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IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors

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Abstract: The current methodologies, including apparatus, procedures, and measurement accuracies, for determining the dynamic characteristics of vibration dampers and damping systems are described. Some basic guidance is provided regarding a given method's strengths and weaknesses. The methodologies and procedures described are applicable to indoor testing only.
Keywords: aeolian, decay method, forced response method, inverse standing wave ratio (ISWR) method, overhead conductors, power dissipation characteristics, power method, vibration dampers

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Introduction

(This introduction is not a part of IEEE Std 664-1993, IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors.)

This guide describes current methodologies for the testing of vibration dampers in the laboratory. Included within the scope are specific descriptions of the apparatus, procedures, and measurement accuracies for the testing of vibration dampers.

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IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors

1. Scope

The purpose of this guide is to describe the current methodologies, including apparatus, procedures, and measurement accuracies, for the testing of vibration dampers. In addition, some basic guidance is also provided to inform the potential user of a given method's strengths and weaknesses (see clause 6).

Due to the variety of vibration damper designs, more than one test method may be required to obtain the necessary information on dissipation characteristics. This guide is written to describe some of the procedures for determining the dynamic characteristics of vibration dampers and damping systems. It is hoped that it will assist in the standardization of the methods included as well as result in providing a more detailed perspective in obtaining reliable information on a vibration damper's dissipation characteristics. Please note that the methodologies and procedures incorporated in this guide are applicable to indoor testing only and are in no way associated with the field testing of vibration dampers. By using the appropriate technique(s) outlined, data can be acquired that can be utilized in the application of dampers; however, this topic is considered beyond the scope of this guide. In general, it is hoped that this guide will provide an improved understanding of vibration testing procedures.

2. Definitions

2.1 decay [test] method: A test that determines the power dissipation characteristics of a damper by the measurement of the decay rate of the amplitude of motion of a span following a period of forced vibration at a natural frequency and a fixed test amplitude.

2.2 dynamics characteristics test: *See*: **forced response [test] method**.

2.3 forced response [test] method: A test that determines the power dissipation characteristics of a damper by the measurement of the force and velocity imparted to a damper that is mounted directly on the shaker.

2.4 inverse standing wave ratio [test] method: A test that determines the power dissipation characteristics of a damper by the measurement of antinodal and nodal amplitudes on the span at each tunable harmonic.

2.5 power [test] method: A test that determines the power dissipation characteristics of a damper by the measurement of the force and velocity imparted to the test span at the point of attachment to the shaker.

3. General technical considerations

The basic engineering approach to the control of vibration of overhead conductors is to compare the total power dissipation characteristics of vibration dampers and of the conductor itself to the projected wind power input to the conductor span. The wind power input can be estimated by using the techniques described in [B1], [B2], and [B5].[1] The power lost to self-damping in conventional conductors can be obtained using the methods described in IEEE Std 563-1978 [B7]. For a given conductor span at a given frequency and excitation level, the difference between the wind power input and the conductor self-damping is the amount of power that ideally should be dissipated by the vibration damper [B10].

This guide is written to quantify the power dissipation characteristics of vibration dampers by applying an appropriate laboratory test method. The four test methods provided in this guide are: Inverse Standing Wave Ratio (ISWR), Power, Decay, and Forced Response. It is understood that the methods outlined here may not be all inclusive and that the development of new methodologies is strongly encouraged. Since there is a variety of damping devices currently commercially available, the appropriateness of the method selected and the qualification/disqualification of a given product are left strictly up to the end user.

In addition, this document is intended as a guide to the practical and economical principal methods that have been usefully applied in the past, and which merit consideration by those contemplating the measurement of the dissipation characteristics of vibration dampers. A more detailed survey of previously used methods, along with a discussion of errors associated with the laboratory testing environment, can be found in [B9].

4. Test methods and procedures using a conductor test span

This clause will outline the methods and procedures for tests using a conductor span [B11], [B12]. The general apparatus described here will apply to the ISWR, Power, and Decay methods. The methodology and procedures for the Forced Response method do not require the use of a conductor test span and are provided in clause 5.

4.1 Test span arrangement and general procedures

The test span's construction should be as shown in figure 1. The shaker's placement and free span length may affect the number of measurements that can be performed on conductors. For example, it is recommended that a minimum of two loops be utilized to obtain satisfactory measurements (three loops for the ISWR method). Considering current typical test span lengths, the testing on large conductors may require a higher starting frequency than would normally be requested due to insufficient free span length. In addition, for small diameter conductors and shield wires, conditions may arise where a loop will form between the shaker and its nearest termination within the specified test frequency range. This may cause erroneous test results at these measurement points, thereby leading to discontinuity in the data. This does not nullify the entire test, but rather leaves the overall test subject to interpretation. Some recommendations for the shaker's placement to minimize some of these phenomena are provided in 4.1.3. To ensure test tension stability, testing should be performed in an area where the ambient temperature can be controlled within 1 °C.

4.1.1 Span terminations

The test span should have the capability of maintaining a constant test tension.

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[1] The numbers in brackets correspond to those in the bibliography in clause 7.

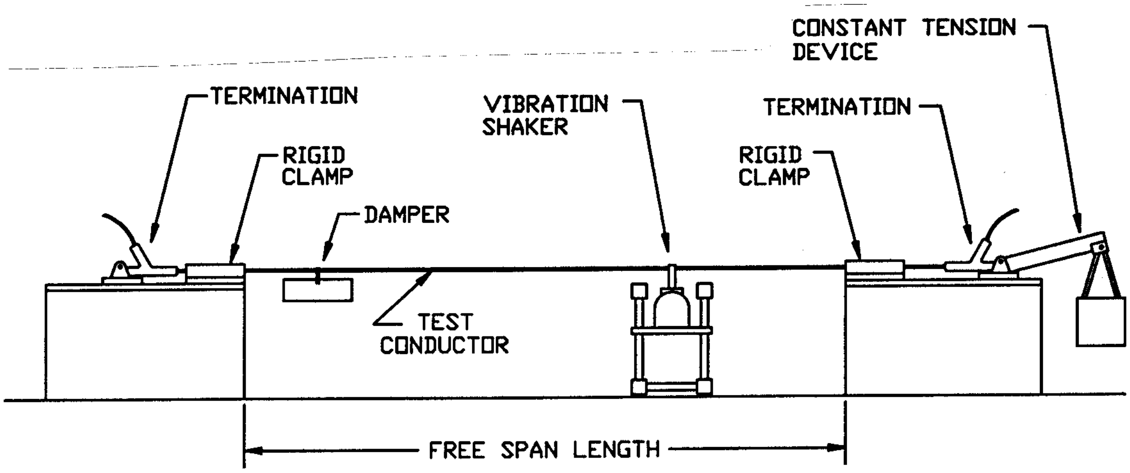


Figure 1—Basic test span layout

Hydraulic and pneumatic cylinders, springs, and pivotal balance beams have been used successfully. A rigid nonarticulating clamp similar to that shown in figure 2 should be used to minimize termination energy dissipation. Examples of typical termination designs are provided in IEEE Std 563-1978 [B7]. Terminating fixtures and rigid clamps should be of sufficient stiffness to ensure that losses do not occur beyond the test span's extremities. If there is uncertainty about this, care should be taken in assessing these energy losses, and they should be accounted for in the final results. Termination losses can be verified using the methods outlined in [B8]. The termination supports should not be used to maintain tension on the span.

4.1.2 Test conductor conditioning

All excessive looseness in the strand layers of the test conductor should be worked out. If compression end fittings are used, then they should be reverse compressed to prevent looseness from being worked back into the span. The stress of the span should be relieved by holding it at the highest tension at which the testing is to be performed for a minimum of 12 hours.

4.1.3 Shaker

The shaker utilized should be able to provide a sinusoidal force to the test span. The shaker's input range should be sufficient to induce the range of span amplitudes and frequencies required. Input amplitudes and frequencies should be controllable to an accuracy of ±2% and input frequencies should be stable within ±0.1%.

The armature of the drive unit can be connected to the test span either rigidly or by the use of a “soft” or nonrigid connection. Rigidly affixing the shaker has a tendency to create distortion in the standing wave vibration. Care should be taken when establishing span resonance to minimize this effect. The use of a “soft” connection generally reduces distortion of the loop where the shaker is attached. The location of the shaker (in reference to the span's extremity) should be chosen to facilitate the required test frequency range. For example, selecting the distance less than the span's calculated loop length at the highest test frequency will ensure that whole loops will not be forced to occur between the shaker and the nearest span extremity.

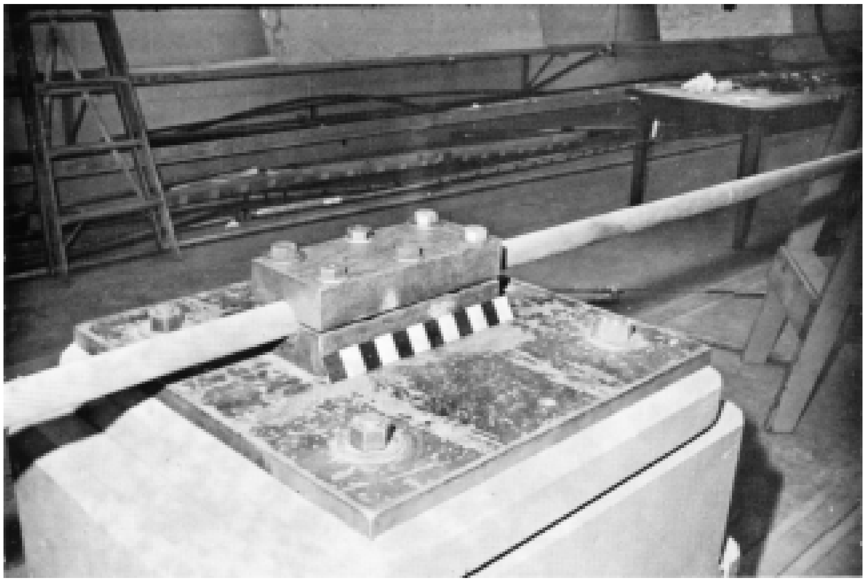


Figure 2—Typical rigid clamp

4.1.4 General test procedures

The damper being tested is to be positioned on the end of the span opposite the shaker. The placement of the damper should be at the manufacturer's recommended position unless otherwise specified. The testing of five dampers is recommended to provide a sufficient sample size for comparing results.

The tension used during testing, if not specifically required by a particular application, should be suitably chosen in order to represent normal conductor loadings. Typically, a tension level of 25% rated breaking strength (RBS) is utilized, but, this load should be governed by the objectives of the test program. It should be noted that for tensions below 25% RBS, the power dissipation characteristics of the test conductor without the test damper should be assessed at each test tension, frequency, and input velocity using the appropriate methodologies outlined in IEEE Std 563-1978 [B7]. These conductor self-damping results should be subtracted from the data acquired with the damper attached to the span to determine the true dissipation characteristics of the damper. During testing, the tension should be maintained within ±0.5% RBS. Should the tension change more than this level (i.e., due to temperature variations, etc.), the rigid clamps should be released and reattached to ensure tension stability.

Testing should be performed at a constant loop velocity of 200 mm/s at each tunable harmonic frequency. This velocity corresponds approximately to an antinodal amplitude (mm) of $67/f$ where f is the frequency of vibration. Additional testing at other loop velocities (100 mm/s, 300 mm/s, etc.) can be used to provide a good spectrum of results for the end user's evaluation. The input antinodal velocity should be maintained within ±2% of the calculated value at each test frequency. The measurement of nodal and antinodal amplitudes (when required) should be made within ±5%. The measurement of input force and velocity signals at the vibration shaker should be made within ±5% of the measured value. The measurement of the phase angle between the input force and velocity signals should be made with sufficient accuracy to ensure that the cosine of the phase angle is within ±1% of the measured value.

The frequencies used during testing should cover the spectrum corresponding to a wind velocity range of 1–7 m/s (2–15 mi/h) unless otherwise specified. It is recommended that measurements be made at each tunable frequency; however, this criterion may be modified in accordance with the results desired by the end user. A minimum of 10 test frequencies should be utilized. It should be understood that a stable condition is required for damping measurements. The natural frequencies of the span may be estimated by using the following equation:

$$f = \frac{n}{2L}\sqrt{\frac{T}{m}} \tag{1}$$

where

f is natural frequency
n is number of loops in the span
L is free span length
T is conductor tension
m is mass per unit length of the active span without dampers

Adding a damper and a shaker to the span will modify the vibration modes, and thereby change the natural frequency. However, equation (1) provides a good starting point for finding resonances.

There are two sets of resonant frequencies at which there will be the same number of whole wave loops in the span:

a) *Span resonance*. The natural frequency of the span, without the effect of shaker impedance, with all loops approximately the same length.
b) *System resonance*. The natural frequency of the span plus shaker system, in which the loop with the shaker attached is shortened, and the remaining loops in the span are proportionately longer. The natural frequency of the span plus shaker system is lower than the natural frequency of the span only.

The test method employed determines which set of resonances are to be used for testing. Either set may be used for ISWR measurements, and equally valid results should be obtained. Span resonance should be used for the power method, because the power factor (cosine of phase angle) is near unity, and normally the small force signal is not obscured by the reactive force required to move the shaker armature. However, depending upon the mass of the shaker armature, it may not be possible to attain desired test amplitudes at span resonance at the higher frequencies. The force needed to vibrate that mass, even without the span attached, may be beyond the capability of the shaker system. Span resonance should be used for the decay test only if the armature is mechanically released from the span at the start of the decay phase. If a modal shaker is used for the decay test, system resonance is appropriate because the armature is active during both the forced vibration and the decay phase of the test.

4.1.4.1 Determination of span resonance

The shaker attachment should be instrumented for force and velocity, and their relative phase angle. The frequency is tuned until the phase angle between the force and the velocity signals is stable at or near zero degrees. In practice, the force signal may be distorted, and filtering, or signal analysis equipment will be needed to obtain a valid phase measurement.

4.1.4.2 Determination of system resonance

Modal shakers, which have no suspension system and low-mass armatures, are designed to excite resonance modes with minimal distortion of the natural mode shape. In lieu of a suspension system, the armature mass is suspended from the test conductor and becomes part of the dynamic system. The shaker armature should have low-friction guide bearings to minimize damping by the shaker. If the armature mass is sufficiently low, the natural frequency of the span plus shaker armature system is very close to the span resonance. The loop with the shaker is minimally distorted. To find the system resonance, the shaker is operated at a trial power setting, and the frequency control is adjusted to provide for maximum displacement of the conductor at an antinode. Then the shaker power controls are adjusted to provide the correct loop velocity at an anti-node. Frequency is fine-tuned to maximize loop amplitude. If necessary, the shaker power is again adjusted to provide the desired loop amplitude. System resonance has been found when adjustment of the frequency control no longer results in an increase in loop velocity. Testing is performed when the standing wave is stable at the correct amplitude.

4.2 ISWR method

The ISWR method determines the power dissipation characteristics of a damper by the measurement of nodal and antinodal amplitudes on the span at each tunable harmonic [B12].

The ISWR testing procedure is as follows:

a) Establish span resonance beginning at the first tunable harmonic within the prescribed frequency range (minimum of three whole loops).
b) Locate the first free antinode and first free node from the damper within the span (see figure 3).
c) Adjust the antinodal velocity to the prescribed level (200 mm/s) and record this value and its corresponding amplitude.
d) Measure and record the nodal amplitude.
e) Measure and record the loop length and the damper clamp amplitude.
f) Proceed to the next tunable harmonic frequency.
g) Continue this procedure until the upper end of the required frequency range has been reached.
h) Repeat this procedure for all samples to be tested. Please note that if the end user chooses not to make measurements at each tunable harmonic, then all samples should be tested at the same points within the frequency spectrum.

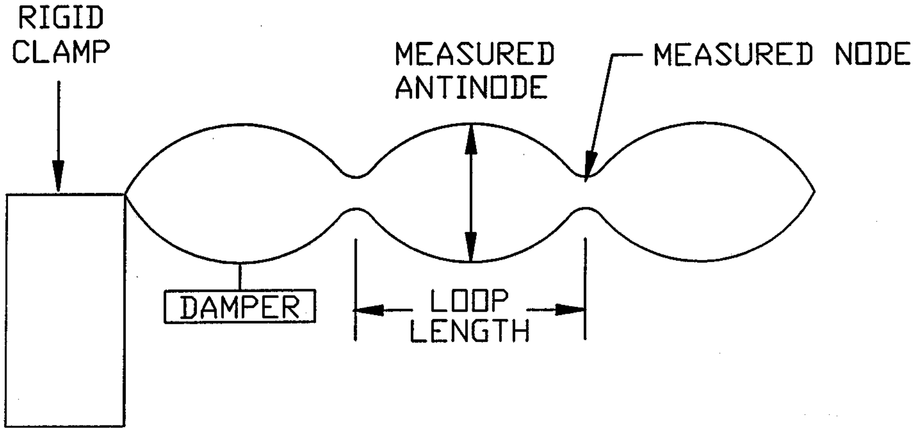


Figure 3—Location of nodal and antinodal measurements

Following the acquisition of data, the power dissipated by the damper can be calculated from the following equation:

$$P = \sqrt{Tm}\frac{V_a^2}{2}\left(\frac{a}{Y_0}\right) = ez\frac{V_a^2}{2} \tag{2}$$

where

P is power dissipated by the damper
T is conductor tension
m is mass per unit length of the span
V_a is velocity of the antinode
a is amplitude at the node
Y_0 is amplitude at the antinode
e is efficiency $\frac{a}{Y_0}$
z is characteristic impedance of the conductor $(\sqrt{Tm})$

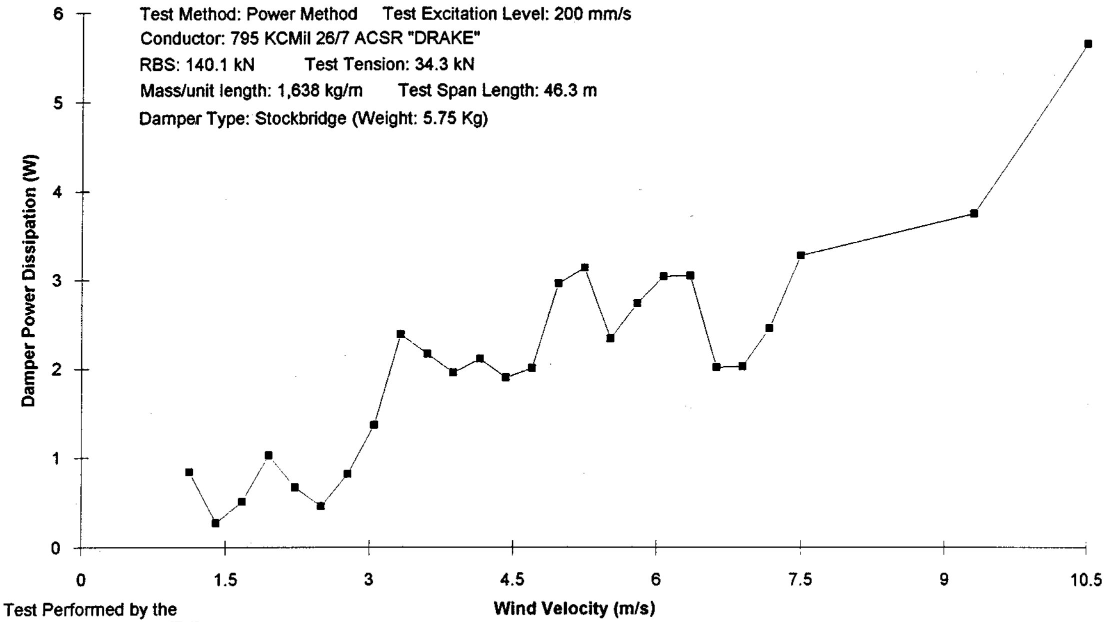
All measured end losses should be subtracted from the results to ensure the accurate determination of the damper's power dissipation. The calculated power dissipation can be plotted vs. frequency or wind velocity (see figure 4) based on the Strouhal relation [B5]:

$$f = 0.185\frac{V}{D} \tag{3}$$

where

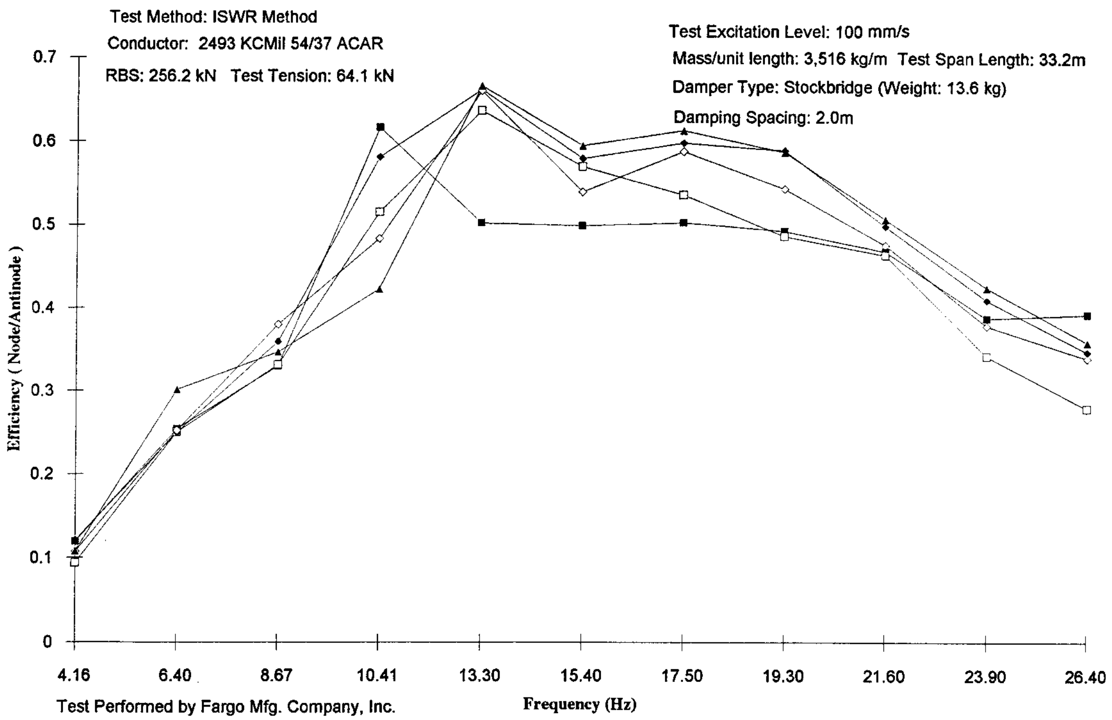
f is frequency
V is wind velocity
D is conductor diameter

In addition, the data may also be plotted as an efficiency (a/Y_0) vs. frequency (see figure 5) or wind velocity.



Test Performed by the
Politecnico di Milano [B4]

Figure 4—Example of vibration damper power dissipation vs. wind velocity



Test Performed by Fargo Mfg. Company, Inc.

Figure 5—Example of vibration damper efficiency vs. frequency

4.3 Power method

The power method determines the dissipation characteristics of a damper by the measurement of the force and velocity imparted to the test span at the point of attachment to the shaker [B3]. Due to the general nonlinear characteristics of dampers, it may not always be possible to produce a pure sinusoidal force or velocity signal at resonance. The components of the signals, other than that of the fundamental, should be filtered out. This filtering will not significantly affect the dissipation measurement, provided that the velocity signal is relatively free of distortion. If analog filtering is used, both the force and velocity signals should be filtered, and the filters should be matched for phase and gain. Alternatively, a suitable two-channel Fast Fourier Transform (FFT) analyzer may be used.

The transducers used to measure force and velocity should be checked for phase accuracy, and linearity, over the anticipated testing frequency range. The transducers should be mounted on a shaker table. A small mass, rigidly attached to the conductor clamp, should be shaken at all proposed test frequencies, and at approximately the amplitude expected during the damper test. Correct operation of the transducers is demonstrated by two criteria: (1) the phase angle between force and velocity should be at or near 90 degrees, and (2) the ratio of force to acceleration (F/A_s) should be constant at all frequencies. The acceleration may be obtained by the differentiation of the velocity signal acquired or by the use of an accelerometer. The first test verifies that there is no spurious phase shifting due to effects of fixtures, transducers, and signal conditioning. The second test verifies that force and motion transducers are linear with respect to frequency. The constant, F/A_s, is the effective mass of the test mass and associated fixtures. Corrections to damper test data may be required should phase or linearity errors cause unacceptable discrepancies in dissipation results.

The power method test procedure is as follows:

a) Establish span resonance beginning at the first tunable harmonic within the prescribed frequency range (minimum of three whole loops).
b) Locate the first free antinode within the span (see figure 3).
c) Adjust the antinodal velocity to the prescribed level (200 mm/s) and record this value.
d) Record the input force and velocity and their phase angle differential at the vibration shaker.
e) Measure and record the loop length and the damper clamp amplitude.
f) Proceed to the next tunable harmonic frequency.
g) Continue this procedure until the upper end of the required frequency range has been reached.
h) Repeat this procedure for all samples to be tested. Please note that if the end user chooses not to make measurements at each tunable harmonic, then all samples should be tested at the same points within the frequency spectrum.

Following the acquisition of data, the power dissipated by the damper can be calculated from the following equation:

$$P = \frac{1}{2}(FV_s)\mathrm{Cos}\theta_v \qquad (4)$$

where

P is power dissipated by the damper
F is force measured at the vibration shaker
V_s is velocity measured at the vibration shaker
θ_v is phase angle difference between the measured force and velocity signals

If an accelerometer is used for the data acquisition, then the power dissipated by the damper can be calculated from the following equation:

$$P = \frac{1}{4\pi f} F A_s \mathrm{Sin}\theta_a \tag{5}$$

where

f is frequency
A_s is acceleration (peak) measured at the shaker
θ_a is phase angle difference between the force and acceleration signals measured

It should be noted that in either case the phase angle may have to be corrected due to phase shifting within the transducers and signal conditioning equipment.

The calculated power can be plotted vs. wind velocity (see figure 4) or frequency.

4.4 Decay method

The decay method determines the power dissipation characteristics of a damper by the measurement of the decay rate of the amplitude of motion of a span following a period of forced vibration at a natural frequency and fixed test amplitude [B6]. Two methods have been used to terminate forced vibration of a span: (1) a fusible link to mechanically release a spring loaded clamp, and (2) a modal shaker (with a decay relay) which is left attached to the span during the decay phase. Analysis of the data is the same with either method. The conduct of the test differs in the following respects.

For fusible link release, span resonance (see 4.1.4.1) should be used to determine the test frequency. The release of the armature should not change the mode shape of the span, nor bump the span and distort the decay curve.

For a modal shaker with decay relay, system resonance (see 4.1.4.2) should be used to determine the test frequency. The mass of the armature will be active during both the forced vibration and decay phase of the test. The effect will be negligible if the armature mass is small when compared with the total mass of the vibrating span. Friction in the armature bearings will contribute to the dissipation of the system. This damping can be evaluated by repeating the decrement runs with the damper removed from the span. The decrements for the undamped span will reflect all the non-damper sources of dissipation, including friction in the shaker. These undamped decrements may be subtracted from those obtained with the damper on the span, if they show significant damping.

The decay test procedure is as follows:

a) Establish span resonance beginning at the first tunable harmonic within the prescribed frequency range.
b) Locate the instrumentation for vertical displacement measurement at an antinode within the span.
c) Adjust the antinodal velocity to be somewhat greater than the prescribed level (normally 200 mm/s). This is done to ensure that the test velocity passes through the prescribed level during the decay.
d) Record loop length, loop amplitude, and damper clamp amplitude.
e) Terminate forced vibration, and record the decay rate. An oscillographic or other waveform recorder may be used for this purpose.
f) Proceed to the next tunable harmonic frequency.
g) Continue this procedure until the upper end of the frequency range has been reached.

Following the acquisition of data, the log decrement can be calculated by the following equation:

$$\delta = \frac{1}{N}\ln\left(\frac{Y_0}{Y_n}\right) = \frac{0.69}{N_2} \tag{6}$$

where

δ is log decrement of the damping system
N is number of cycles recorded during the decay
Y_0 is amplitude at the antinode before the release of the vibration generator
Y_n is amplitude at the antinode after "n" cycles have been recorded
N_2 is number of cycles required to reach one-half of the initial antinodal amplitude

The power dissipated by the damper can be estimated using the log decrement by the following equation:

$$P = \frac{1}{2} f m V_a^2 L \delta \tag{7}$$

where

P is power dissipated by the damper
m is mass per unit length of the span
V_a is maximum loop velocity at the initial antinode amplitude
f is frequency of excitation
δ is log decrement
L is span length

It should be understood that the equations above treat the span as a single-degree-of-freedom system. It is actually a continuous system. Consequently, the decrements obtained in the tests have a step structure, rather than a smooth exponential decay. Immediately following the termination of forced vibration, all loops in the span have the same amplitude, except the damper loop. The first step in the decay curve is due to energy dissipated by the damper as each of the waves at initial amplitude travels down the span and is attenuated by the damper. Each of the attenuated waves is reflected back into the span by the span terminations. The second step is due to the further attenuation of the waves as they pass the damper a second time. The time between steps is, therefore, equal to the travel time of a wave up and down the test span. The number of cycles in each step is approximately equal to the number of loops in the active span.

The power being transmitted by the waves in each step can be calculated from the loop velocity from the following equation:

$$P = \sqrt{Tm}\frac{V_a^2}{2} \tag{8}$$

The difference in P, between successive steps, is the power being dissipated by the damper at a loop velocity equal to the average of the loop velocities for the two steps. This is equivalent to setting efficiency (a/Y_0) in equation (2), equal to (A–B)/(A+B), where A and B are the loop amplitudes of successive steps. The power dissipation can be plotted vs. frequency or wind velocity (see figure 4).

5. Forced response method

The forced response method (also known as the dynamics characteristics test) determines the power dissipation characteristics of a damper by the measurement of the force and velocity imparted to a damper that is mounted directly on the shaker [B11].

5.1 Apparatus and accuracy

The forced response method requires a shaker with a sweep generator and compressor control module to provide a constant velocity output across the required frequency spectrum. The shaker should be able to control the output velocity of the shaker's armature to within ±2% of the value selected. The measurement of the force and velocity signals should be made within ±2% of the measured value. The measurement of the phase angle between the force and velocity signals should be made with sufficient accuracy to ensure that the cosine of the phase angle is within ±1% of the measured value. Special attention may be required to ensure that phase shifting by the transducers and the signal conditioning electronics does not occur. Since both the force and velocity signals vary with time, it is imperative that the appropriate instrumentation be present to measure the signals at the same instant. During testing, the damper should be clamped to a rigid round bar (whose diameter lies within the damper's clamping range) that is rigidly mounted to the shaker table. Ideally, the damper should be positioned to represent its normal field installation; however, an inverted position may be used if the accuracy of the test results is not affected by this change in orientation. A sufficient sample size of dampers should be used for comparing results.

5.2 Test procedure

The forced response test procedure is as follows:

a) Calibrate the test apparatus using a fixed mass. This will allow power dissipated due to the damping effects of the fixtures and load cells to be determined so that it can be subtracted from the power obtained during the testing of the damper. Amounts ≥ 2% of the values recorded are considered significant.

b) Mount the damper and sweep through the prescribed frequency range corresponding to the wind velocity spectrum of 1–7 m/s (2–15 mi/h). An input velocity at the damper clamp of 100 mm/s is recommended; this value should be kept constant through the prescribed frequency range. Additional testing at other loop velocities (200 mm/s, 300 mm/s, etc.) can be used to provide a good spectrum of results for the end user's evaluation. An appropriate sweep rate should be established to ensure that the vibration of the damper reaches a quasi-static state where the damper's response is not distorted by the sweep rate. The upper and lower frequency limits should be calculated by using the diameter of a conductor that is representative of the damper's application.

c) Measure and record the fundamental velocity and force, and their relative phase angle difference along the entire frequency spectrum.

d) Repeat the procedure for all samples to be tested.

Following the acquisition of data, the power dissipated can be calculated by equation (4). The use of an accelerometer in lieu of a velocity transducer will allow equation (5) to be utilized for the power dissipation calculation. The use of a computer-controlled data acquisition system in the calculation of the continuous spectrum of data may be beneficial. The calculated power dissipation can be plotted vs. frequency (see figure 6).

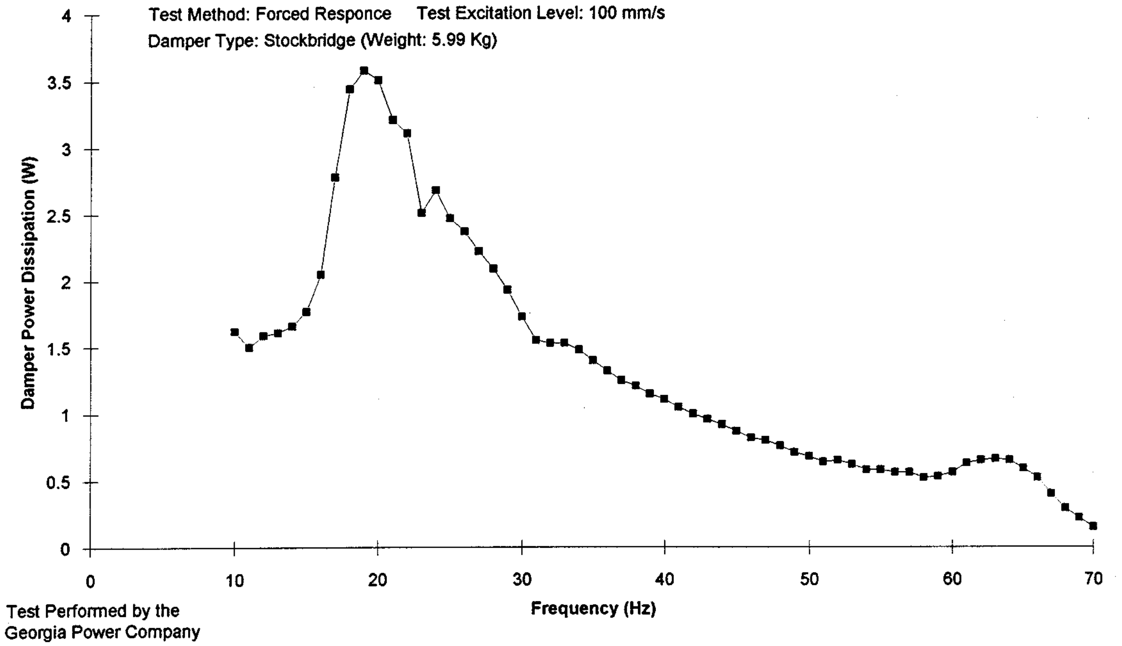


Figure 6—Example of vibration damper power dissipation vs. frequency

6. Reporting and procedural recommendations

The reporting of test results should be as complete as possible to aid in test repeatability. Table 1 is an example of a typical table of results. Additional information such as test span description, measurement apparatus utilized, method(s) and specific testing procedures that were implemented, ambient temperature during testing, and a description of the items tested (and, if applicable, their placement) should be reported to facilitate test repeatability.

The choice of which method to apply with respect to the dampers to be tested is left up to the end user to decide. In general, each of the four methods described contains obvious pros and cons. A comparative summary of some general characteristics of each of the methods is given in table 2.

Although widely accepted, the ISWR and power methods are considered costly to equip and tedious to perform. In addition, these two, as well as the decay method, provide only a series of finite data points. As a result, valuable data about a damper may be missed which may otherwise be relevant to the device's end application. The decay method is intuitively easy to understand, relatively easy to perform, and requires minimal instrumentation. Comparison of decay curves is a quick way to obtain a relative comparison among dampers. The decay test has good accuracy and resolution when damping is low. The method has low resolution with a heavily damped span, because only a few vibration cycles are required to dissipate the energy in the span. It should be noted that both the power method and the ISWR method suffer reduced accuracy when damping is low; therefore, the decay test can be an excellent complement to these methods.

Table 1—Sample test results—Vibration damper power dissipation

Test method: power method

Test excitation level: V_s = 200 mm/s

Conductor 795 kcmil 26/7 ACSR "DRAKE"

RBS: 140.1 kN

Mass/unit length: 1.638 kg/m

Conductor test tension: 34.3 kN

Test span length: 46.3 m

Damper type: Stockbridge (weight: 5.75 kg)

Damper spacing: 0.8 m

Frequency (Hz)	Loop length (m)	Y_0 (mm)	Y_0/D	Damper power dissipation (W)
7.94	18.64	8.35	0.29	0.84
9.58	15.46	6.61	0.23	0.27
11.14	13.30	6.18	0.22	0.51
12.79	11.59	5.70	0.20	1.03
14.42	10.29	4.20	0.14	0.67
15.89	9.35	4.14	0.14	0.46
18.03	8.25	3.59	0.12	0.82
19.23	7.74	3.29	0.11	1.37
22.92	6.51	3.19	0.11	2.39
24.53	6.10	2.61	0.09	2.17
26.13	5.73	2.19	0.07	1.96
27.72	5.41	2.33	0.08	2.11
29.33	5.12	2.11	0.07	1.90
30.72	4.90	2.03	0.07	2.01
35.84	4.23	1.87	0.06	2.96
37.29	4.07	1.76	0.06	3.14
39.09	3.89	1.62	0.05	2.34
40.62	3.75	1.60	0.05	2.74
42.22	3.62	1.56	0.05	3.04
44.19	3.47	1.62	0.05	3.05
45.61	3.34	1.48	0.05	2.02
47.60	3.23	1.31	0.04	2.03
49.25	3.13	1.25	0.04	2.46
51.08	3.03	1.26	0.04	3.28
62.77	2.52	1.00	0.03	3.75
68.82	2.32	0.97	0.03	5.66

Extracted from Diana, G., Falco, M., Curami, A., and Maneni, A., "A method to define the efficiency of damping devices for single and bundled conductors of EHV and UHV lines," *IEEE Transactions on Power Delivery*, vol. PWRD–2, no. 2, pp. 464–476, Apr. 1987 [B4].

Table 2—Comparison of laboratory methods

General characteristics	ISWR	Power	Decay	Forced response
Test span required	Yes	Yes	Yes	No
Continuous or discrete test frequencies	Discrete	Discrete	Discrete	Continuous
Damper types that can be tested	All	All	All	*
Testing time per sample	8 h	4 h	4 h	30 min
Main advantage	Avoids some waveform problems	Straightforward data collection and analysis	Provides a wide range of testing amplitudes	Rapid data collection and continuous frequency data
Main disadvantage	Difficult to measure amplitudes	Possible errors due to end losses	Measurement difficulty with high levels of damping (and possible errors due to end losses)	Does not measure conductor interactions

*The forced response method is not applicable to dampers such as the Bretelle, torsional, Festoon or helical/tube impact-type dampers as defined in [B5].

The forced response method is relatively inexpensive to equip, is easy to apply, and provides the ability to obtain a continuous frequency spectrum of data. However, such tests are performed without regard to the damper’s interaction with the conductor. Thus, any damping that results from such interaction is not measured. Also, one may measure damping requiring force levels that the conductor is unable to produce in the field. Therefore the proper matching of a damper and a conductor is not evaluated. The results acquired are useful if they are comparable to those of a damper properly matched with the conductor under study.

There are still areas of disagreement between researchers regarding the acceptability of any one test method for all types of dampers. Therefore, further research into this area could provide a significant contribution to the application of indoor testing in the evaluation of aeolian vibration dampers.

7. Bibliography

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Annex
List of symbols

(informative)

(This informative annex is not a part of IEEE Std 664-1993, IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors, but is included for information only.)

Symbol	**Unit of Measurement**
a is amplitude at a node (peak to peak)	mm
A_s is acceleration at the shaker (peak)	m/s^2
D is conductor diameter	m
e is efficiency	dimensionless
F is excitation force at the shaker (peak)	N
f is frequency	Hz
L is free span length (between last virtual nodes)	m
m is mass per unit length	kg/m
n is number of loops	dimensionless
N is number of cycles	dimensionless
N_2 is number of cycles to reach one-half of initial amplitude	dimensionless
P is power dissipation	W
T is conductor tension	N
V is wind velocity	m/s
V_a is velocity at antinode (peak)	m/s
V_s is velocity at the shaker (peak)	m/s
Y_0 is amplitude at antinode (peak to peak)	mm
Y_N is amplitude at antinode after “N” cycles (peak to peak)	mm
z is characteristic impedance of the conductor	N·s/m
θ_v is phase angle between excitation force and velocity at the shaker	degrees
θ_a is phase angle between excitation force and acceleration at the shaker	degrees
δ is log decrement	dimensionless
RBS is rated breaking strength	N