean, fan A.

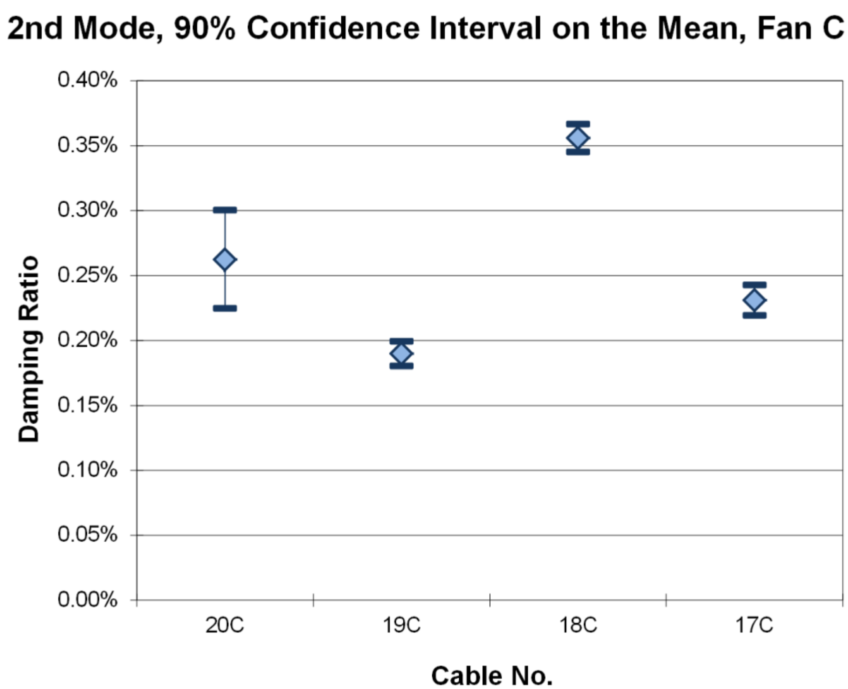


Figure 69. Graph. Phase 1, second mode 90 percent confidence interval on the mean, fan C.

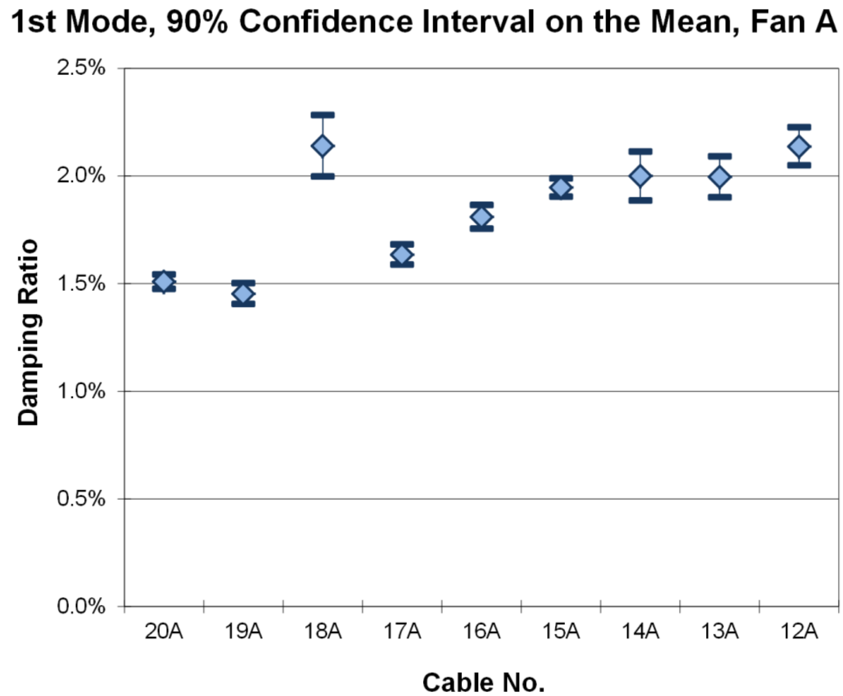


Figure 70. Graph. Phase 2, first mode 90 percent confidence interval on the mean, fan A.

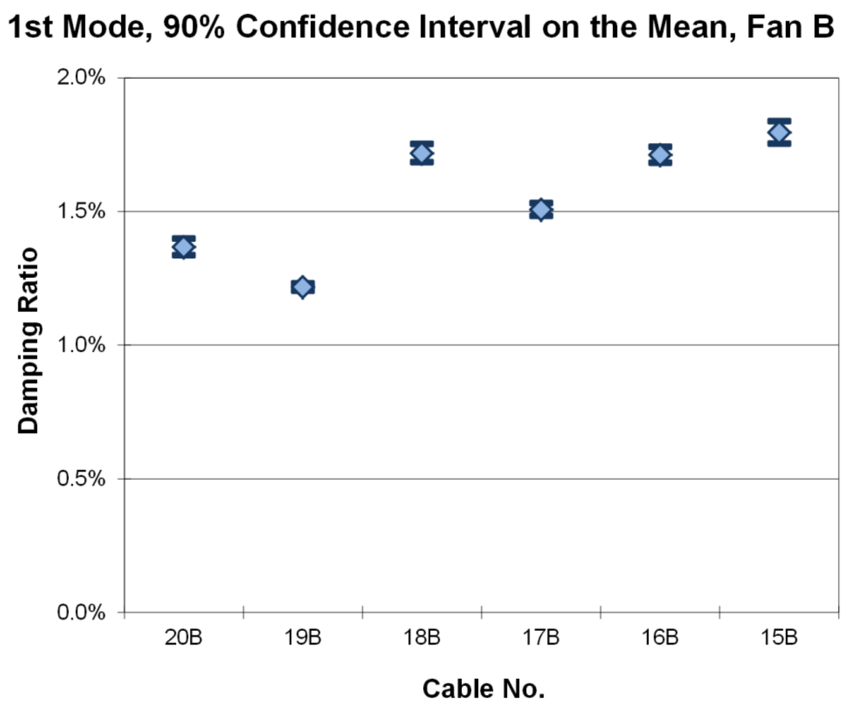


Figure 71. Graph. Phase 2, first mode 90 percent confidence interval on the mean, fan B.

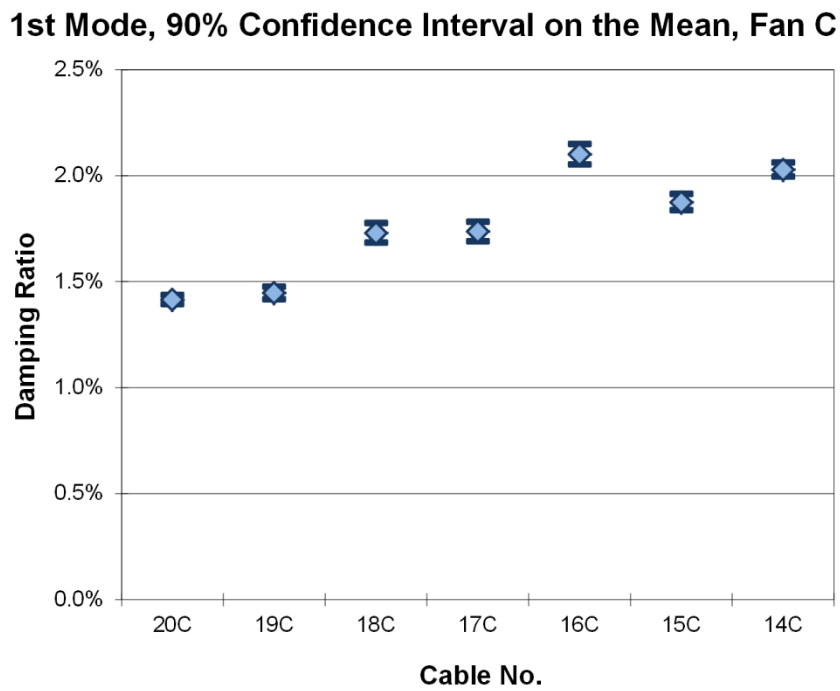


Figure 72. Graph. Phase 2, first mode 90 percent confidence interval on the mean, fan C.

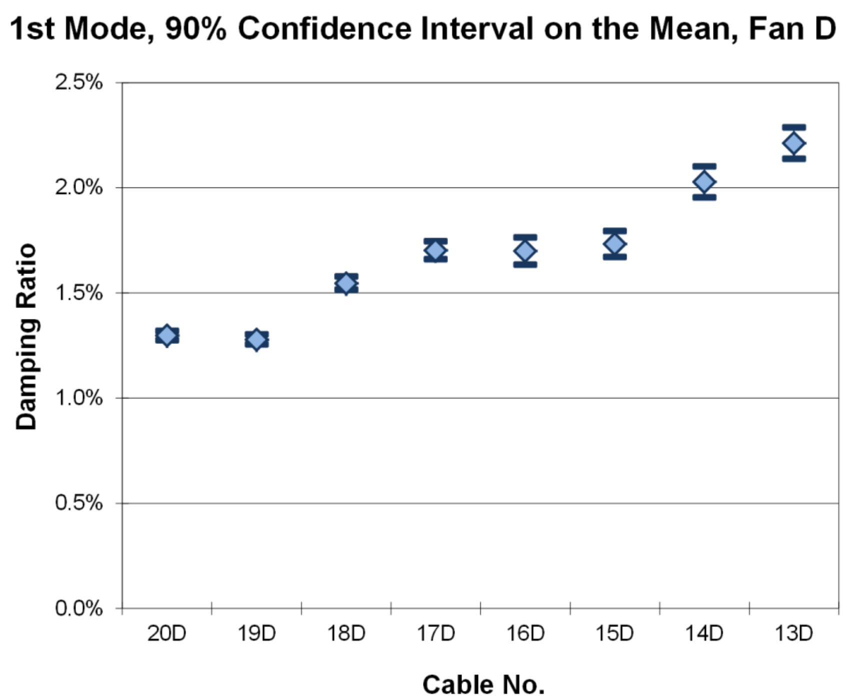


Figure 73. Graph. Phase 2, first mode 90 percent confidence interval on the mean, fan D.

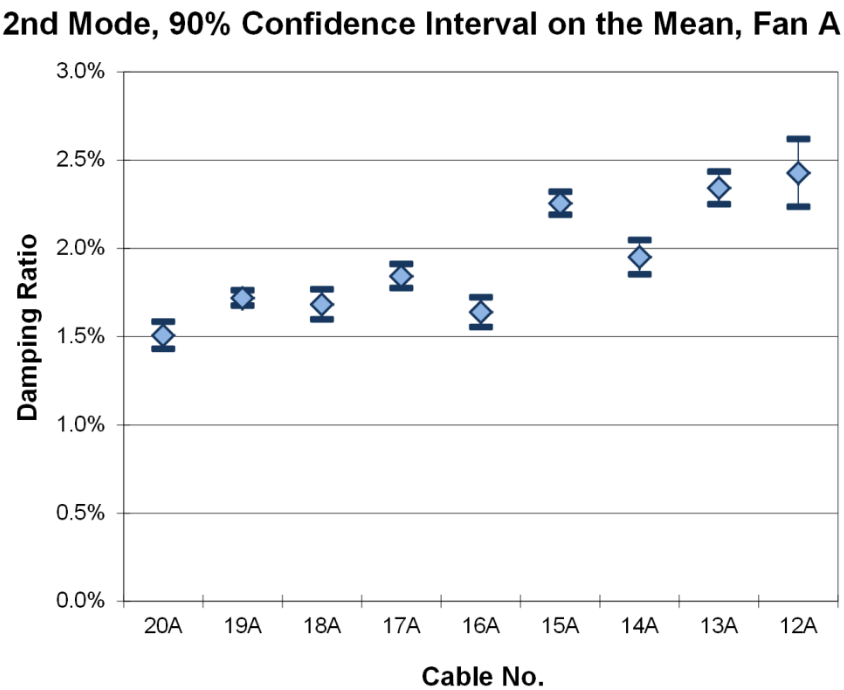


Figure 74. Graph. Phase 2, second mode 90 percent confidence interval on the mean, fan A.

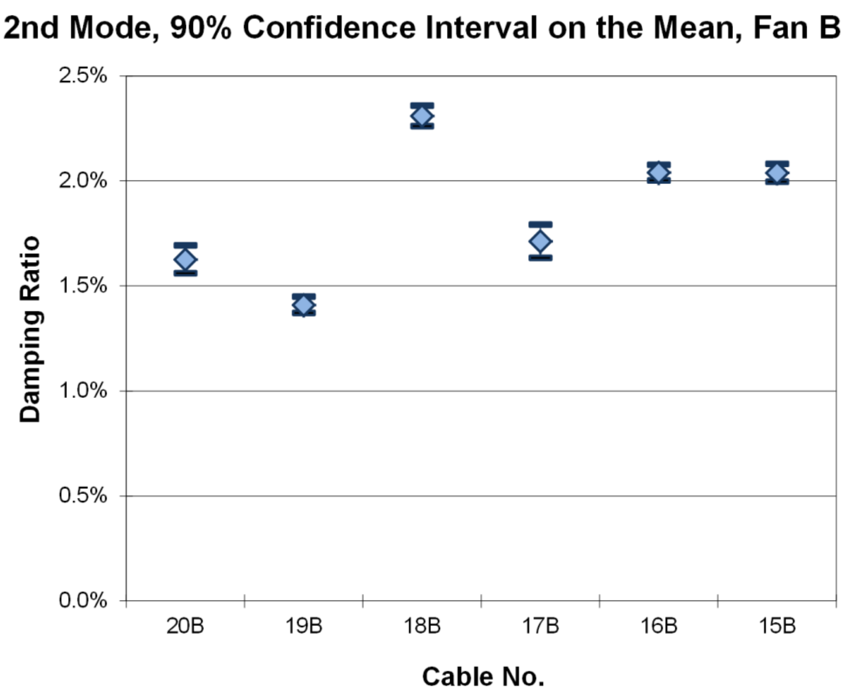


Figure 75. Graph. Phase 2, second mode 90 percent confidence interval on the mean, fan B.

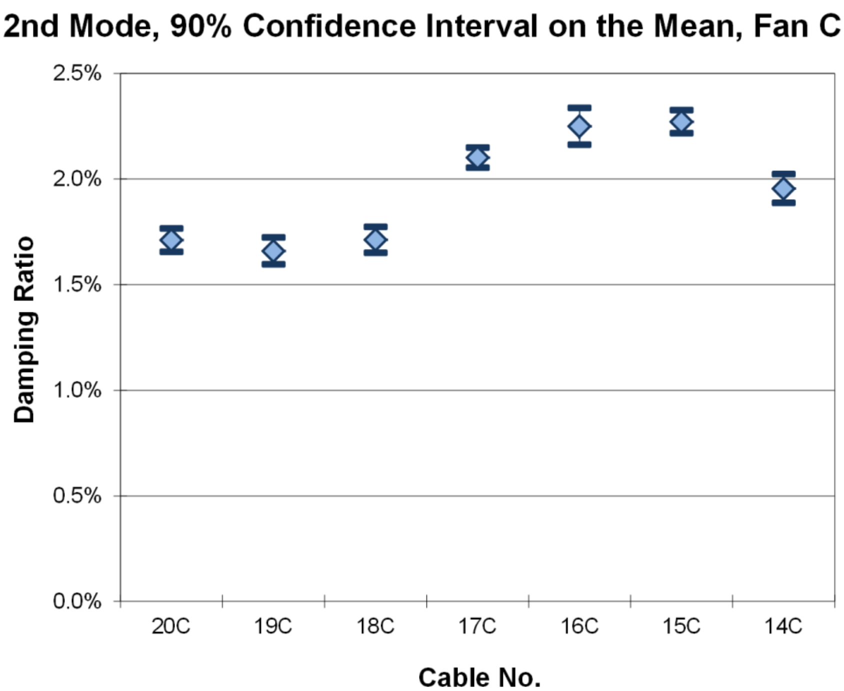


Figure 76. Graph. Phase 2, second mode 90 percent confidence interval on the mean, fan C.

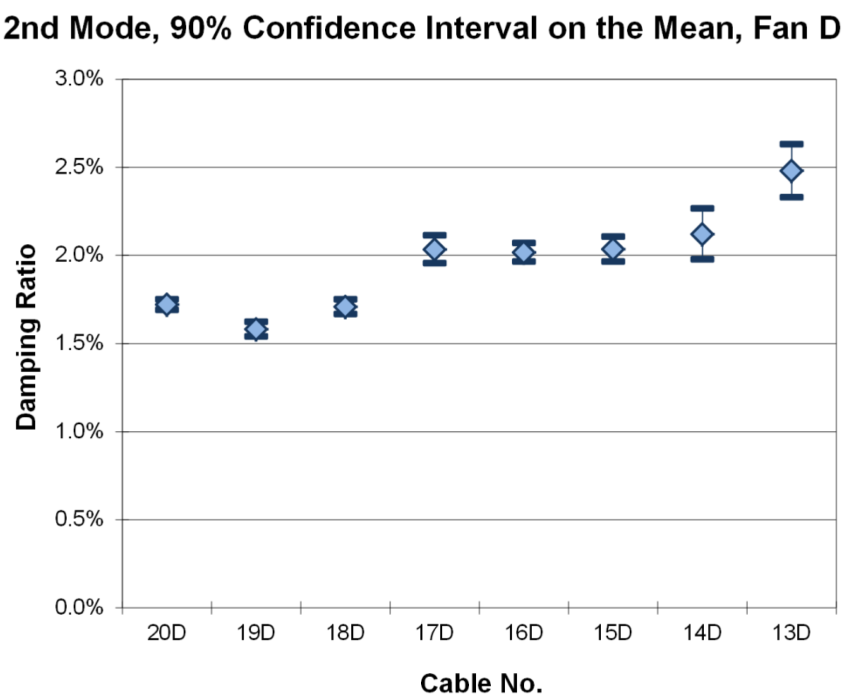


Figure 77. Graph. Phase 2, second mode 90 percent confidence interval on the mean, fan D.

APPENDIX E. AERODYNAMIC DAMPING DATA

Table 24. Phase 1 average wind speed and wind direction.

			Total		Decay Only			Average
Cable	Run	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	Damping (percent)
20A	2	0.2	108.0	0.2	0.3	97.9	0.3	0.230
20A	3	0.1	126.1	0.1	0.1	146.7	0.1	0.210
20A	4	0.2	113.7	0.2	0.5	91.5	0.5	0.282
20A	5	0.7	97.2	0.7	0.8	98.7	0.8	0.212
20A	6	1.8	72.9	1.7	1.4	65.2	1.3	0.225
20A	7	1.0	103.2	0.9	0.7	103.6	0.6	0.294
20A	8	0.7	71.1	0.7	0.7	91.6	0.7	0.228
19A	2	1.5	120.4	1.4	1.6	76.1	1.5	0.227
19A	3	0.6	129.1	0.6	0.4	125.6	0.4	0.190
19A	4	0.4	117.6	0.3	0.2	115.7	0.2	0.203
19A	5	0.9	122.8	0.8	0.4	120.9	0.3	0.209
19A	6	0.4	127.5	0.4	0.0	105.1	0.0	0.182
19A	7	0.9	102.1	0.9	1.5	102.4	1.4	0.195
19A	8	0.2	110.3	0.2	0.2	96.7	0.2	0.204
19A	9	1.8	159.9	1.8	1.6	150.0	1.6	0.220
18A	2	0.5	153.3	0.4	0.5	150.4	0.5	0.324
18A	3	0.7	127.6	0.7	0.6	123.0	0.6	0.295
18A	4	0.9	137.6	0.8	1.0	130.8	0.9	0.263
18A	6	0.2	121.2	0.2	0.2	125.0	0.2	0.322
18A	7	1.2	158.7	1.2	1.0	149.7	1.0	0.355
18A	8	0.6	119.3	0.5	0.3	126.8	0.3	0.289
18A	9	0.6	142.3	0.6	0.7	153.4	0.7	0.279
18A	10	0.8	60.9	0.7	0.4	63.9	0.4	0.247
18A	11	0.1	90.6	0.1	0.2	95.5	0.2	0.248
18A	12	0.8	106.4	0.8	0.1	91.6	0.1	0.254
17A	2	0.5	86.3	0.5	0.6	92.4	0.6	0.124
17A	3	0.2	180.3	0.2	0.1	188.8	0.1	0.125
17A	5	0.2	109.5	0.2	0.1	90.3	0.1	0.085
17A	6	0.4	83.9	0.4	0.4	93.6	0.4	0.093
17A	7	0.4	83.0	0.4	0.1	96.9	0.1	0.106
17A	8	0.5	152.5	0.4	0.5	155.5	0.5	0.133
17A	9	0.4	75.6	0.4	0.4	69.4	0.4	0.152
16A	2	1.1	89.4	1.1	1.2	74.8	1.1	0.191
16A	3	0.4	76.3	0.3	0.4	80.4	0.3	0.213
16A	4	0.8	77.5	0.7	1.2	84.1	1.2	0.279
16A	5	0.1	149.8	0.1	0.1	135.2	0.1	0.226
16A	6	0.7	69.1	0.7	0.6	69.3	0.6	0.214
16A	7	2.8	62.5	2.6	2.3	65.3	2.1	0.249
16A	8	1.2	97.0	1.2	0.6	97.6	0.5	0.247

			Total		Decay Only			Average
Cable	**Run**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**Damping (percent)**
15A	2	2.3	270.4	2.3	2.5	272.4	2.6	0.198
15A	3	1.2	257.8	1.2	1.0	267.3	1.0	0.156
15A	4	1.2	249.7	1.2	1.5	263.5	1.5	0.201
15A	5	0.2	248.3	0.1	0.2	263.3	0.2	0.172
15A	6	0.1	263.6	0.1	0.1	259.1	0.1	0.206
15A	7	0.5	248.4	0.4	0.6	249.9	0.5	0.179
12A	2	13.2	176.0	13.2	16.7	172.6	16.7	0.507
12A	4	9.2	177.8	9.2	8.9	171.9	8.9	0.203
12A	5	9.4	182.1	9.4	10.3	203.1	10.2	0.413
12A	6	11.2	187.8	11.2	13.4	195.5	13.3	0.407
12A	7	11.6	173.7	11.6	13.1	167.2	13.1	0.368
12A	8	13.6	172.6	13.6	11.4	168.7	11.4	0.420
12A	9	10.1	180.1	10.1	9.5	175.6	9.5	0.370
12A	10	12.9	176.9	12.9	13.3	167.6	13.3	0.396
20C	2	4.7	203.8	4.5	5.7	202.2	5.4	0.124
20C	3	4.4	224.9	3.7	5.4	227.3	4.5	0.121
20C	4	12.4	239.8	9.6	13.7	240.1	10.6	0.156
20C	5	11.5	241.8	8.8	11.3	241.4	8.7	0.167
20C	6	6.5	244.8	4.9	4.4	225.0	3.8	0.154
20C	7	12.9	235.7	10.3	13.1	236.3	10.4	0.189
20C	8	6.8	232.8	5.5	5.4	220.5	4.7	0.143
19C	2	5.9	250.0	4.5	7.4	250.6	5.7	0.119
19C	3	12.5	243.1	9.8	13.8	243.8	10.8	0.153
19C	4	11.9	241.1	9.4	11.2	241.7	8.8	0.150
19C	5	11.1	248.3	8.6	10.7	251.0	8.3	0.132
19C	6	8.0	244.9	6.3	8.3	240.6	6.6	0.115
18C	2	5.8	254.0	4.4	4.2	279.0	3.2	0.099
18C	3	5.7	250.6	4.3	5.8	247.4	4.4	0.092
18C	4	5.5	250.8	4.2	4.7	259.8	3.5	0.112
18C	5	6.6	230.8	5.5	7.6	232.0	6.2	0.142
18C	6	4.7	231.2	3.9	4.3	219.7	3.8	0.084
17C	2	6.3	252.0	4.9	6.1	254.0	4.8	0.128
17C	3	5.0	268.6	4.0	4.6	270.5	3.6	0.134
17C	4	5.1	272.6	4.1	4.7	272.0	3.8	0.139
17C	5	4.0	261.9	3.1	3.0	261.9	2.4	0.136

Note: Cables 14A and 13A did not have valid wind data recorded during their testing. “Total” refers to wind data recorded over entire test run, while “Decay Only” refers to wind data that is only recorded between the start and stop times of the time filter.

Table 25. Phase 2 average wind speed and wind direction.

			Total			Decay Only		Average
Cable	Run	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	Damping (percent)
20A	1	0.0	65.7	0.0	0.0	51.9	0.0	1.46
20A	2	0.0	148.5	0.0	0.0	148.5	0.0	1.66
20A	3	0.0	148.5	0.0	0.0	148.5	0.0	1.52
20A	4	0.0	148.5	0.0	0.0	148.5	0.0	1.39
20A	5	0.0	77.6	0.0	0.0	77.6	0.0	1.51
20A	6	0.0	77.6	0.0	0.0	77.6	0.0	1.48
20A	7	0.0	77.6	0.0	0.0	77.6	0.0	1.53
20A	8	0.0	77.6	0.0	0.0	77.6	0.0	1.59
20A	9	0.0	77.6	0.0	0.0	77.6	0.0	1.39
20A	10	0.0	77.6	0.0	0.0	77.6	0.0	1.41
19A	2	0.0	77.6	0.0	0.0	77.6	0.0	1.35
19A	3	0.0	77.6	0.0	0.0	77.6	0.0	1.33
19A	4	0.0	77.6	0.0	0.0	77.6	0.0	1.40
19A	5	0.0	77.6	0.0	0.0	77.6	0.0	1.33
19A	6	0.0	77.6	0.0	0.0	77.6	0.0	1.62
19A	7	0.0	77.6	0.0	0.0	77.6	0.0	1.47
19A	8	0.0	77.6	0.0	0.0	77.6	0.0	1.51
18A	2	0.0	77.6	0.0	0.0	77.6	0.0	1.91
18A	3	0.0	77.6	0.0	0.0	77.6	0.0	1.88
18A	4	0.0	77.6	0.0	0.0	77.6	0.0	1.85
18A	5	0.0	77.6	0.0	0.0	77.6	0.0	1.70
18A	6	0.0	77.6	0.0	0.0	77.6	0.0	1.93
18A	7	0.0	77.6	0.0	0.0	77.6	0.0	1.94
18A	8	0.0	77.6	0.0	0.0	77.6	0.0	1.77
18A	9	0.0	77.6	0.0	0.0	77.6	0.0	1.78
17A	2	0.0	135.8	0.0	0.0	101.5	0.0	1.57
17A	3	0.1	340.3	0.1	0.1	341.5	0.1	1.59
17A	4	0.1	354.3	0.1	0.1	354.3	0.1	1.57
17A	5	0.1	354.3	0.1	0.1	354.3	0.1	1.54
17A	6	0.1	354.3	0.1	0.1	354.3	0.1	1.50
17A	7	0.1	354.3	0.1	0.1	354.3	0.1	1.44
17A	8	0.1	354.3	0.1	0.1	354.3	0.1	1.51
17A	9	0.1	354.3	0.1	0.1	354.3	0.1	1.56
17A	10	0.1	354.3	0.1	0.1	354.3	0.1	1.49
16A	3	1.2	67.4	1.1	1.8	36.0	1.7	1.66
16A	4	1.9	33.2	1.8	2.0	37.2	1.9	1.69
16A	5	2.0	30.3	1.9	1.6	31.2	1.5	1.69
16A	6	2.7	37.8	2.6	2.6	50.5	2.4	1.70
16A	7	2.3	71.4	2.2	2.2	23.9	2.2	1.69
16A	8	1.9	41.7	1.8	1.8	43.4	1.7	1.67
16A	9	1.9	73.7	1.8	1.6	25.4	1.5	1.70

			Total		Decay Only			Average
Cable	Run	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	Damping (percent)
16A	10	2.0	20.0	2.0	2.6	23.0	2.6	1.66
16A	11	1.9	32.9	1.8	2.4	25.7	2.3	1.68
15A	2	4.9	102.8	4.9	4.5	83.8	4.5	1.86
15A	3	3.6	95.9	3.6	3.4	92.7	3.4	1.88
15A	4	5.9	93.5	6.0	6.4	98.0	6.4	1.79
15A	5	5.5	114.8	5.2	4.7	140.1	4.5	1.89
15A	6	3.6	104.9	3.6	3.9	101.6	3.9	1.87
15A	7	3.4	90.8	3.5	5.6	85.4	5.6	1.85
15A	8	3.3	55.1	3.2	2.4	44.7	2.3	1.86
15A	9	4.3	80.9	4.3	4.7	76.1	4.7	1.79
15A	10	3.3	95.3	3.3	2.8	95.5	2.8	1.86
14A	2	1.7	111.5	1.6	1.2	115.2	1.1	1.93
14A	3	2.0	107.8	1.9	2.5	110.3	2.4	1.83
14A	4	3.0	93.0	2.9	4.3	88.4	4.3	1.84
14A	5	3.4	128.5	3.2	4.2	131.8	4.0	1.78
14A	6	2.6	102.1	2.5	3.2	93.3	3.2	1.80
14A	7	1.5	184.9	1.5	2.0	179.5	2.0	1.85
14A	8	0.9	163.9	0.9	0.4	179.2	0.4	1.77
14A	9	1.0	168.1	1.0	0.0	236.6	0.0	1.79
14A	10	2.5	101.4	2.5	2.0	108.6	1.9	1.79
14A	11	0.1	183.6	0.1	0.1	100.9	0.1	1.78
13A	2	3.3	93.5	3.4	3.0	105.0	3.0	1.78
13A	3	2.3	122.3	2.3	1.6	145.3	1.6	1.75
13A	4	3.8	136.1	3.7	4.6	134.5	4.4	1.78
13A	5	3.4	136.6	3.3	3.5	115.4	3.5	1.80
13A	6	3.1	133.3	3.0	2.8	129.9	2.7	1.79
13A	7	3.5	118.8	3.4	2.4	113.9	2.4	1.81
13A	8	5.3	123.8	5.1	5.6	124.3	5.4	1.82
13A	9	3.8	118.9	3.7	3.5	133.5	3.3	1.84
13A	10	3.5	123.9	3.4	4.1	140.9	3.9	1.80
13A	11	1.9	105.0	1.9	1.0	97.4	1.0	1.70
12A	2	1.3	131.4	1.3	0.8	132.2	0.7	1.91
12A	3	2.3	120.7	2.3	2.0	94.7	2.0	1.93
12A	4	2.7	88.2	2.8	2.3	69.1	2.3	1.92
12A	5	3.2	92.2	3.3	3.5	83.7	3.6	1.94
12A	6	2.8	77.6	2.8	2.2	96.0	2.2	1.91
12A	7	4.2	81.2	4.2	4.7	84.2	4.8	1.91
12A	8	2.9	105.1	2.9	3.3	127.4	3.1	1.93
12A	9	3.1	90.2	3.2	3.9	91.9	4.0	1.97
12A	10	2.3	97.0	2.4	2.3	122.6	2.2	1.95
12A	11	1.7	121.7	1.6	1.1	140.8	1.0	1.92
20C	5	11.4	206.8	10.7	9.4	216.4	8.4	1.35

			Total			Decay Only		Average
Cable	**Run**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**Damping (percent)**
20C	6	7.8	195.4	7.6	7.3	204.9	7.0	1.34
20C	7	9.6	199.1	9.3	9.4	202.7	9.0	1.45
20C	8	13.5	222.4	11.7	14.3	216.6	12.8	1.39
20C	9	9.3	228.8	7.7	9.0	227.4	7.5	1.38
20C	10	16.0	219.1	14.1	12.7	216.9	11.3	1.45
20C	11	7.5	245.5	5.6	5.9	245.4	4.4	1.42
20C	12	11.3	238.2	8.8	9.0	243.2	6.9	1.33
20C	13	6.0	233.9	4.8	10.3	221.7	9.0	1.44
20C	14	5.5	228.8	4.5	4.9	254.8	3.7	1.35
19C	2	7.5	241.6	5.9	10.5	268.0	8.2	1.50
19C	3	5.5	220.0	4.9	6.2	207.0	5.9	1.52
19C	4	5.2	243.5	4.1	4.4	269.5	3.4	1.59
19C	5	8.9	231.2	7.3	10.5	268.5	8.2	1.47
19C	6	10.7	236.7	8.6	11.7	228.3	9.8	1.44
19C	7	8.7	233.9	7.1	8.7	214.7	7.9	1.53
19C	8	8.2	238.1	6.6	5.0	271.0	3.9	1.36
19C	9	10.1	236.4	8.1	10.3	220.6	9.1	1.42
19C	10	5.9	238.9	4.7	6.1	200.5	5.9	1.41
18C	2	10.2	246.9	7.8	9.8	266.6	7.5	1.75
18C	3	8.6	244.3	6.6	5.9	247.7	4.5	1.58
18C	4	7.7	229.2	6.4	9.8	193.7	9.7	1.65
18C	5	14.8	204.0	14.1	17.7	213.6	16.2	1.79
18C	6	13.4	222.8	11.6	16.1	223.9	13.9	1.62
18C	7	10.1	215.6	9.1	9.3	204.0	8.8	1.64
18C	8	7.3	214.8	6.6	4.9	211.8	4.5	1.65
18C	9	6.5	237.0	5.2	4.5	238.9	3.6	1.65
18C	10	8.4	217.9	7.5	4.6	247.6	3.5	1.63
17C	2	13.5	223.4	11.8	15.7	208.4	14.7	1.71
17C	3	10.1	227.2	8.6	10.0	233.4	8.3	1.67
17C	4	10.1	234.0	8.4	11.8	225.5	10.2	1.61
17C	5	4.9	239.9	4.0	6.2	247.8	4.9	1.60
17C	6	8.0	223.9	7.0	10.3	251.2	8.1	1.68
17C	7	9.4	243.0	7.5	11.3	230.5	9.5	1.63
17C	8	10.4	235.9	8.5	12.9	228.7	11.0	1.66
17C	9	8.3	242.1	6.7	9.7	237.5	7.9	1.65
16C	2	11.9	225.6	10.2	14.8	228.4	12.6	1.96
16C	3	10.3	230.6	8.6	8.1	253.5	6.3	1.96
16C	4	10.5	233.7	8.6	10.2	232.5	8.4	2.07
16C	5	10.6	212.0	9.8	4.8	200.5	4.6	2.00
16C	6	8.4	210.5	7.9	8.5	219.1	7.5	2.08
16C	7	8.3	244.1	6.5	11.0	263.4	8.6	2.03
16C	8	4.7	194.5	4.6	5.3	197.4	5.2	1.97

			Total		Decay Only			Average
Cable	Run	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	Damping (percent)
16C	9	7.0	229.3	5.9	6.3	145.5	5.7	1.99
16C	10	4.6	247.8	3.6	5.5	219.1	4.9	2.00
15C	2	7.8	251.2	6.3	7.5	218.5	6.8	1.84
15C	3	5.5	234.3	4.6	3.0	183.1	3.0	1.76
15C	4	11.2	234.6	9.4	15.5	248.5	12.6	1.80
15C	5	8.7	251.7	7.0	10.4	225.8	9.1	1.76
15C	6	6.2	215.3	5.7	8.5	237.6	7.0	1.80
15C	7	15.1	238.6	12.5	20.4	244.6	16.6	1.82
15C	8	7.9	266.4	6.6	9.0	279.4	7.4	1.81
15C	9	10.6	238.4	8.8	12.6	233.5	10.6	1.79
15C	10	10.7	255.7	8.7	12.3	261.9	10.1	1.76
14C	2	8.6	268.5	6.9	11.4	261.5	9.1	1.93
14C	3	13.3	264.9	10.6	14.2	258.0	11.3	2.10
14C	4	10.9	261.6	8.7	13.9	256.3	11.0	2.19
14C	5	4.3	216.3	3.9	3.8	175.0	3.8	1.99
14C	6	8.9	260.1	7.1	10.4	241.5	8.3	2.04
14C	7	12.0	259.9	9.6	12.0	257.2	9.5	2.04
14C	8	10.2	272.8	8.2	9.7	273.0	7.8	1.98
20B	2	3.1	252.6	2.3	2.1	283.3	1.6	1.45
20B	3	0.9	230.9	0.7	0.4	116.7	0.3	1.30
20B	4	6.2	251.9	4.6	5.8	259.3	4.3	1.24
20B	5	2.6	251.5	2.0	1.8	278.8	1.4	1.34
20B	6	3.8	208.6	3.6	4.4	191.3	4.3	1.30
20B	7	4.6	206.5	4.4	5.1	199.6	5.0	1.32
20B	8	4.2	224.1	3.6	4.8	225.9	4.1	1.30
20B	9	2.4	249.3	1.8	2.2	250.8	1.6	1.36
20B	10	2.8	260.4	2.1	1.8	233.6	1.5	1.36
19B	2	4.8	251.6	3.7	5.1	229.2	4.3	1.24
19B	3	6.7	259.4	5.2	7.1	254.4	5.5	1.21
19B	4	7.6	249.7	5.9	7.4	258.5	5.7	1.20
19B	5	2.7	255.1	2.1	3.2	272.7	2.5	1.19
19B	6	2.3	262.1	1.8	0.6	285.7	0.4	1.18
19B	7	5.5	261.1	4.2	2.8	271.7	2.2	1.20
19B	8	2.1	259.3	1.6	2.2	278.6	1.7	1.15
19B	9	3.0	165.3	2.9	4.9	208.3	4.6	1.20
19B	10	3.5	150.1	3.3	0.7	122.0	0.5	1.19
19B	11	6.8	251.4	5.2	6.8	262.9	5.3	1.17
18B	2	5.2	298.2	4.0	5.1	315.4	4.4	1.62
18B	3	2.5	279.5	1.9	0.8	298.6	0.6	1.73
18B	4	5.2	315.8	4.4	6.4	331.8	5.9	1.67
18B	5	3.3	248.4	2.5	3.1	254.6	2.4	1.61
18B	6	1.2	188.6	1.2	1.3	219.2	1.2	1.75

			Total		Decay Only			Average
Cable	**Run**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**Damping (percent)**
18B	7	2.1	210.9	1.9	0.2	93.9	0.2	1.67
18B	8	2.2	156.7	2.1	2.3	127.5	1.9	1.77
18B	9	3.6	227.1	3.1	2.6	290.1	1.9	1.84
17B	2	4.5	243.9	3.6	1.7	216.5	1.6	1.55
17B	3	5.2	236.5	4.2	5.2	244.4	4.1	1.49
17B	4	8.4	192.2	8.3	9.1	180.1	9.1	1.48
17B	5	7.9	249.1	6.3	8.1	248.9	6.4	1.48
17B	6	4.6	238.8	3.7	6.3	245.1	5.0	1.43
17B	7	3.8	259.8	3.0	4.8	265.8	3.8	1.48
17B	8	3.0	223.6	2.6	3.8	223.7	3.3	1.45
17B	9	5.8	239.2	4.7	4.4	199.8	4.2	1.42
17B	10	4.1	241.5	3.3	3.5	249.4	2.8	1.54
16B	2	5.6	244.8	4.4	6.9	284.2	5.4	1.72
16B	3	7.5	213.0	6.9	8.0	235.1	6.5	1.63
16B	4	4.6	231.8	3.9	5.1	200.7	5.0	1.60
16B	5	5.3	261.9	4.1	2.5	282.8	1.9	1.69
16B	6	8.9	247.9	6.9	8.1	244.3	6.4	1.66
16B	7	4.5	267.3	3.6	1.7	248.9	1.3	1.69
16B	8	4.4	272.7	3.5	4.2	247.4	3.3	1.63
16B	9	2.4	237.5	1.9	3.2	260.0	2.5	1.66
16B	10	2.2	223.0	1.9	3.7	239.0	2.9	1.65
15B	2	2.5	221.1	2.2	4.7	246.8	3.8	1.78
15B	3	6.6	225.1	5.8	8.3	224.5	7.3	1.73
15B	4	6.1	236.0	5.1	6.0	229.0	5.2	1.72
15B	5	2.3	232.0	1.9	1.4	293.1	1.2	1.74
15B	6	6.7	308.4	5.7	8.3	315.6	7.3	1.78
15B	7	7.7	251.5	6.2	7.4	254.6	6.0	1.71
15B	8	3.4	257.5	2.7	3.4	268.3	2.8	1.72
15B	9	5.9	293.3	4.8	4.8	267.0	4.0	1.63
15B	10	3.5	270.9	2.9	4.4	289.3	3.6	1.64
20D	2	1.6	236.8	1.4	1.7	228.1	1.5	1.34
20D	3	1.3	218.8	1.2	1.3	220.8	1.2	1.30
20D	4	1.4	204.0	1.3	1.7	199.6	1.7	1.25
20D	5	1.9	204.7	1.9	1.9	204.9	1.8	1.27
20D	6	1.6	225.0	1.5	1.6	223.3	1.5	1.28
20D	7	1.1	225.9	1.0	0.9	211.0	0.9	1.23
20D	8	2.1	206.5	2.0	1.7	220.6	1.6	1.22
20D	9	1.9	194.4	1.9	2.2	209.0	2.1	1.24
19D	1	2.0	199.7	2.0	1.6	199.6	1.5	1.26
19D	2	2.1	193.1	2.1	1.4	189.8	1.4	1.26
19D	3	3.0	191.8	3.0	3.0	183.7	3.0	1.23
19D	4	2.9	189.5	2.9	3.3	187.4	3.3	1.29

			Total		Decay Only			Average
Cable	Run	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	U_{ave} (mi/h)	θ_{ave}	U_{eq} (mi/h)	Damping (percent)
19D	5	2.7	196.0	2.7	2.9	189.7	2.9	1.25
19D	6	3.6	196.8	3.6	4.1	196.4	4.0	1.24
19D	7	2.9	197.7	2.8	3.3	178.8	3.3	1.17
19D	8	3.5	195.8	3.4	3.2	196.8	3.1	1.23
18D	1	2.1	220.4	1.9	2.5	246.0	2.3	1.50
18D	2	1.2	196.9	1.2	0.7	220.5	0.7	1.54
18D	3	3.4	195.0	3.3	4.8	183.8	4.8	1.48
18D	4	2.8	196.8	2.8	2.0	210.7	1.9	1.44
18D	5	2.3	202.4	2.3	1.4	199.0	1.4	1.57
18D	6	3.5	199.1	3.5	5.3	178.8	5.3	1.49
18D	7	3.2	190.5	3.2	3.0	184.6	3.0	1.43
18D	8	4.4	201.2	4.3	5.3	211.2	5.1	1.52
17D	1	3.4	181.8	3.4	5.6	194.0	5.5	1.66
17D	2	4.7	205.9	4.6	5.4	188.6	5.4	1.67
17D	3	3.2	200.3	3.1	2.5	202.1	2.5	1.56
17D	4	2.9	212.7	2.8	3.5	183.6	3.5	1.59
17D	5	4.6	193.3	4.5	5.0	208.9	4.9	1.60
17D	6	6.3	191.4	6.3	5.6	208.1	5.5	1.66
17D	7	5.8	192.6	5.8	5.2	189.3	5.2	1.57
17D	8	1.9	229.1	1.8	1.4	306.1	1.3	1.66
16D	1	6.3	191.6	6.3	7.2	195.7	7.2	1.69
16D	2	6.8	200.3	6.7	5.0	202.1	4.9	1.63
16D	3	5.9	192.0	5.8	7.5	185.6	7.4	1.54
16D	4	5.2	196.1	5.2	5.7	188.8	5.6	1.57
16D	5	5.2	199.4	5.1	6.5	169.4	6.5	1.58
16D	6	4.2	191.6	4.2	5.4	179.7	5.4	1.55
16D	7	3.9	208.4	3.8	5.4	189.9	5.3	1.61
15D	1	3.1	173.7	3.1	1.4	168.4	1.4	1.62
15D	2	5.9	187.9	5.9	7.0	183.0	7.0	1.62
15D	3	4.9	177.3	4.9	5.0	193.6	5.0	1.63
15D	4	7.3	177.9	7.3	7.1	193.9	7.1	1.52
15D	5	4.2	174.6	4.2	3.3	171.4	3.3	1.60
15D	6	4.9	169.1	4.9	3.2	184.1	3.2	1.68
15D	7	7.7	184.3	7.7	9.5	164.5	9.4	1.57
15D	8	8.9	168.0	8.9	8.6	172.2	8.5	1.62
14D	1	8.4	165.8	8.3	9.6	159.2	9.4	1.96
14D	2	5.1	165.3	5.1	7.7	165.9	7.7	1.83
14D	3	3.2	163.8	3.2	3.0	175.4	3.0	1.88
14D	4	6.0	183.0	6.0	7.7	161.0	7.6	1.83
14D	5	6.1	182.0	6.1	8.0	185.4	8.0	1.83
14D	6	9.4	164.3	9.3	9.9	150.8	9.6	1.83
14D	7	7.2	173.9	7.2	5.1	201.4	5.0	1.88

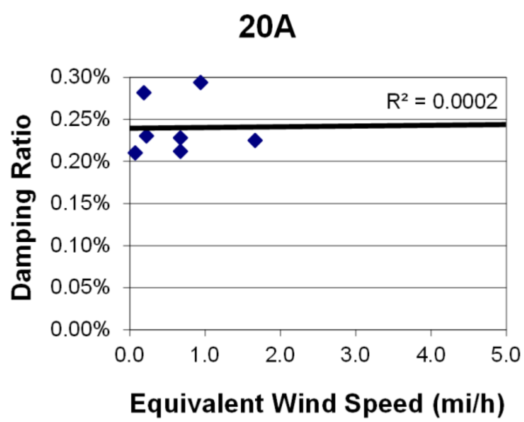
			Total		Decay Only			Average
Cable	**Run**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**U_{ave} (mi/h)**	**θ_{ave}**	**U_{eq} (mi/h)**	**Damping (percent)**
14D	8	7.0	185.1	7.0	10.3	191.5	10.2	1.93
13D	1	8.1	166.8	8.0	7.1	166.2	7.0	2.17
13D	2	5.2	176.5	5.2	5.3	196.4	5.3	2.07
13D	3	9.4	166.5	9.4	11.2	159.3	11.0	2.04
13D	4	5.7	163.8	5.6	1.7	158.1	1.7	2.11
13D	5	8.9	179.8	8.9	10.7	178.3	10.7	2.10
13D	6	6.3	173.5	6.3	6.2	178.5	6.2	2.01
13D	7	6.4	180.4	6.4	5.7	181.6	5.7	2.04
13D	8	5.6	164.9	5.6	3.7	166.7	3.7	2.10

Note: “Total” refers to wind data recorded over entire test run, while “Decay Only” refers to wind data that is only recorded between the start and stop times of the time filter.

APPENDIX F. AERODYNAMIC DAMPING PLOTS

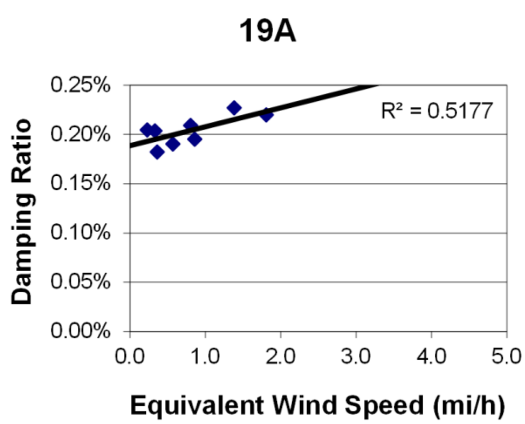
PHASE 1 AERODYNAMIC DAMPING PLOTS

Note that cables 14A and 13A did not have valid wind data recorded during their testing. In these plots, “Total” refers to wind data recorded over the entire test run, while “Decay Only” refers to wind data that is recorded only between the start and stop values of the time filter.



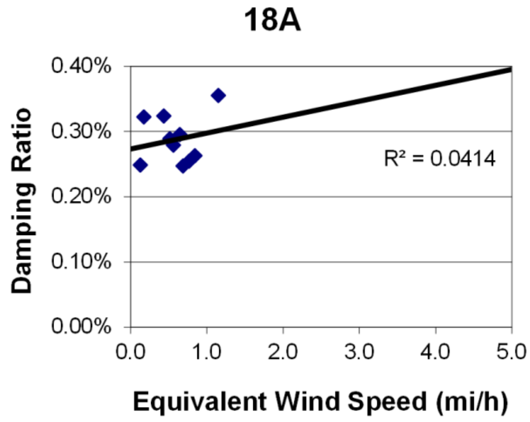
1 mi/h = 1.61 km/h

Figure 78. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 20A.



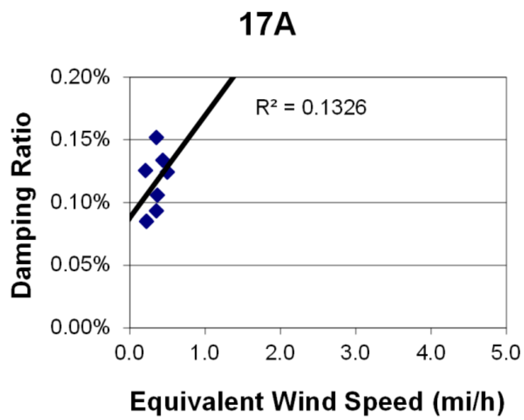
1 mi/h = 1.61 km/h

Figure 79. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 19A.



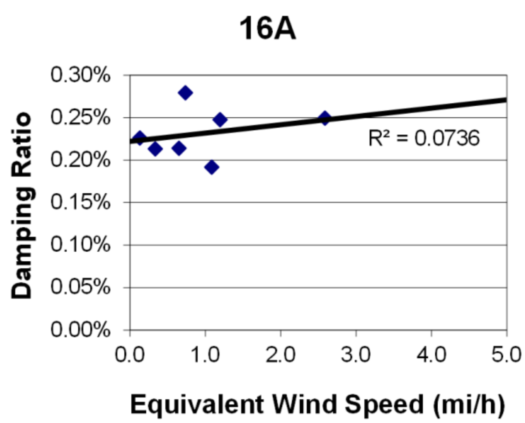
1 mi/h = 1.61 km/h

Figure 80. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 18A.



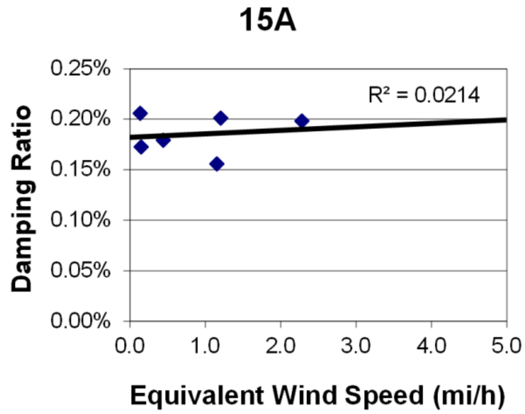
1 mi/h = 1.61 km/h

Figure 81. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 17A.



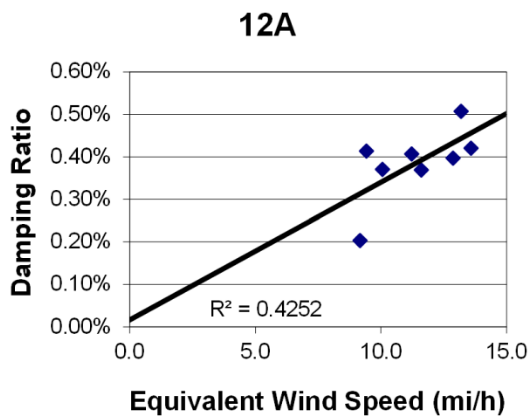
1 mi/h = 1.61 km/h

Figure 82. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 16A.



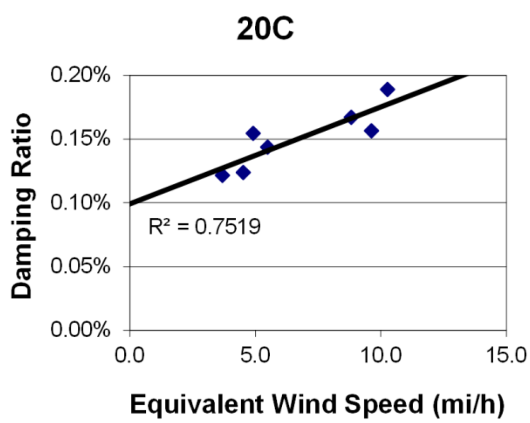
1 mi/h = 1.61 km/h

Figure 83. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 15A.



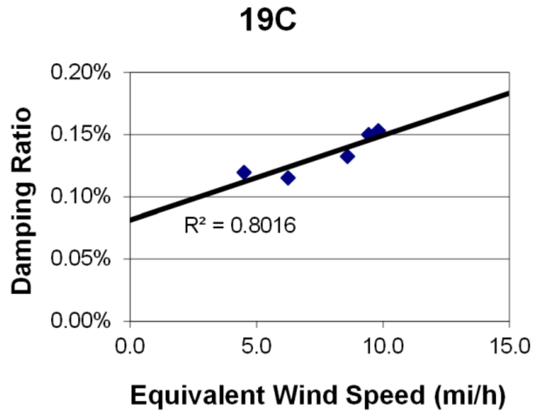
1 mi/h = 1.61 km/h

Figure 84. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 12A.



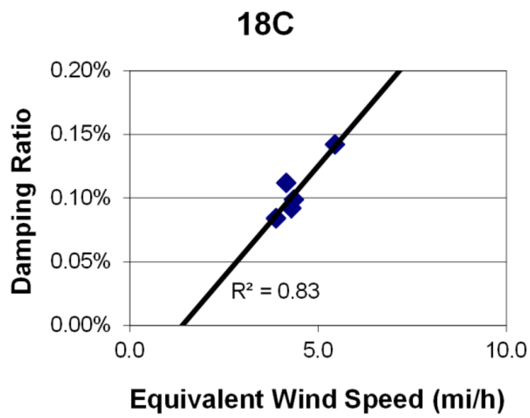
1 mi/h = 1.61 km/h

Figure 85. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 20C.



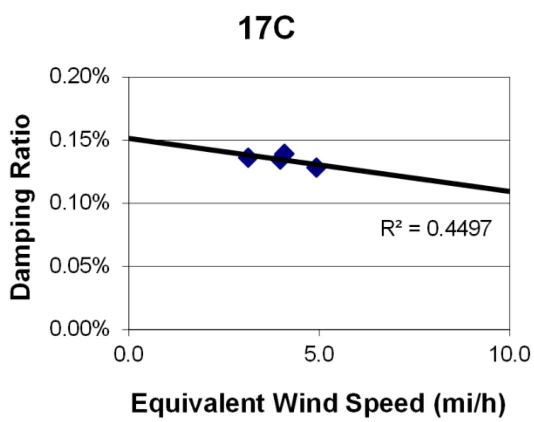
1 mi/h = 1.61 km/h

Figure 86. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 19C.



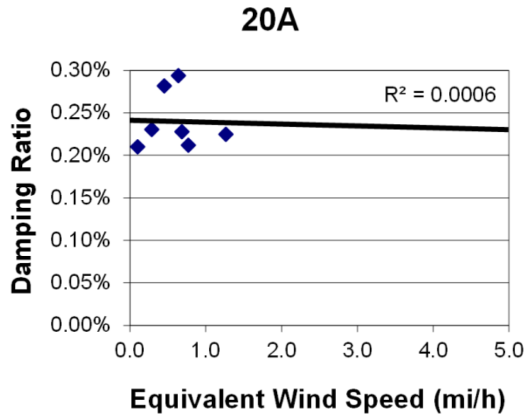
1 mi/h = 1.61 km/h

Figure 87. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 18C.



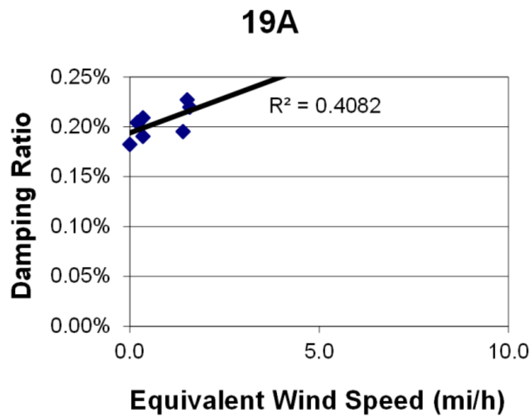
1 mi/h = 1.61 km/h

Figure 88. Graph. Phase 1, damping ratio versus total equivalent wind speed for cable 17C.



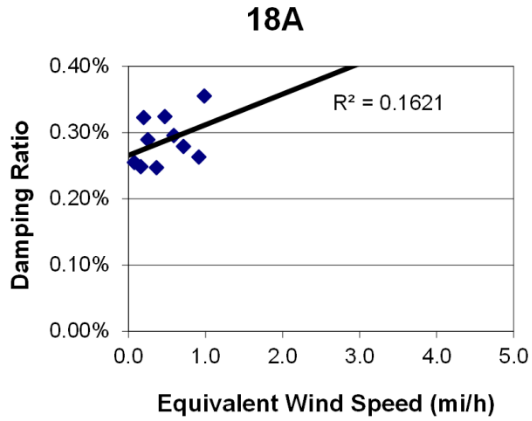
1 mi/h = 1.61 km/h

Figure 89. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 20A.



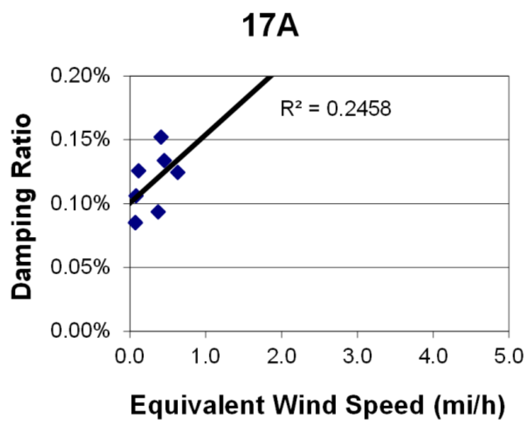
1 mi/h = 1.61 km/h

Figure 90. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 19A.



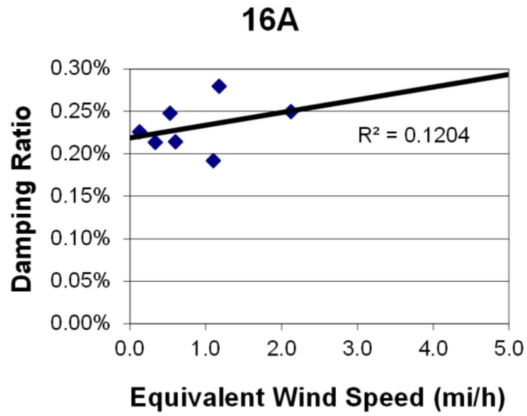
1 mi/h = 1.61 km/h

Figure 91. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 18A.



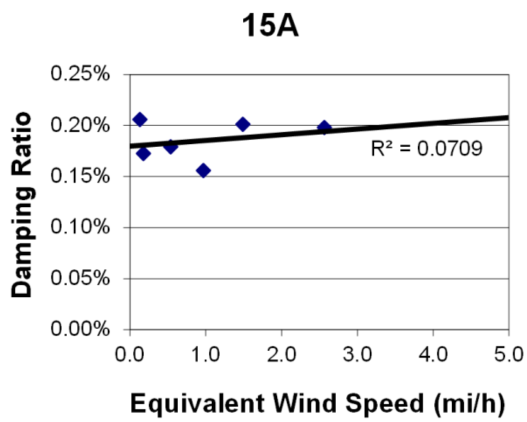
1 mi/h = 1.61 km/h

Figure 92. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 17A.



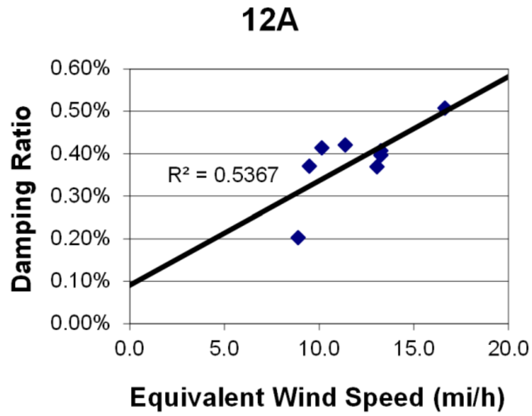
1 mi/h = 1.61 km/h

Figure 93. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 16A.



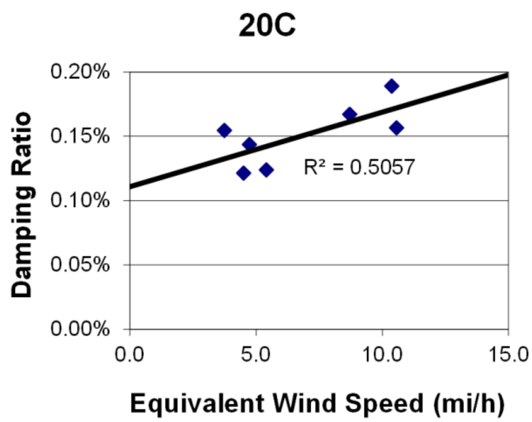
1 mi/h = 1.61 km/h

Figure 94. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 15A.



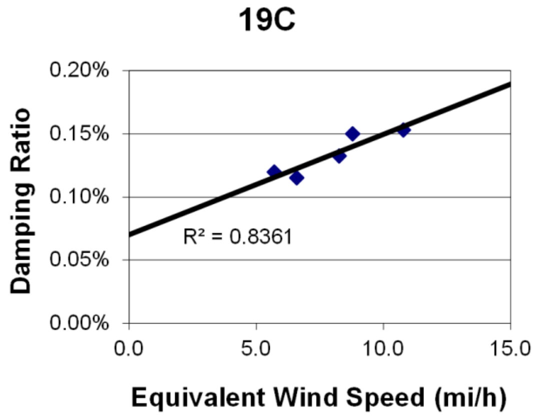
1 mi/h = 1.61 km/h

Figure 95. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 12A.



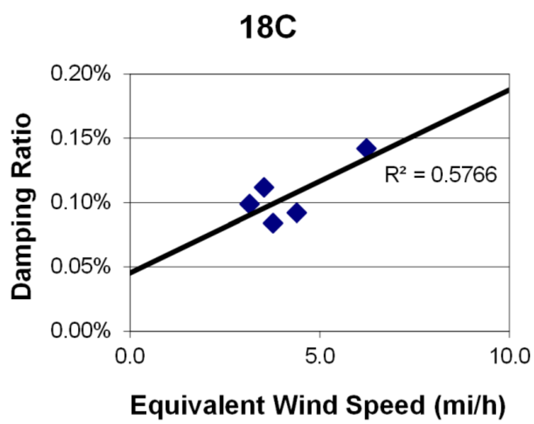
1 mi/h = 1.61 km/h

Figure 96. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 20C.



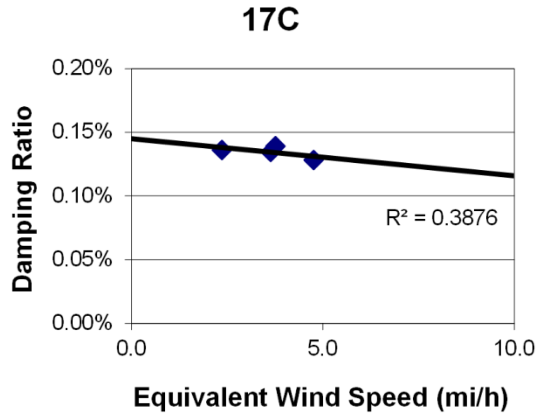
1 mi/h = 1.61 km/h

Figure 97. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 19C.



1 mi/h = 1.61 km/h

Figure 98. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 18C.

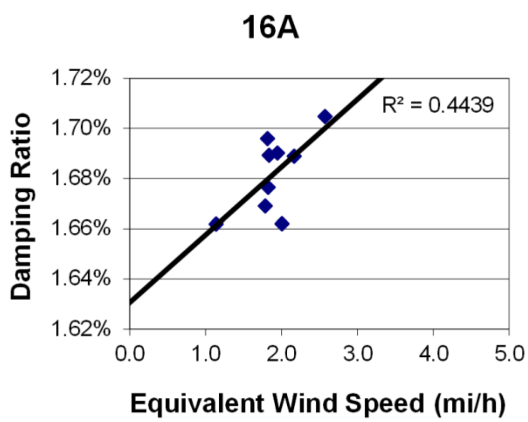


1 mi/h = 1.61 km/h

Figure 99. Graph. Phase 1, damping ratio versus decay-only equivalent wind speed for cable 17C.

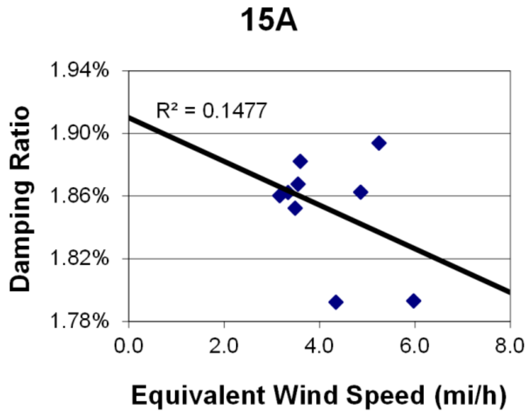
PHASE 2 AERODYNAMIC DAMPING PLOTS

Note that cables 20A, 19A, 18A, and 17A did not have significant wind data recorded during their testing. In these plots, "Total" refers to wind data recorded over the entire test run, while "Decay Only" refers to wind data that is recorded only between the start and stop values of the time filter.



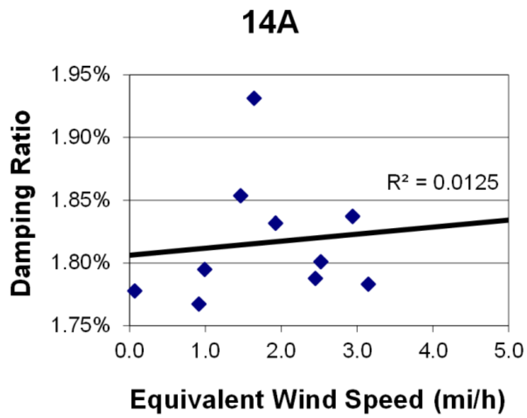
1 mi/h = 1.61 km/h

Figure 100. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 16A.



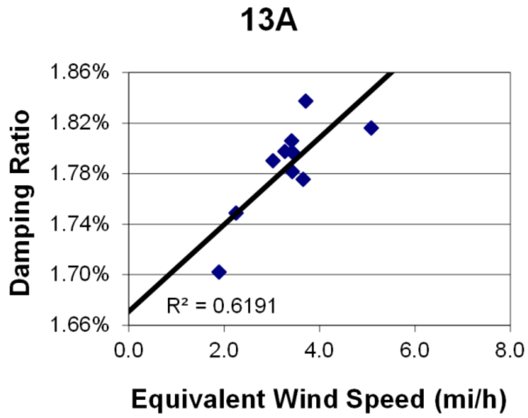
1 mi/h = 1.61 km/h

Figure 101. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 15A.



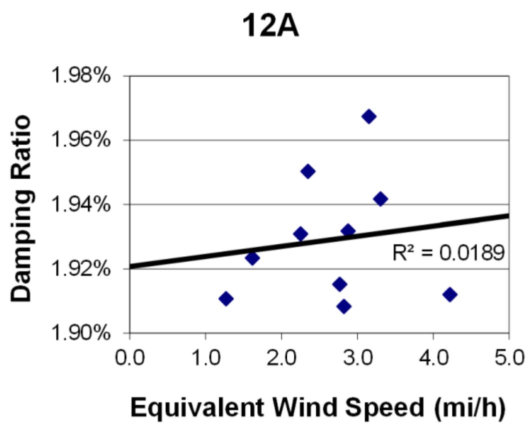
1 mi/h = 1.61 km/h

Figure 102. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 14A.



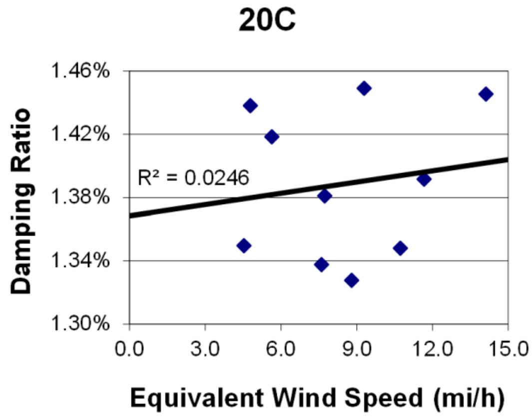
1 mi/h = 1.61 km/h

Figure 103. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 13A.



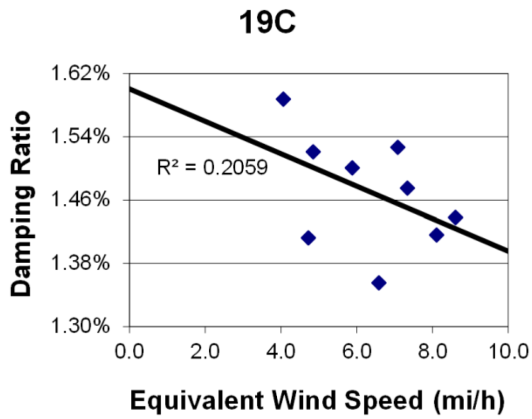
1 mi/h = 1.61 km/h

Figure 104. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 12A.



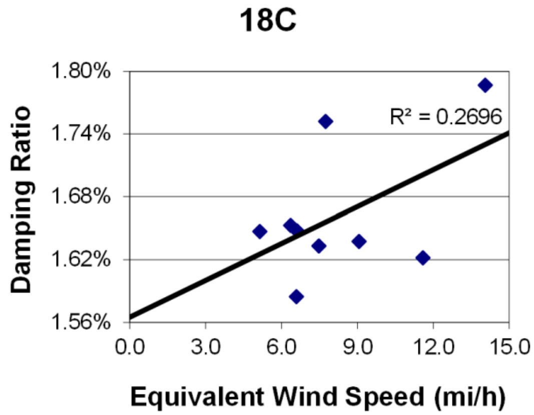
1 mi/h = 1.61 km/h

Figure 105. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 20C.



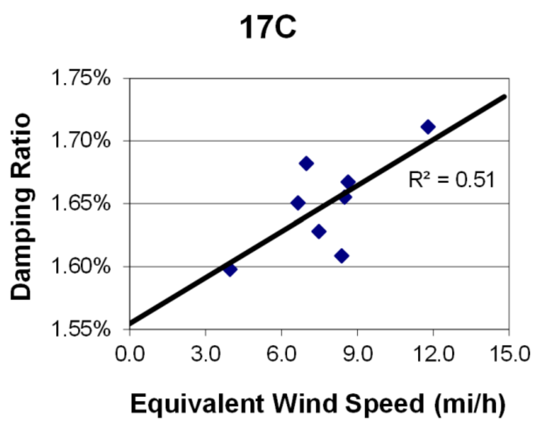
1 mi/h = 1.61 km/h

Figure 106. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 19C.



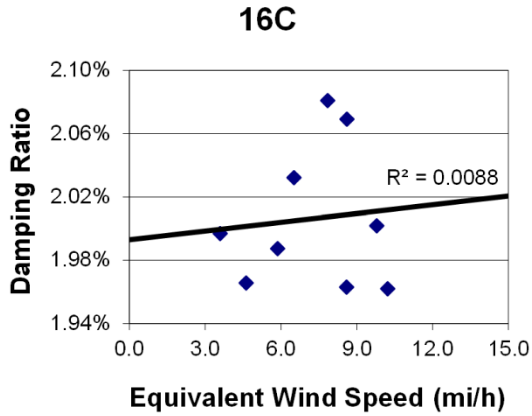
1 mi/h = 1.61 km/h

Figure 107. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 18C.



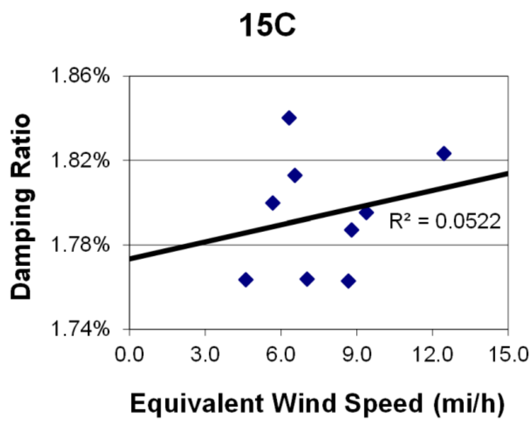
1 mi/h = 1.61 km/h

Figure 108. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 17C.



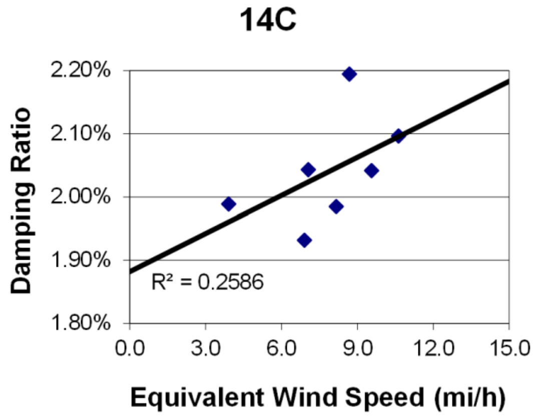
1 mi/h = 1.61 km/h

Figure 109. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 16C.



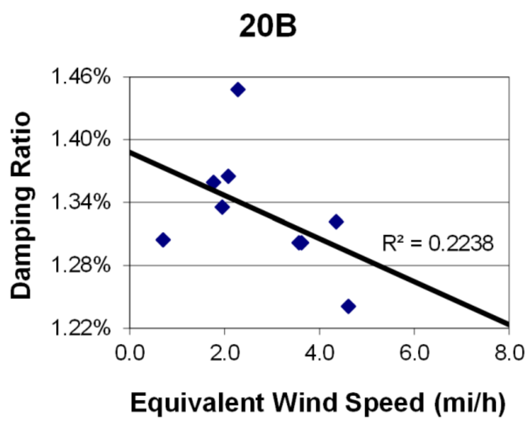
1 mi/h = 1.61 km/h

Figure 110. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 15C.



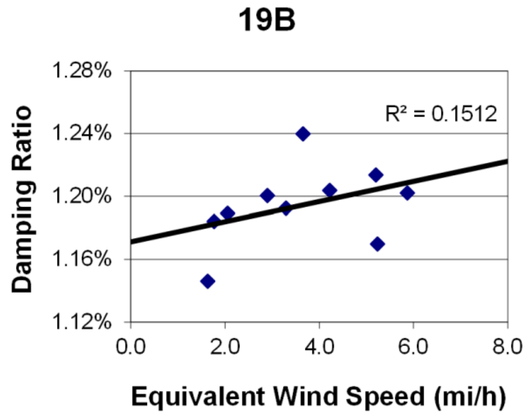
1 mi/h = 1.61 km/h

Figure 111. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 14C.



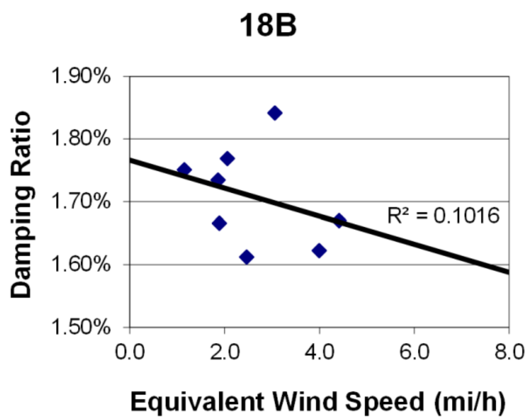
1 mi/h = 1.61 km/h

Figure 112. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 20B.



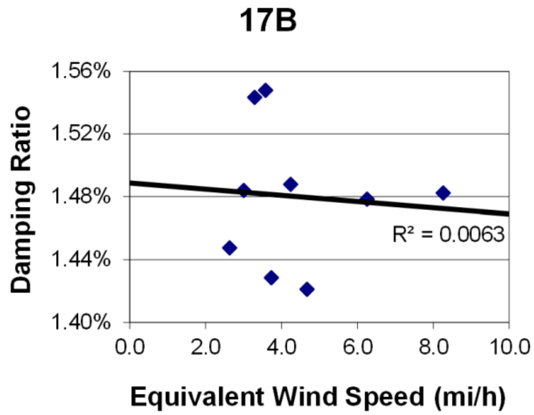
1 mi/h = 1.61 km/h

Figure 113. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 19B.



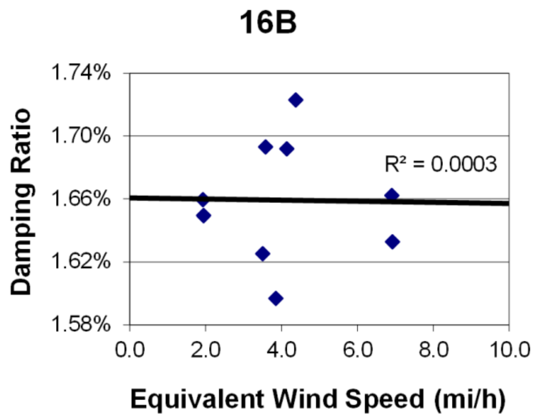
1 mi/h = 1.61 km/h

Figure 114. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 18B.



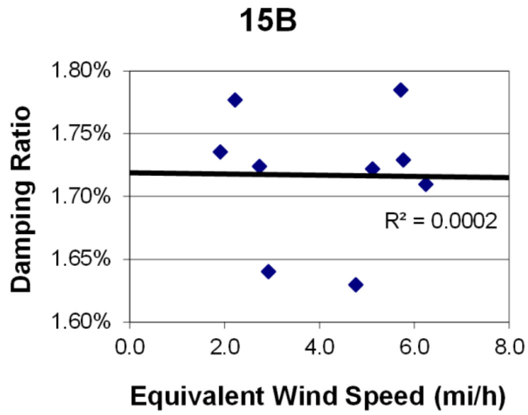
1 mi/h = 1.61 km/h

Figure 115. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 17B.



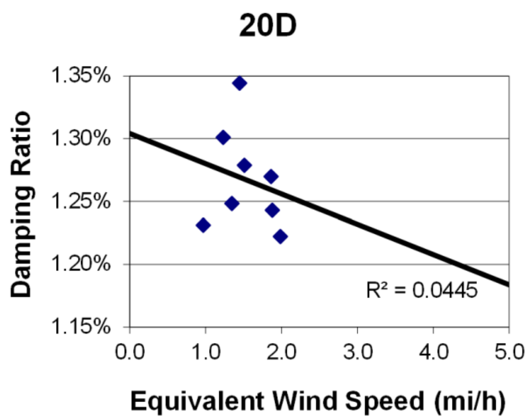
1 mi/h = 1.61 km/h

Figure 116. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 16B.



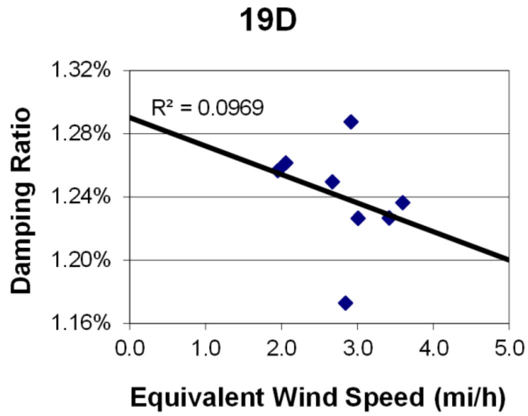
1 mi/h = 1.61 km/h

Figure 117. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 15B.



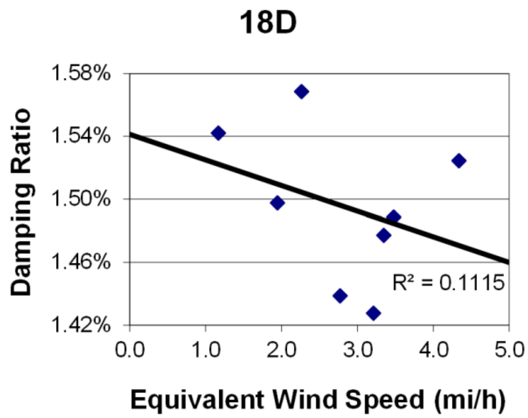
1 mi/h = 1.61 km/h

Figure 118. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 20D.



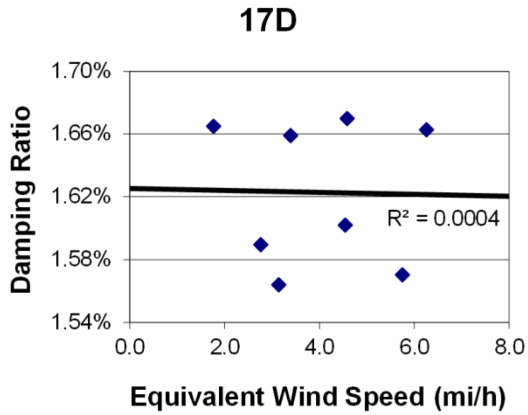
1 mi/h = 1.61 km/h

Figure 119. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 19D.



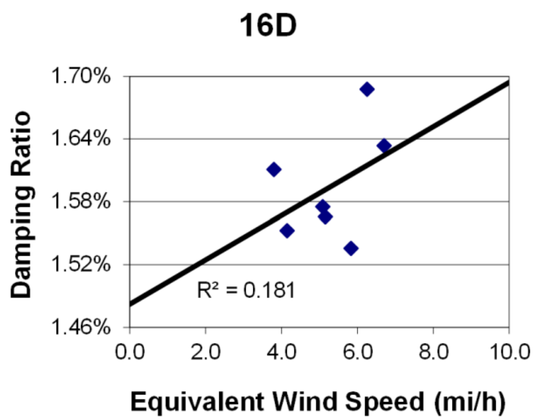
1 mi/h = 1.61 km/h

Figure 120. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 18D.



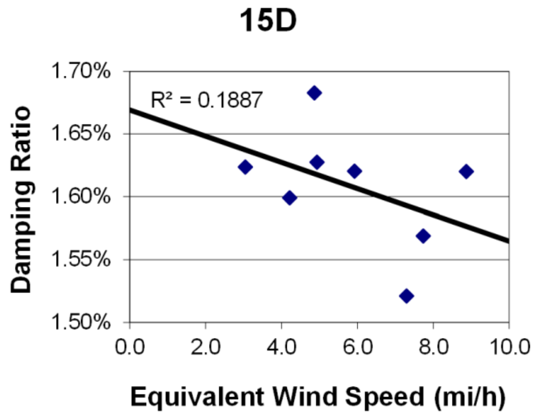
1 mi/h = 1.61 km/h

Figure 121. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 17D.



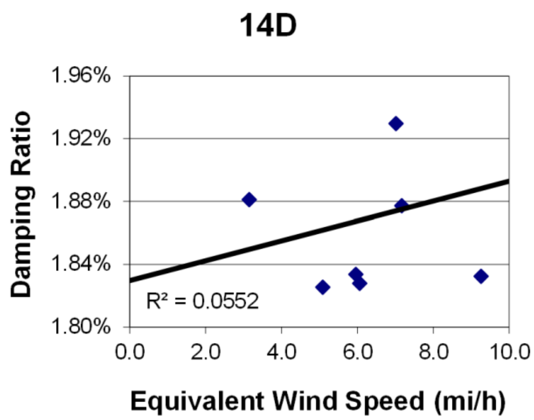
1 mi/h = 1.61 km/h

Figure 122. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 16D.



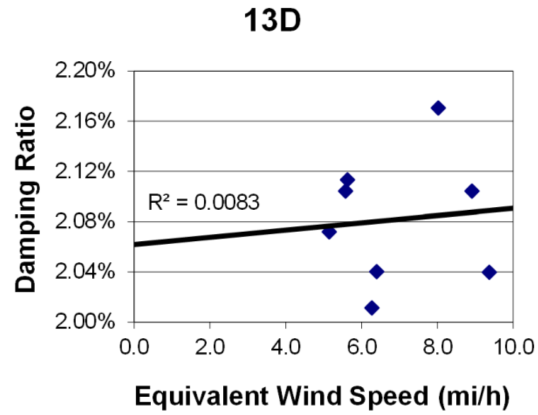
1 mi/h = 1.61 km/h

Figure 123. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 15D.



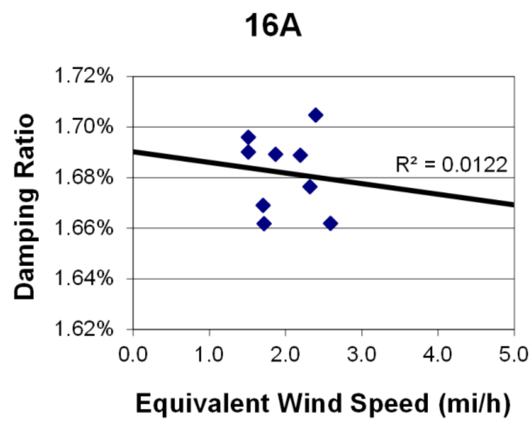
1 mi/h = 1.61 km/h

Figure 124. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 14D.



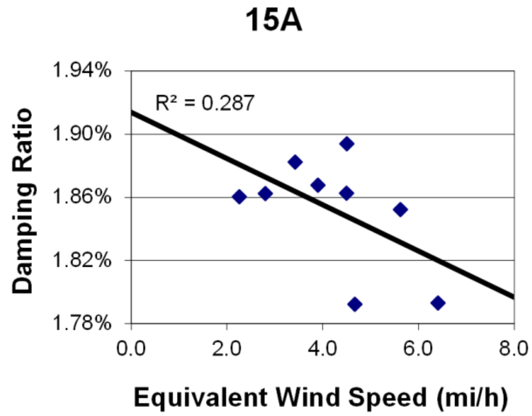
1 mi/h = 1.61 km/h

Figure 125. Graph. Phase 2, damping ratio versus total equivalent wind speed for cable 13D.



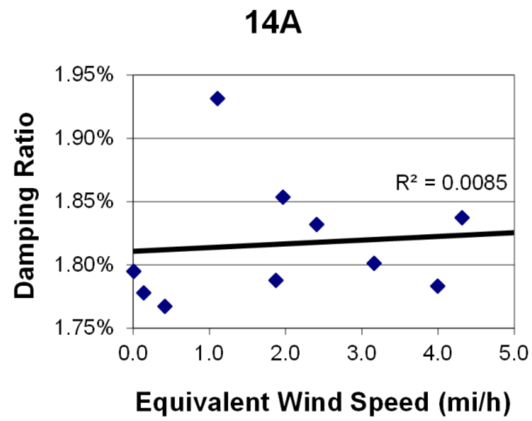
1 mi/h = 1.61 km/h

Figure 126. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 16A.



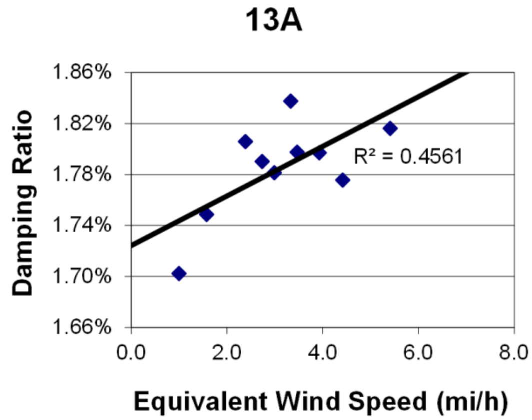
1 mi/h = 1.61 km/h

Figure 127. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 15A.



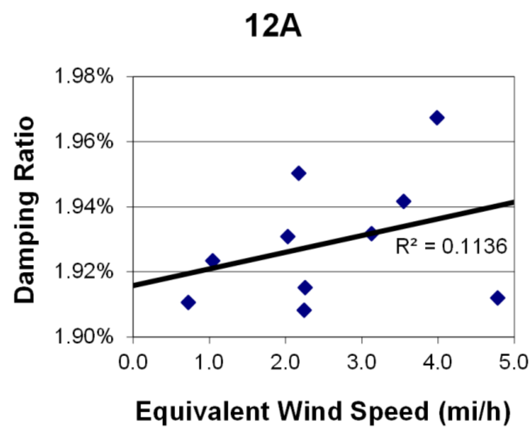
1 mi/h = 1.61 km/h

Figure 128. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 14A.



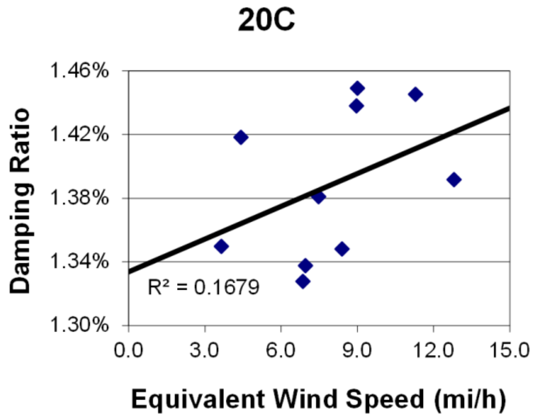
1 mi/h = 1.61 km/h

Figure 129. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 13A.



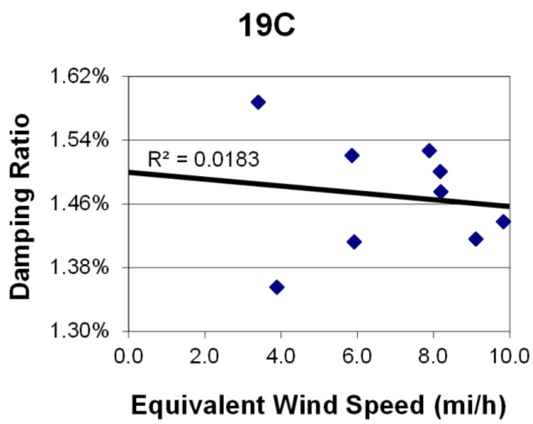
1 mi/h = 1.61 km/h

Figure 130. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 12A.



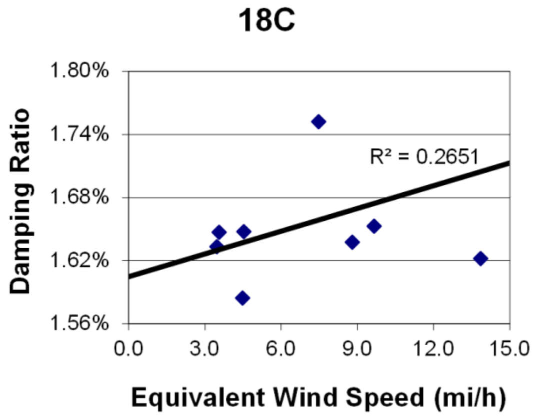
1 mi/h = 1.61 km/h

Figure 131. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 20C.



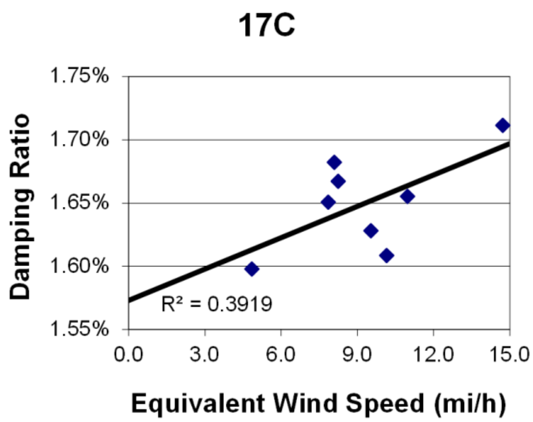
1 mi/h = 1.61 km/h

Figure 132. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 19C.



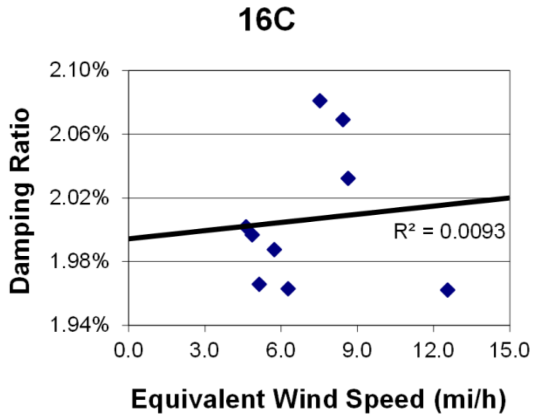
1 mi/h = 1.61 km/h

Figure 133. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 18C.



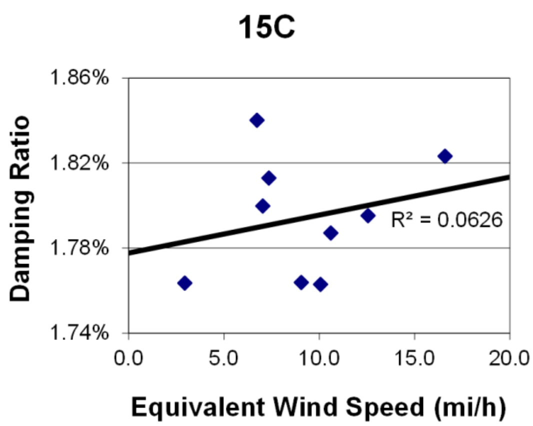
1 mi/h = 1.61 km/h

Figure 134. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 17C.



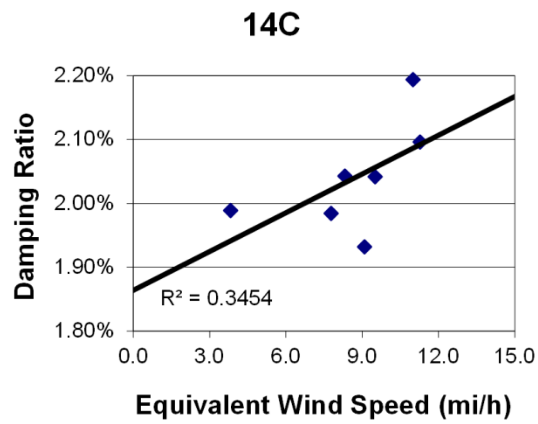
1 mi/h = 1.61 km/h

Figure 135. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 16C.



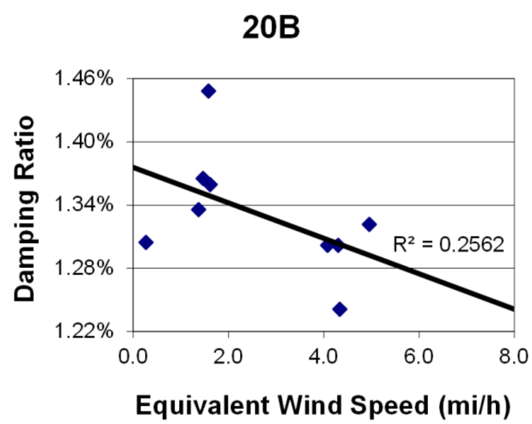
1 mi/h = 1.61 km/h

Figure 136. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 15C.



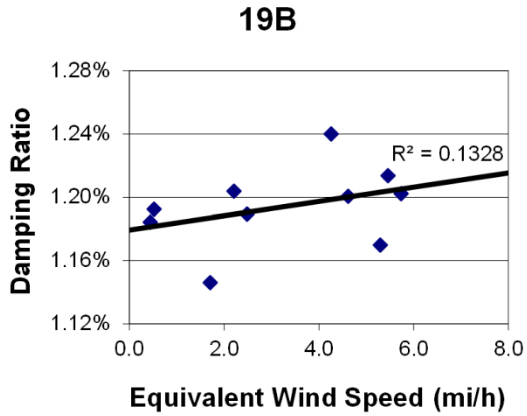
1 mi/h = 1.61 km/h

Figure 137. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 14C.



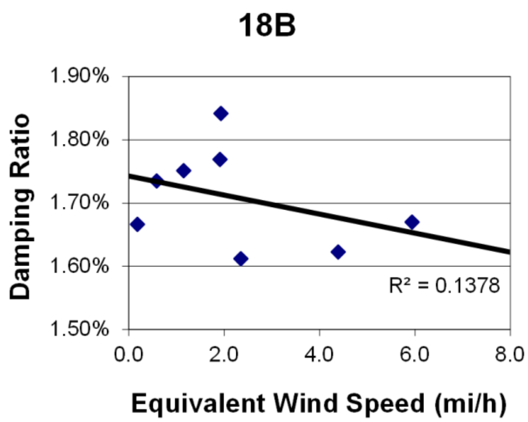
1 mi/h = 1.61 km/h

Figure 138. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 20B.



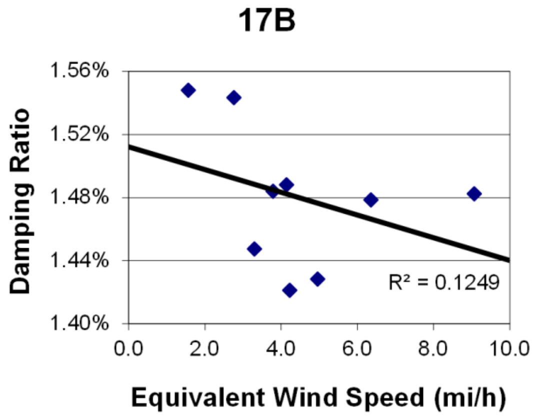
1 mi/h = 1.61 km/h

Figure 139. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 19B.



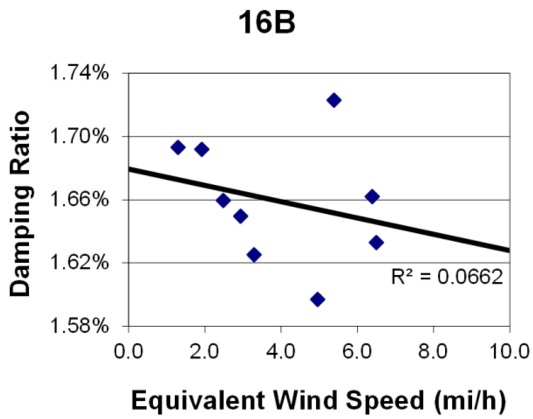
1 mi/h = 1.61 km/h

Figure 140. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 18B.



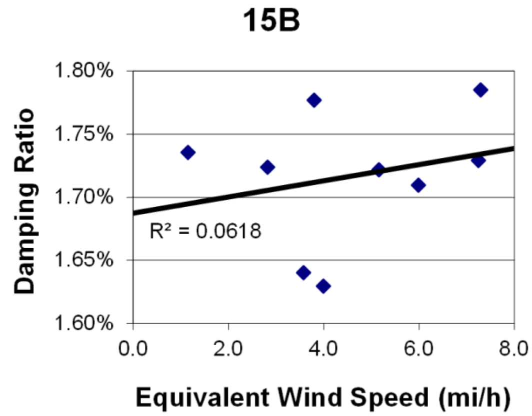
1 mi/h = 1.61 km/h

Figure 141. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 17B.



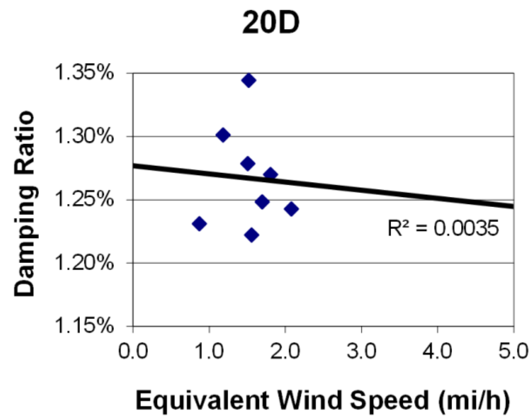
1 mi/h = 1.61 km/h

Figure 142. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 16B.



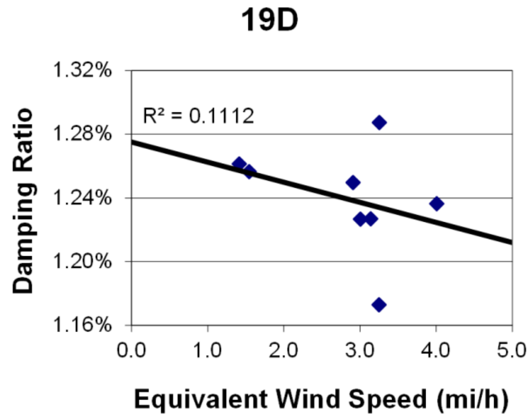
1 mi/h = 1.61 km/h

Figure 143. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 15B.



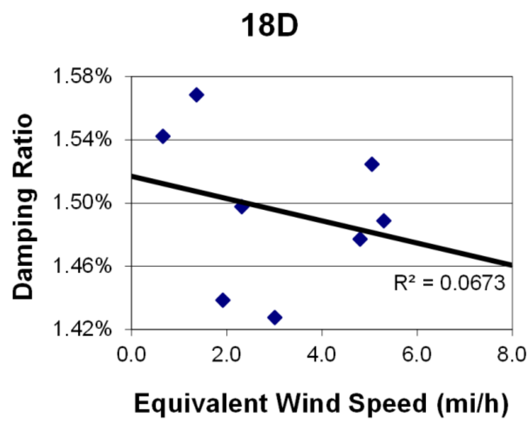
1 mi/h = 1.61 km/h

Figure 144. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 20D.



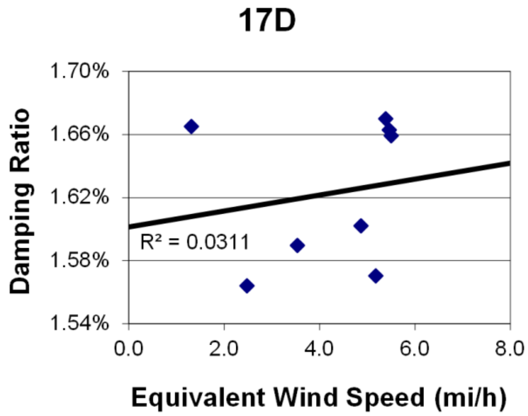
1 mi/h = 1.61 km/h

Figure 145. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 19D.



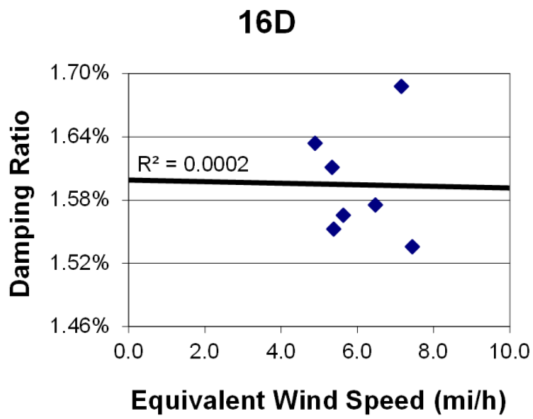
1 mi/h = 1.61 km/h

Figure 146. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 18D.



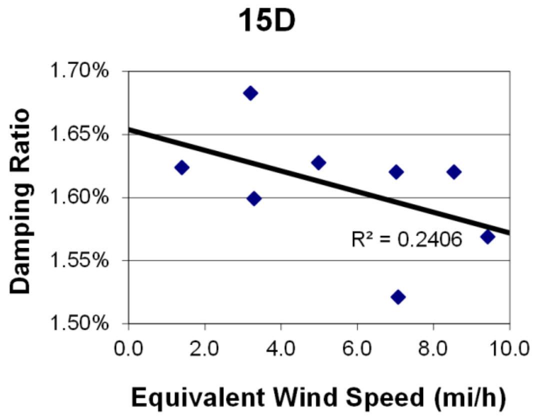
1 mi/h = 1.61 km/h

Figure 147. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 17D.



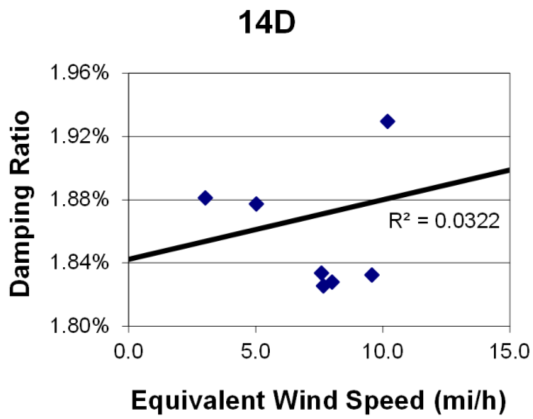
1 mi/h = 1.61 km/h

Figure 148. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 16D.



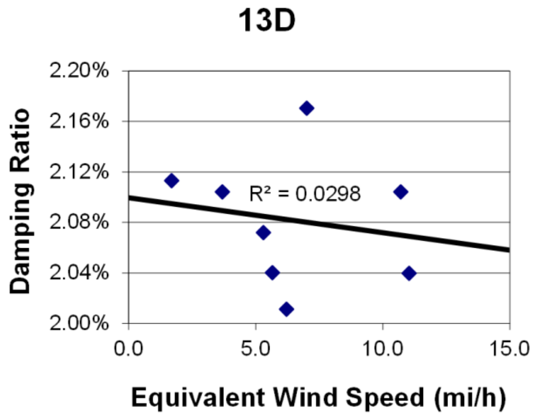
1 mi/h = 1.61 km/h

Figure 149. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 15D.



1 mi/h = 1.61 km/h

Figure 150. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 14D.



1 mi/h = 1.61 km/h

Figure 151. Graph. Phase 2, damping ratio versus decay-only equivalent wind speed for cable 13D.

APPENDIX G. CABLE PROPERTIES

Table 26. General properties of tested cables (SI units).

Cable Number	Strand Number	Unit Mass (kg/m)	Diameter (m)	Length (m)	β[1] (degree)
20A	72	106.1	0.40	157.3	27.9
19A	72	106.1	0.40	151.9	28.9
18A	72	106.1	0.40	144.1	28.4
17A	70	103.7	0.40	138.8	29.6
16A	71	104.9	0.40	131.0	29.0
15A	68	101.4	0.40	125.6	30.4
14A	70	103.7	0.40	117.8	29.8
13A	68	101.4	0.40	112.5	31.3
12A	69	102.5	0.40	104.7	30.8
20B	72	106.1	0.40	181.2	22.1
19B	72	106.1	0.40	174.4	23.0
18B	72	106.1	0.40	165.8	22.5
17B	70	103.7	0.40	159.1	23.6
16B	71	104.9	0.40	150.6	23.3
15B	68	101.4	0.40	144.0	24.4
20C	72	106.1	0.40	181.2	22.1
19C	72	106.1	0.40	174.4	23.0
18C	72	106.1	0.40	165.8	22.5
17C	70	103.7	0.40	159.1	23.6
16C	71	104.9	0.40	150.6	23.3
15C	68	101.4	0.40	144.0	24.4
14C	70	103.7	0.40	135.1	23.7
20D	72	106.1	0.40	157.4	27.9
19D	72	106.1	0.40	152.0	28.9
18D	72	106.1	0.40	144.2	28.4
17D	70	103.7	0.40	138.8	29.6
16D	71	104.9	0.40	131.0	29.0
15D	68	101.4	0.40	125.6	30.4
14D	70	103.7	0.40	117.8	29.8
13D	68	101.4	0.40	112.5	31.3

[1]The angle of the cable's inclination from the horizontal.

Table 27. General properties of tested cables (English units).

Cable Number	Strand Number	Unit Mass (slug/ft)	Diameter (ft)	Length (ft)	β[1] (degree)
20A	72	2.216	1.312	515.9	27.9
19A	72	2.216	1.312	498.3	28.9
18A	72	2.216	1.312	472.8	28.4
17A	70	2.167	1.312	455.2	29.6
16A	71	2.191	1.312	429.7	29.0
15A	68	2.118	1.312	412.1	30.4
14A	70	2.167	1.312	386.5	29.8
13A	68	2.118	1.312	369.1	31.3
12A	69	2.142	1.312	343.4	30.8
20B	72	2.216	1.312	594.3	22.1
19B	72	2.216	1.312	572.1	23.0
18B	72	2.216	1.312	543.7	22.5
17B	70	2.167	1.312	521.7	23.6
16B	71	2.191	1.312	494.1	23.3
15B	68	2.118	1.312	472.2	24.4
20C	72	2.216	1.312	594.3	22.1
19C	72	2.216	1.312	572.1	23.0
18C	72	2.216	1.312	543.7	22.5
17C	70	2.167	1.312	521.7	23.6
16C	71	2.191	1.312	494.1	23.3
15C	68	2.118	1.312	472.2	24.4
14C	70	2.167	1.312	443.0	23.7
20D	72	2.216	1.312	516.2	27.9
19D	72	2.216	1.312	498.4	28.9
18D	72	2.216	1.312	472.9	28.4
17D	70	2.167	1.312	455.2	29.6
16D	71	2.191	1.312	429.7	29.0
15D	68	2.118	1.312	412.1	30.4
14D	70	2.167	1.312	386.5	29.8
13D	68	2.118	1.312	369.1	31.3

[1]The angle of the cable’s inclination from the horizontal.

ACKNOWLEDGEMENTS

The authors would like to thank MaineDOT for providing access to the bridge construction site and support in performing this work. We would also like to thank the bridge designers, Figg Engineering Group, for providing information regarding the bridge design and cable details. Additionally, we would like to express our gratitude to the construction team, Cianbro and Reed & Reed, for their vital assistance and logistical support during testing and accommodation of our activities during bridge construction. Finally, we would like to acknowledge the creators of Generic Mapping Tools for developing the software used to generate the map of the bridge site and the contributors of OpenStreetMap for providing their road data.

REFERENCES

1. Bosch, H.R., "Rain/Wind Induced Vibration of Bridge Cables in the United States," *Proceedings of Thirty-Second USA–Japan Conference on Wind and Seismic Effects*, Gaithersburg, MD, 2000.

2. Graff, K.F., *Wave Motion in Elastic Solids*, Oxford University Press, United Kingdom, 1975.

3. Craig Jr., R., *Structural Dynamics*, John Wiley & Sons, New York, NY, 1981.

4. American Society of Civil Engineers, *Bridging to the Future of Engineering*, Press Release, March 12, 2007. Retrieved August 25, 2009 from http://www.asce.org/pressroom/news/display_press.cfm?uid=3272.

5. Milton, J., and Arnold, J., *Introduction to Probability and Statistics*, McGraw Hill, New York, NY, 2003.

6. Simiu, E., and Scanlan, R.H., *Wind Effects on Structures*, 3rd Ed., John Wiley & Sons, New York, NY, 1996.

7. Irwin, P.A., "Wind Vibrations of Cables on Cable-Stayed Bridges," *Proceedings of ASCE Structures Congress*, 1997, pp. 383–387.

8. Post-Tensioning Institute, *PTI DC45.1-12: Recommendations for Stay Cable Design, Testing, and Installation*, Sixth Edition, 2012.

9. Kumarasena, S., Jones, N.P., Irwin, P., and Taylor, P., *Wind-Induced Vibration of Stay Cables*, Report Number FHWA-HRT-05-083, Federal Highway Administration, McLean, VA, 2007.

10. Macdonald, J., "Separation of the Contributions of Aerodynamic and Structural Damping in Vibrations of Inclined Cables," *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 90, 2002, pp. 19–39.

HRDI-50/09-14(WEB)E