INCH-POUND

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DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

MECHANICAL VIBRATIONS OF SHIPBOARD EQUIPMENT (TYPE I – ENVIRONMENTAL AND TYPE II – INTERNALLY EXCITED)

AMSC 7651 AREA ENVR

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FOREWORD

1. This standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. This standard establishes requirements and acceptance criteria for:

a. Environmental vibration testing of shipboard equipment.

b. Balancing shipboard rotating equipment subjected to internally induced vibration during operation.

3. Shipboard equipment that conforms to the requirements of MIL-STD-167-1A is found to satisfactorily perform its functions aboard ship. Equipment for which compliance with MIL-STD-167-1A is not specified or is waived could experience failures induced by vibration in shipboard service.

4. MIL-STD-167-1A, environmental vibration testing, and MIL-S-901D, equipment shock testing, provide complementary requirements for the survivability of shipboard equipment.

5. This specification was revised to address the following:

a. Requirements for test instrumentation and testing machines.

b. Guidance in the selection of response prominences for endurance testing.

c. Revisions to requirements for applicable frequency ranges.

d. Revisions to attachment methods for equipment.

e. Updated for conformance with MIL-STD-962D, "Defense Standards Format and Content".

6. Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05Q, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to commandstandards@navsea.navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

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1. SCOPE

1.1 Scope. This standard specifies procedures and establishes requirements for environmental and internally excited vibration testing of Naval shipboard equipment installed on ships with conventionally shafted propulsion (see 6.1.e and 6.1.f).

1.2 Applicability. The test methods specified herein are applicable to shipboard equipment subjected to mechanical vibrations from the environment and from internal excitation caused by unbalanced rotating components of Naval shipboard equipment. For those mechanical vibrations associated with reciprocating machinery and lateral and longitudinal vibrations of propulsion system and shafting, see MIL-STD-167-2.

1.3 Classification. The following types of vibration are covered in this standard:

Type I - Environmental vibration

Type II - Internally excited vibration

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-M-17191	-	Mounts, Resilient: Portsmouth Bonded Spool Type
MIL-M-17508	-	Mounts, Resilient: Types 6E100, 6E150, 7E450, 6E900, 6E2000, 5E3500, 6E100BB, 6E150BB, 7E450BB, and 6E900BB
MIL-M-19379	-	Mounts, Resilient, Mare Island Types 11M15, 11M25, and 10M50
MIL-M-19863	-	Mount, Resilient: Type 5B5, 000H
MIL-M-21649	-	Mount, Resilient, Type 5M10, 000-H
MIL-M-24476	-	Mounts, Resilient: Pipe Support, Types 7M50, 6M150, 6M450, 6M900, and 5M3500

(Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or http://assist.daps.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acceptance authority. As used in this standard, the term "acceptance authority" means the government activity (or its designated representative) having approval authority to determine vendor compliance with the requirements of this standard.

3.2 Amplitude, single. See amplitude, vibratory displacement.

3.3 Amplitude, vibratory displacement. Vibratory displacement amplitude is the maximum displacement of simple linear harmonic motion from the position of rest. This is also referred to as single amplitude. It is expressed in inches, mils (0.001 inch), or mm (0.001 meter).

3.4 Balancing. Balancing is a procedure by which the radial mass distribution of a rotor is adjusted so that the mass centerline approaches the geometric centerline of the rotor, and, if necessary, adjusted in order to ensure that the vibration of the journals and/or forces on the bearings, at a frequency corresponding to operational speed, are within specified limits.

3.4.1 Balancing, multi-plane. Multi-plane balancing refers to any balancing procedure that requires unbalance correction in more than two axially separated correction planes.

3.4.2 Balancing, single-plane (static). Single-plane (static) balancing is a procedure by which the mass distribution of a rigid rotor is adjusted in order to ensure that the residual static unbalance is within specified limits and which requires correction in only one plane. (Note: Single-plane balancing can be done on a pair of knife edges without rotation of the rotor but is now more usually done on centrifugal balancing machines.)

3.4.3 Balancing, two-plane (dynamic). Two-plane (dynamic) balancing is a procedure by which the mass distribution of a rigid rotor is adjusted in order to ensure that the residual unbalance in two specified planes is within specified limits.

3.5 Critical speed. Critical speed is the speed of a rotating system that corresponds to a natural frequency of the system.

3.6 Environmental vibration. Environmental vibration is vibratory force, which is imposed on equipment installed aboard ships, caused by the hydrodynamic forces on the propeller blades interacting with the hull and by other sources.

3.7 Equipment. Equipment is any machine, subsystem, or part thereof, which is intended to be installed aboard ship.

3.8 Grade, balance quality. Balance quality grade, G, refers to the amount of permissible unbalance of a rotor. The balance quality grade is the product of the maximum permissible eccentricity (distance between the shaft axis and the rotor center of gravity (in mm)) and the rotational velocity (radians/sec). The units for balance quality grade, G, are mm/sec. By this definition, a particular grade rotor will be allowed a mass eccentricity ($e=G/\omega$), which is inversely proportional to the operating speed.

3.9 Internally excited vibration. Internally excited vibration is vibration of machinery generated by mass unbalance of a rotor.

3.10 Isolation mount. An isolation mount is a device used to attenuate the force transmitted from the equipment to its foundation.

3.11 Mass unbalance. Mass unbalance occurs when the mass centerline does not coincide with the geometric centerline of a rotor.

3.12 Maximum design rpm. Maximum design rpm is the highest shaft rpm for which the ship is designed.

3.13 Method of correction. A method of correction is a procedure whereby the mass distribution of a rotor is adjusted to reduce unbalance, or vibration due to unbalance, to an acceptable value. Corrections are usually made by adding material to, or removing it from, the rotor.

3.14 Mode. Mode is the manner or pattern of vibration at a natural frequency and is described by its natural frequency and relative amplitude curve.

3.15 Plane, correction. A correction plane is a plane transverse to the shaft axis of a rotor in which correction for unbalance is made.

3.16 Plane, measuring. A measuring plane is a plane transverse to the shaft axis in which the amount and angle of unbalance is determined.

3.17 Residual unbalance. Residual unbalance is unbalance of any kind that remains after balancing.

3.18 Resonance. Resonance is the magnification of structural response, which occurs when a linear lightly damped system is driven with a sinusoidal input at its natural frequency. Resonances are the cause of many, but not all, response prominences.

3.19 Response prominence. Response prominence is a general term denoting a resonance or other distinct maximum, regardless of magnitude, in a transmissibility function, including local maxima which may exist at the frequency endpoints of the transmissibility function. Typically, a response prominence is identified by the frequency of its maximum response, which is the response prominence frequency. A response prominence of a system in forced oscillation exists when any change, for both plus and minus increments however small, in the frequency of excitation results in a decrease of the system response at the observing sensor registering the maximum. A response prominence may occur in an internal part of the equipment, with little or no outward manifestation at the vibration measurement point, and in some cases, the response may be detected by observing some other type of output function of the equipment, such as voltage, current, or any other measurable physical parameter. Instruction on how to identify response prominences is provided in Appendix A.

3.20 Rotor, flexible. A flexible rotor is one that does not meet the criteria for a rigid rotor. The unbalance of a flexible rotor changes with speed. Any value of unbalance assigned to a flexible rotor must be at a particular speed. The balancing of flexible rotors requires correction in more than two planes.

3.21 Rotor, rigid. A rotor is considered to be rigid when its unbalance can be corrected in any two arbitrarily selected planes. After correction, its residual unbalance does not exceed the allowed tolerance, relative to the shaft axis, at any speed up to the maximum service speed and when running under conditions which approximate closely to those of the final supporting system.

3.22 Simple harmonic motion. A simple harmonic motion is a motion such that the displacement is a sinusoidal function of time.

3.23 Test fixture resonance. A test fixture resonance is any enhancement of the response of the test fixture to a periodic driving force when the driving frequency is equal to a natural frequency of the test fixture.

3.24 Transmissibility. Transmissibility is the non-dimensional ratio of the response amplitude in steady-state forced vibration to the excitation amplitude. The ratio may be one of forces, displacements, velocities, or accelerations. Transmissibility is displayed in a linear-linear plot of transmissibility as a function of frequency, or in tabular form. Instructions for determining and displaying transmissibility are given in A.2.1 of Appendix A.

4. GENERAL REQUIREMENTS

4.1 Notification of tests. When specified (see 6.2.b), notification of Type I or Type II testing shall be made in accordance with DI-MISC-81624 (see 6.3).

4.2 Identification of component compliance. When specified (see 6.2.c), the information verifying that the component complies with Type I and Type II testing shall be identified on the component drawing, the Test Report (DI-ENVR-81647) (see 6.3), or an identification plate attached to the component.

4.3 Disposition of tested equipment. The requirements for tested equipment, fixturing, associated test records, and other documentation shall be as specified (see 6.2.d).

5. DETAILED REQUIREMENTS

5.1 Type I – environmental vibration. When Type I vibration requirements are specified (see 6.2.e), the equipment shall be subjected to a simulated environmental vibration as may be encountered aboard naval ships. This standard provides an amplitude sufficiently large within the selected frequency range to obtain a reasonably high degree of confidence that equipment will not malfunction during service operation.

a. For Type I vibration testing, this standard shall be used for equipment subjected to the vibration environment found on Navy ships with conventionally shafted propeller propulsion. Type I vibration testing shall not be applicable to high-speed or surface-effect ships that are subject to vibrations from high-speed wave slap, which produce vibration amplitudes and frequencies in excess of the levels on conventional Navy ships.

b. This standard applies to Type I vibration testing for equipment used in Navy ships with conventionally shafted propeller propulsion, and is not necessarily applicable to waterjet, podded, or other propulsor types, including those that have been designed to minimize blade-rate forces.

c. For equipment installed on ships with propulsion systems with frequency ranges not covered by Table I, this standard shall not apply.

5.1.1 Basis of acceptability. For equipment that can be vibration tested, acceptability shall be contingent upon the ability of the equipment to withstand tests specified in 5.1.2 and the ability to perform its principal functions during and after vibration tests. Minor damage or distortion will be permitted during the test providing such damage or distortion does not in any way impair the ability of the equipment to perform its principal functions (see 6.2.f(1) and 6.2.f(6)). Because of the numerous types of equipment covered by this standard, a definite demarcation between major and minor failures cannot be specified. Therefore, during testing a determination shall be made whether a failure is minor or major to determine whether testing should continue (see 6.2.f(2)). In general, a major failure is one that would cause maloperation or malfunction of the item of equipment for a long period. Non-repetitive failures of such parts as connectors, knobs/buttons, certain fasteners, and wiring, which can be easily replaced or repaired, are generally considered minor failures. As such, the repair could be made and the test continued with no penalty to the remainder of the equipment. The critical use of the equipment shall be considered when determining the category of failure; that is, a failure of a part in a lighting circuit may be considered minor. The same failure in a control circuit may be major.

5.1.2 Test procedures. The tests specified herein are intended to expose equipment to:

a. Vibration magnitudes in prescribed frequency and amplitude ranges to reveal any critical response prominences (see 3.19) or potential deficiencies.

b. A 2-hour minimum endurance test at the response prominence frequency or frequencies most seriously affecting its functional and/or structural integrity.

5.1.2.1 Testing machine. Vibration tests shall be made by means of any testing machine capable of meeting the conditions specified in 5.1.2.4, and the additional requirements contained herein. Means shall be provided for controlling the direction of vibration of the testing machine and for adjusting and measuring its frequencies and amplitude of vibration to keep them within prescribed limits. It is acceptable to utilize different machines for the vertical and horizontal directions. The testing machine, including table, actuator, and attachment fixtures, shall be rigid within the frequency range to be tested. This includes test fixture resonances that may result from interaction between the table and mounted equipment. Testing machine rigidity shall be demonstrated by analysis or by measuring transmissibility in accordance with 5.1.2.2.d.

5.1.2.2 Additional test instrumentation. Vibration measurement transducers, such as accelerometers, shall be installed on the test equipment to aid in the determination of response prominences during the exploratory and variable frequency vibration tests of 5.1.2.4.2 and 5.1.2.4.3. The number, orientation, and placement of vibration transducers will depend upon the equipment under test and should be sufficient to provide a suitable survey for identifying response prominences of the tested equipment and testing machine. When required, approval of transducer locations shall be obtained from the procuring activity (see 6.2.f(3)). Guidance below shall be used in selection of measurement locations:

a. Measurements shall be made at locations corresponding to components or areas on the equipment of particular concern for operation of the equipment, whose failure would impair the ability of the equipment to perform its principal function. Such locations shall be determined prior to test.

b. A sufficient number of measurement locations should be selected such that the response of the equipment is measured at locations near the base, top, and center of the equipment to measure response prominences associated with global motion of the equipment. These transducers should be attached to rigid areas of the equipment representing major structural components such as the housing, shell, or body of the equipment.

c. The transducers shall be oriented to measure vibration in the direction of the vibration excitation provided for any given test. Transducers may be re-oriented between tests to accomplish this.

d. If the testing machine rigidity has not been demonstrated by analysis, a sufficient number of transducers shall be located on the testing machine to demonstrate that the testing machine is rigid over the frequency range of the test. At a minimum, these transducers should be located at the point of force application to the table and at the equipment attachment interface(s) to the testing machine.

5.1.2.3 <u>Methods of attachment</u>.

5.1.2.3.1 <u>Shipboard equipment</u>. For all tests, the equipment shall be secured to the testing machine at the same points or areas of attachment that it will be secured shipboard. In case alternate attachment points or areas are specified, tests shall be performed using each attachment configuration. Equipment that is hard mounted (i.e., not isolation mounted) aboard ship shall be hard mounted to the testing machine. For equipment designed to be secured to a deck and a head brace support, a vertical bracket shall be used to simulate a bulkhead. The bracket shall be sufficiently rigid to ensure that its motion will be essentially the same as the motion of the platform on the testing machine. For isolation mounted shipboard equipment, see 5.1.2.3.4.

5.1.2.3.2 <u>Shipboard portable and test equipment</u>. Portable and test equipment that is designed for permanent or semi-permanent attachment to ship structure shall be attached to the vibration testing machines in the same manner it is attached to the ship. Equipment that is not designed for permanent or semi-permanent attachment shall be secured to the testing machine by suitable means.

5.1.2.3.3 <u>Orientation for vibration test</u>. Equipment shall be installed on vibration testing machines in such a manner that the direction of vibration will be in turn along each of the three rectilinear orientation axes of the equipment as installed on shipboard – vertical, athwartship, and fore and aft. On a horizontal vibration-testing machine, the equipment may be turned 90 degrees in the horizontal plane in order to vibrate it in each of the two horizontal orientations. At no time shall the equipment be installed in any other way than its normal shipboard orientation.

5.1.2.3.4 <u>Isolation mountings</u>. For Type I testing of equipment to be installed shipboard on isolation mounts, the testing shall be performed on isolation mounts or hard mounted to the testing machine or as specified (see 6.2.f(4)). Type I testing of a particular piece of equipment on isolation mounts is valid only for the isolation mount type and configuration used during testing. Type I vibration testing may be performed hard mounted at some frequencies and isolation mounted at others. For example, the isolation mounts can be removed during the variable frequency and/or the endurance test at resilient mount resonance frequencies determined during the exploratory test, and the equipment can be tested hard mounted at these frequencies. If equipment is tested for Type I vibrations hard mounted to the test fixture throughout the duration of the test, the test is valid for either hard mounted or isolation mounted shipboard installations provided the isolation mounts are Navy standard mounts contained in MIL-M-17191, MIL-M-17508, MIL-M-19379, MIL-M-19863, MIL-M-21649, MIL-M-24476 (see 2.2.1), or distributed isolation material (DIM).

5.1.2.3.5 <u>Internal isolation or shock mountings</u>. Equipment that incorporates other isolation mountings integrally within the equipment box (such as electronic cabinets) shall be tested with the internal mountings in the normal shipboard configuration or as specified (see 6.2.f(5)).

5.1.2.4 <u>Vibration tests</u>. Each of the tests specified herein shall be conducted separately in each of the three principal directions of vibration. All tests in one direction shall be completed before proceeding to tests in another direction. The equipment shall be secured to the vibration table as specified in 5.1.2.3. If major damage (see 5.1.1) occurs, the test shall be discontinued and the entire test shall be repeated following repairs or correction of deficiencies.

5.1.2.4.1 Equipment operation. Except as noted below, equipment shall be energized or operated to perform its normal functions (see 6.2.f(6)). Equipment that is difficult to operate on the testing machine shall be energized and subjected to operating conditions during the test. The equipment shall then be operated after the test to demonstrate that there is no damage from the test (see 6.2.f(1)).

5.1.2.4.2 Exploratory vibration test. To determine the presence of response prominences (see 3.19) in the equipment under test, the equipment shall be secured to the vibration table and vibrated at frequencies from 4 Hz to 33 Hz, at a table vibratory single amplitude of 0.010 ± 0.002 inch (see 5.1.2.4.4 and 5.1.2.4.5 for exceptions). The change in frequency shall be made in discrete frequency intervals of 1 Hz and maintained at each frequency for about 15 seconds. Alternately, a continuous frequency sweep with a rate of change of frequency not to exceed 0.067 Hz/second can be used. The frequencies at which functional or structural requirements are affected or violated and frequencies and locations at which response prominences occur shall be recorded, and these frequencies (rounded to the nearest integer frequency if discrete frequency intervals were not used) shall be considered as candidates for endurance testing (see Appendix A).

5.1.2.4.3 Variable frequency test. The equipment shall be vibrated from 4 Hz to 33 Hz in discrete frequency intervals of 1 Hz at the amplitudes shown in Table I (see 5.1.2.4.4 and 5.1.2.4.5 for exceptions). At each integral frequency, the vibration shall be maintained for 5 minutes. The frequencies at which functional or structural requirements are affected or violated and frequencies and locations at which response prominences occur shall be recorded. Note that because of increased amplitudes compared to those mandated by 5.1.2.4.2, response prominences and effects on or violations of functional or structural requirements may show up in this test that were not uncovered in the exploratory vibration test. Therefore, the frequencies at which these response prominences and effects on or violations of functional or structural requirements occur shall also be considered as candidates for endurance testing (see Appendix A).

5.1.2.4.4 Exception. Equipment intended for installation solely on a particular ship class need only be vibrated in the exploratory and variable frequency tests from 4 Hz to (1.15 x maximum design rpm x number of propeller blades/60) rounded up to the nearest integer frequency or the maximum test frequency as specified (see 6.2.f(7)).

5.1.2.4.5 Alternative test amplitudes. For equipment installed on ships with advanced isolation systems or low vibration propellers, alternative test amplitudes from Table I shall be used when specified (see 6.2.f(8)).

5.1.2.4.6 Endurance test. Endurance test frequencies are selected from the candidate list of endurance test frequencies developed during exploratory and variable frequency testing (see 5.1.2.4.2 and 5.1.2.4.3). When specified (see 6.2.f(9)), selection of these frequencies is subject to approval. The equipment shall be vibrated for a total period of at least 2 hours at the frequency determined to most seriously affect the functional or structural integrity of the equipment. Guidance for selecting response prominences from exploratory or variable frequency testing, for determining whether a response prominence is significant, and if the more serious response prominences can be identified, is given in Appendix A. In cases where there are multiple response prominence frequencies selected, the duration of vibration testing at each frequency shall be in accordance with Table II. If neither response prominences nor effects on equipment structural/functional performance are observed, this test shall be performed at 33 Hz or at the upper frequency as specified in 5.1.2.4.4. The amplitudes of vibration shall be in accordance with Table I, unless otherwise specified (see 5.1.2.4.5). See Figure 1 for a graphical representation of the amplitudes in Table I.

TABLE I. Vibratory displacement of environmental vibration.

Frequency range (Hz)	Table single amplitude (inch)
4 to 15	0.030 ±0.006
16 to 25	0.020 ±0.004
26 to 33	0.010 ±0.002

TABLE II. Duration of endurance test in a given orthogonal direction at each test frequency.

Number of endurance test frequencies	Test time duration at each endurance test frequency	Total time
1	2 hours	2 hours
2	1 hour	2 hours
3	40 minutes	2 hours
4	40 minutes	2 hours, 40 minutes
n>2	40 minutes	40 x n minutes

5.1.2.4.7 Endurance test for mast mounted equipment. Equipment intended for installation on masts, such as radar antennae and associated equipment, shall be designed for a static load of 2.5g (1.5g over gravity) in vertical and transverse (athwartship and longitudinal) directions to compensate for the influence of rough weather. In addition, the equipment shall be vibrated for a total period of at least 2 hours, at the response prominences chosen by the test engineer. When specified (see 6.2.f(9)), selection of these frequencies is subject to approval. If no response prominences were observed, this test shall be performed at 33 Hz, unless excepted by 5.1.2.4.4, in which case the maximum frequency specified in 5.1.2.4.4 shall be used. The amplitudes of vibration shall be in accordance with Table III.

TABLE III. Vibratory displacement of environmental vibration for mast mounted equipment.

Frequency range (Hz)	Table single amplitude (inch)
4 to 10	0.100 ± 0.010
11 to 15	0.030 ± 0.006
16 to 25	0.020 ± 0.004
26 to 33	0.010 ± 0.002

5.1.2.5 Test documentation.

5.1.2.5.1 Test plan. When specified (see 6.2.b), an equipment test plan for Type I tests shall be prepared in accordance with DI-ENVR-81647 (see 6.3). The test plan shall specify, describe, or define all requirements and shall be approved by the acceptance authority prior to the test as specified (see 6.2.f(10)).

5.1.2.5.2 Test report. A test report (see 6.2.b) for Type I tests shall be prepared in accordance with DI-ENVR-81647 (see 6.3) and shall be approved by the acceptance authority as specified (see 6.2.f(10)).

5.1.3 Exemption. If equipment size, weight, or center-of-gravity precludes testing on existing vibration facilities, the equipment may be qualified by analysis or individually testing integral parts of the equipment, as approved by the acceptance authority.

5.1.4 Extension of previous testing. Equipment, which is identical or similar to previously tested equipment, may qualify for an extension of the previously approved test. The equipment for which the testing is to be extended must meet all of the following criteria:

a. The tested equipment and the proposed extension equipment are made of the same or similar materials and manufactured using the same or similar processes.

b. The mass of the proposed extension equipment is no more than 10% greater than the mass of the tested equipment.

c. The location of the center of gravity of the proposed extension equipment is within 10% of the location of the center of gravity of the tested equipment.

5.1.4.1 Extension documentation. A request for extension of previously approved testing must be approved by the acceptance authority and must contain the following:

a. Detailed drawings of both the tested equipment and proposed extension equipment.

b. A copy of the test report for the tested equipment.

c. A detailed comparison of the differences in materials and design showing that the proposed extension equipment has equal or greater vibration resistance than the tested equipment. This comparison should include at a minimum the information requested in sections 5.1.4.a, b, and c.

5.2 Type II – internally excited vibration. Type II balance and vibration requirements shall apply to the procurement of rotating machinery, unless otherwise specified (see 6.2.e). This does not apply to suitability from a noise standpoint, nor does it apply to reciprocating machinery. Special vibration and balance requirements may be specified (see 6.2.g(1)). The limitations set forth herein may also be used as criteria on overhaul tolerances, but should not constitute a criterion for the need for overhaul.

5.2.1 Basis of acceptability. All rotating machinery shall be balanced to minimize vibration, bearing wear, and noise. Types of balancing shall be as specified in Table IV. Machinery with rigid rotors shall meet the limits of allowable residual unbalance given in 5.2.2.2. Machinery with rotors which are unable to meet the balance requirements of rigid rotors shall be balanced in accordance with the requirements of 5.2.3.1.

TABLE IV. Types of balancing.

Rotor characteristics	Speed (rpm)	Type of balancing	Balancing methods and limits
Rigid, L/D [1/] $\leq$0.5	0 – 1000	Single-plane	5.2.2
	>1000	Two-plane	5.2.2
Rigid, L/D>0.5	0 – 150	Single-plane	5.2.2
	>150	Two-plane	5.2.2
Flexible	All	Multi-plane	5.2.3

[1/] L – Length of rotor, exclusive of shaft.
D – Diameter of rotor, exclusive of shaft.

5.2.2 Balance procedure for rigid rotors.

5.2.2.1 Balancing methods for rigid rotors. Except for machinery operating below 150 rpm, all balancing shall be accomplished by means of balancing equipment requiring rotation of the work piece. This may be either shop or assembly balancing type equipment. The minimum detectable unbalance of the balancing machine used shall be below the residual unbalance specified in 5.2.2.2. For machinery rated at lower than 150 rpm, the rotor including shaft, may be balanced by symmetrically supporting the rotor on two knife edges and applying correction to attain a static balance unless otherwise specified see 6.2.g(2)).

5.2.2.2 Balance limits for rigid rotors. When balanced as specified in 5.2.2.1, the maximum allowable residual unbalance is given by the following formula:

$$U = 6GW/N$$

Where: U is maximum allowable residual unbalance (oz-in)
G is the total balance quality grade (mm/sec) as specified (see 6.2.g(3))
W is weight of the rotor (lbs)
N is the maximum rotor rpm

For rigid rotors which operate below 1000 rpm, the total balance quality grade shall not exceed G=2.5 mm/s. For rigid rotors which operate at 1000 rpm and above, the total balance quality grade shall not exceed G=1.0 mm/s. For rigid rotors which require low noise, a balance quality grade of G=1.0 mm/s can be specified for all speeds (see 6.2.g(3)). For guidance on balance quality grades of rigid rotors, see ANSI S2.19.

In allocating an allowable unbalance (U) between two planes of correction, the allocation ratio must not be more than 2 to 1. The amount allocated to each plane must be proportional to the distance from the other plane to the center of gravity (c.g.) of the rotor divided by the total distance between planes. If the distance between the correction planes were 10 inches, and the c.g. were 4 inches from plane 1, plane 1 would be allowed 60% of U, and plane 2 would be allowed 40%. If the c.g. were 2 inches from plane 1, plane 1 would be allowed 67% of U (not 80%), and plane 2 would be allowed 33% (not 20%), because the allocation ratio cannot be more than 2 to 1.

When specified (see 6.2.g(4)), the residual unbalance for equipment with rigid rotors shall not result in vibration displacements larger than specified in Figure 2, when tested as specified in 5.2.3.2.

5.2.3 Balance procedure for flexible rotors.

5.2.3.1 Balance limits for flexible rotors. The residual unbalance for flexible rotors shall not result in vibration displacements larger than specified in Figure 2 when tested as specified in 5.2.3.2.

5.2.3.2 Vibration test procedure. When mounted as specified in 5.2.3.2.1 and measured in accordance with 5.2.3.2.2, the vibration displacement amplitude at the rotational frequency shall not exceed the values shown on Figure 2.

5.2.3.2.1 Mounting. The unit shall be completely assembled and mounted elastically at a natural frequency corresponding to less then one-quarter of the frequency associated with the minimal operational speed of the unit. To accomplish this, the minimum static deflection of the mounting should be determined by Figure 3, but in no case shall the deflection exceed one-half the original height of the elastic element. On machinery that cannot be mounted as described, the unit shall be mounted on the shipboard mounting for which it is intended, as specified (see 6.2.g(5)).

5.2.3.2.2 Measurements. Amplitudes of vibration shall be measured on the bearing housing in the direction of maximum amplitude. On constant speed units, measurements shall be made at the operating speed. In the case of variable speed units, measurements shall be made at maximum speed and at all critical speeds (see 3.5) within the operating range. Measurements at many speeds may be required to establish the existence of critical speeds of variable speed units. The maximum frequency step size used when establishing critical speeds shall be 0.25 Hz.

5.2.3.2.3 Instruments. Amplitude and frequency measurements shall be performed with instrumentation which has calibration traceable to the National Institute of Standards and Technology (NIST), and which has dynamic and frequency ranges consistent with the amplitude and frequency range specified in Figure 2.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

a. This standard is used to qualify shipboard equipment for the environmental vibrations and internally excited vibrations encountered during operation of the equipment aboard ship.

b. In some special machinery, equipment, or installations (such as antennae, large machinery items, and certain unique designs), it may be necessary to deviate from this standard.

c. Type I vibration testing is intended to qualify new equipment for exposure to shipboard vibrations during the lifetime of the ship.

d. The primary purpose of Type I vibration testing is to prove the physical and functional integrity of equipment when subject to a prescribed steady-state vibration environment. The results of the application of this standard do not provide a definitive determination of the tested item’s natural frequencies and mode shapes.

e. This standard does not cover vibrations associated with reciprocating machinery or those associated with propulsion and shafting. For these types, see MIL-STD-167-2.

f. The primary purpose of the application of this standard to Type II vibrations is from the standpoint of mechanical suitability, and not from a structureborne noise standpoint. See MIL-STD-740-2 for noise suitability of equipment.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of the standard.

b. Reporting requirements, including requirements for Notification of Test, Equipment Test Plan, and/or Test Report (see 4.1, 5.1.2.5.1, and 5.1.2.5.2).

c. Identification of component compliance on component drawing, in Test Report, or on label plate (see 4.2).

d. Disposition of tested equipment and related material (see 4.3).

e. Type(s) of vibration required (see 5.1 and 5.2).

f. Type I:

(1) How the equipment will be operated after the test to demonstrate the machinery or equipment has no damage from the test, including acceptable operational degradations (see 5.1.1 and 5.1.2.4.1).

(2) Whether the test engineer needs concurrence of the procuring agency for determination of major vs. minor failures before continuing testing (see 5.1.1).

(3) Whether measurement transducer locations need to be approved by the procuring agency for Type I testing (see 5.1.2.2).

(4) Methods of mounting equipment for test (see 5.1.2.3.4).

(5) Whether internal mounts should be installed for all, a specific part, or none of the test (see 5.1.2.3.5).

(6) How equipment will be energized or operated during Type I vibration tests (e.g., pressure, flow rate, voltage current, and cycling of principal functions during testing), including acceptable operational degradations (see 5.1.1 and 5.1.2.4.1).

(7) When required, the maximum test frequencies (see 5.1.2.4.4).

(8) Alternative test amplitudes (see 5.1.2.4.5).

(9) Whether approval is required for selection of frequencies used for endurance testing (see 5.1.2.4.6 and 5.1.2.4.7).

(10) The acceptance authority for the test report and any other approval items (see 5.1.2.5.1 and 5.1.2.5.2).

g. Type II:

(1) Special vibration and balance requirements (see 5.2).

(2) Whether dynamic balance is required for machinery rated at lower than 150 rpm (see 5.2.2.1).

(3) Balance quality grade (see 5.2.2.2).

(4) Whether vibration acceptance criteria of Figure 2 is specified for equipment with rigid rotors (see 5.2.2.2).

(5) When required, methods of mounting equipment for test (see 5.2.3.2.1).

6.3 Associated Data Item Descriptions (DIDs). This standard has been assigned an Acquisition Management Systems Control (AMSC) number authorizing it as the source document for the following DIDs. When it is necessary to obtain the data, the applicable DIDs must be listed on the Contract Data Requirements List (DD Form 1423).

DID Number	DID Title
DI-ENVR-81647	Mechanical Vibrations of Shipboard Equipment Measurement Test Plan and Report
DI-MISC-81624	Notification of Test/Trials

6.4 Tailoring guidance for contractual application.

Note: Equipment installed aboard naval ships is subjected to varying frequencies and amplitudes of environmental vibration for extended periods of time, during which they are required to perform their normal function. Principal causes of steady state shipboard vibration are propeller blade excitation and unbalanced forces of the propeller and shafting. Vibrations are also experienced by shipboard mounted equipment caused by mounting system resonances, changes in ship speed and heading, and changes in sea state. Vibration magnitudes measured on a ship during vibration trials should not be compared with the magnitudes shown in Table I because ship vibration trials are conducted in quiet water to achieve repeatable results during which changes in speed and heading are not made. See ANSI S2.25 for additional tailoring guidance.

a. The frequency range for Type I vibrations is determined based on blade rate frequencies associated with a specific ship design. If equipment is to be tested for use on multiple ship classes, the equipment may be tested over the frequency range encompassing various ship classes as required.

b. For Type I testing, if equipment is to be tested for use on multiple ship classes, the choice of equipment mounting may affect the number of equipment tests required to qualify the equipment for use on the intended ships.

6.5 Superseding data. This standard covers Types I and II vibration requirements formerly covered in MIL-STD-167-1 (SHIPS). Types III, IV, and V requirements are covered in MIL-STD-167-2 (SH).

6.6 Subject term (key word) listing.

Balance quality grade

Balancing

Flexible rotor

Response prominence

Rigid rotor

6.7 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

6.8 Guidance documents. The following documents provide design guidance and definitions in the field of vibration:

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

S1.1	-	Acoustical Terminology
S2.4	-	1990, American Standard Methods for the Specifying of Characteristics of Auxiliary Analog Equipment for Shock and Vibration
S2.5	-	1990, American Standard Methods for Specifying the Performance of Vibration Machines
S2.7	-	1990, American Standard Terminology for Balancing Rotating Machinery
S2.19	-	Mechanical Vibration – Balance Quality Requirements of Rigid Rotors, Part 1: Determination of Permissible Residual Unbalance, Including Marine Applications
S2.25	-	Guide for the Measurement, Reporting, and Evaluation, of Hull and Superstructure Vibration in Ships

INTERNATIONAL STANDARDS ORGANIZATION (ISO)

1940/1	-	1986, Mechanical Vibration – Balance Quality Requirements of Rigid Rotors – Part 1: Determination of Permissible Residual Unbalance

SPECIFICATIONS

MILITARY

MIL-M-17185	-	Mounts, Resilient; General Specifications and Tests for (Shipboard Application)

STANDARDS

MILITARY

MIL-STD-740-2	-	Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

NAVSHIPS 94323	-	Maintainability Design Criteria Handbook for Design of Shipboard Electronic Equipment
NAVSHIPS 0967-316-8010	-	BUSHIPS Reliability Design Handbook (Electronics)
NAVSHIPS 0967-309-3010	-	Design of Shock and Vibration Resistant Electronic Equipment for Shipboard Use
NAVSEA 0900-LP-090-3010	-	Guideline to Military Standard MIL-STD-167-1 (SHIPS) Mechanical Vibrations of Shipboard Equipment, December 1993
SVM-18	-	Shock and Vibration Design Manual, Naval Sea Systems Command, April 2001

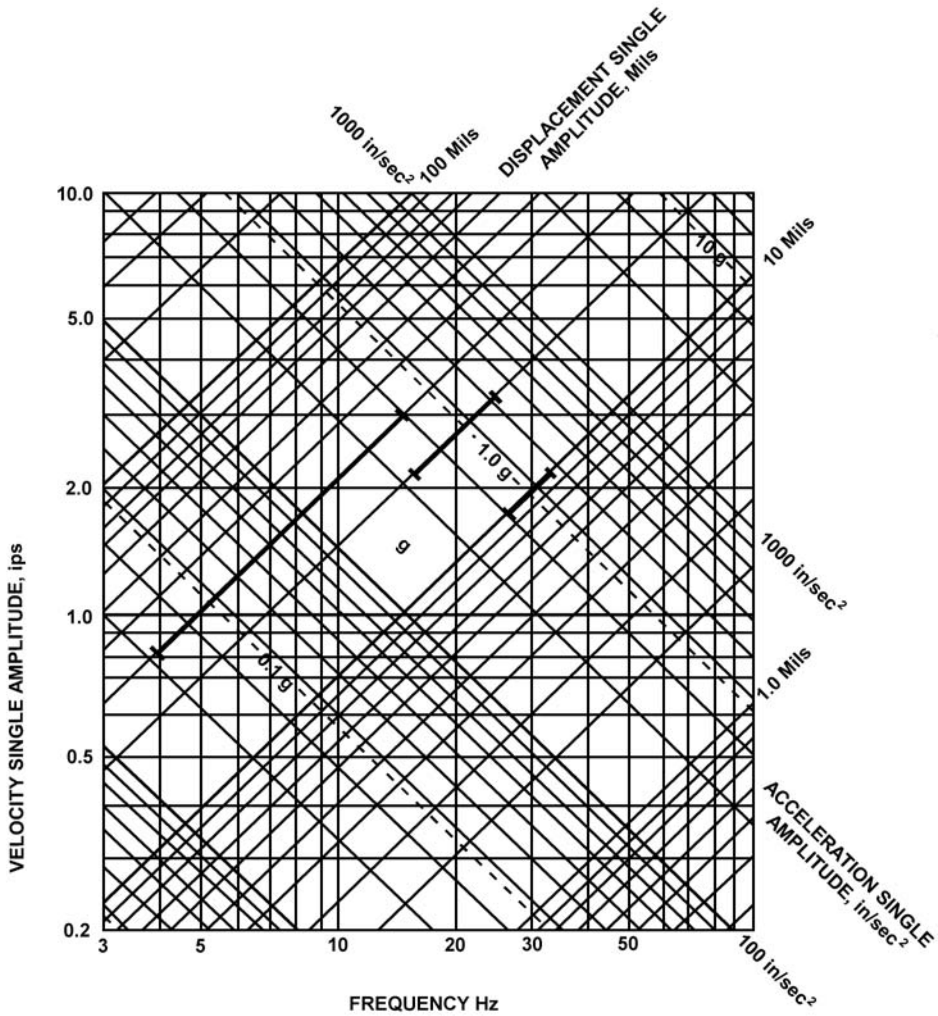

FIGURE 1. Type I environmental vibration limits (black bars represent a graphical presentation of table I expressed in displacement, velocity, and acceleration).

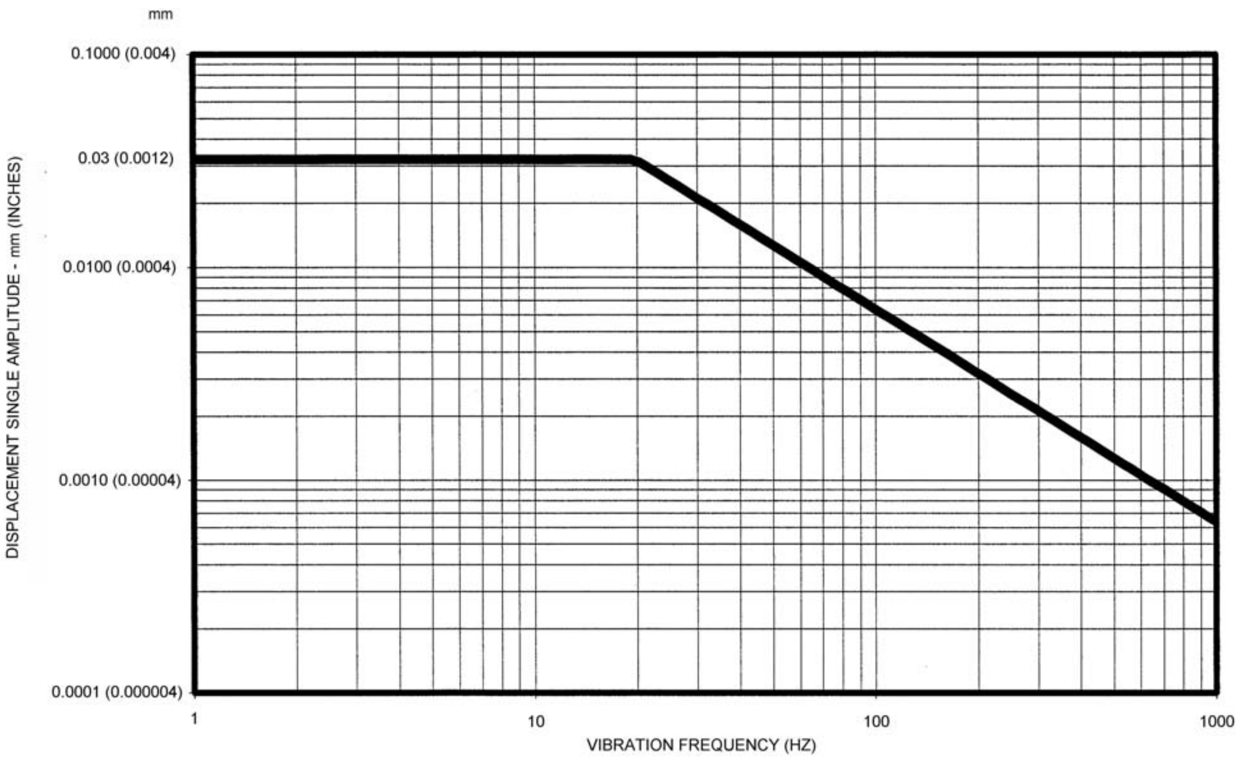

FIGURE 2. Vibration acceptance criteria for Type II vibration.

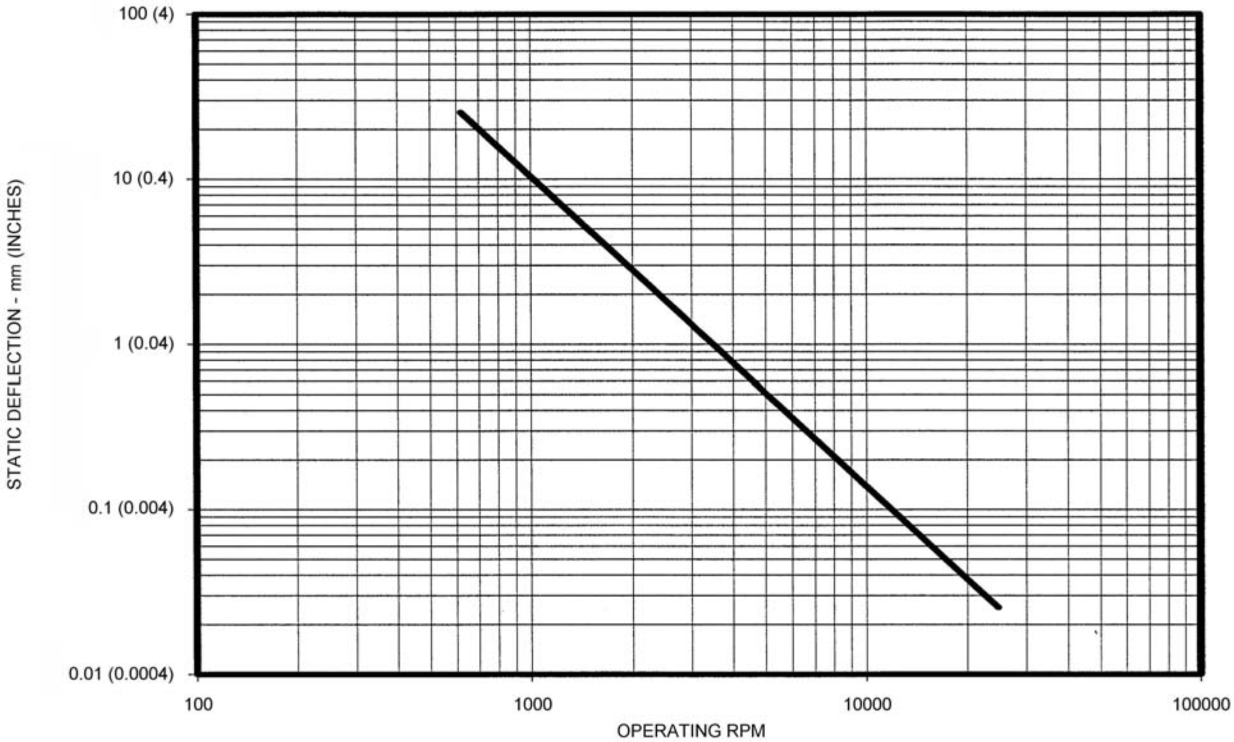

FIGURE 3. Minimum static deflection of mounting for Type II vibration test.

APPENDIX A

IDENTIFYING RESPONSE PROMINENCES TO BE INCLUDED IN ENDURANCE TESTING

A.1 SCOPE

A.1.1 Scope. This appendix details the procedures for identifying response prominences to be included in endurance testing. This appendix is not a mandatory part of the standard. The information contained herein is intended for guidance only.

A.2 PROCEDURE

A.2.1 Determining and displaying transmissibility. Transmissibility information should be presented using the output responses and prescribed inputs. The transmissibility magnitudes for both exploratory and variable frequency tests are to be used for response prominence determinations.

A.2.1.1 Transmissibility magnitudes. Transmissibility magnitudes are to be developed by dividing the measured output amplitudes by the input amplitudes using consistent units (e.g., acceleration in g's or inches/sec^2).

A.2.1.2 Transmissibility and frequency. Transmissibility information is to be presented in linear-linear format. Plots or tabulations are acceptable. Both the transmissibility and frequency information must be presented in linear units (i.e., no logarithms or dB of either frequency or transmissibility are to be used to compute or display the data used for response prominence determinations).

A.2.2 Identifying response prominences. Regardless of whether or not the transmissibility exceeds 1.0, find all local maxima in the transmissibility magnitude-frequency data and include the frequency endpoints in the list of maxima.

a. For each of these maxima, determine if there is reason to believe that the maximum is attributable to an instrumentation error, a fixture resonance or from a numerical error related to computation of the transmissibility (round-off errors may appear as maxima). Any maxima that are attributable to an instrumentation error, fixture resonance, or numerical errors must be discarded as a potential response prominence. Fixture resonances are not permitted and refixturing must be employed to eliminate such resonances.

b. Examine the end points for indications that a resonance may exist outside the test frequency range.

c. An initial decrease in transmissibility with increasing frequency above the frequency of the lower end point suggests a potential response prominence outside the lower bound of the test frequency range. If this condition is observed and is not attributed to shaker problems at low frequencies, include the lower endpoint in the candidate list of endurance test frequencies noting whether or not it affects functional or structural integrity. If this condition is not observed, the lower bound test frequency may be discarded as a potential response prominence. At these low frequencies, noticeable displacement magnitude amplifications may occur if a true response prominence exists below the lower frequency bound of testing and this fact may be used to help determine the nearby presence of a true response prominence.

d. Similarly, an increase in transmissibility with increasing frequency near the upper bound test frequency suggests a potential response prominence outside the upper bound of the test frequency range. If this condition is observed, include the upper endpoint in the candidate list of endurance test frequencies noting whether or not it affects functional or structural integrity. If it is not observed, this frequency cannot be excluded from the list of endurance test frequencies unless other response prominence frequencies are found.

e. Observe whether or not equipment function (if permitted by the ordering data) or structural integrity is affected at any of the frequencies used in exploratory or variable frequency testing. Include those frequencies at which equipment functional or structural integrity is affected in the candidate list of endurance test frequencies. Also include frequencies at which maxima occur in the candidate list of endurance test frequencies if the impact on functional/structural performance cannot be established.

f. Examine the remaining maxima for classic signs of resonance (i.e., a moderate to rapid increase in transmissibility to the peak followed by a moderate to rapid decrease in the transmissibility with increasing frequency after the peak suggests that a response prominence may exist in this region) and include any maxima that exhibit these characteristics in the candidate list of endurance test frequencies.

A.2.3 Selecting endurance test frequencies.

A.2.3.1 Non-response prominence frequencies where functional or structural integrity is affected. Include in the list of endurance test frequencies, any frequency at which a structural, functional, mechanical, or electrical anomaly has occurred (if permitted by the acceptance criteria (see 5.1.1 and 6.2.f(1))). Examples of these manifestations could be unexpected switch closures, unexpected changes in pressure or flow, variations in voltage, current, etc. The frequencies where any minor impairment of function occurs which does not warrant interruption of testing to develop a fix must also be included in the list of endurance test frequencies.

A.2.3.2 Frequencies where response prominences have been identified. Components may contain many parts and subassemblies that can resonate. Some components may have nonlinear characteristics such as clearances between parts or equipment mounted on isolation mounts. Therefore, the amplitude of excitation may be important relative to identifying response prominences for these components. Input amplitude dependent response prominences may potentially be the same overall resonance rather than different ones. In light of this potential, unusual test results, such as uncovering response prominences during variable frequency testing that were not uncovered during exploratory testing, need to be thoroughly investigated to not only try and determine the cause of the response prominence but to ascertain whether the response prominence is unique or part of another response prominence. Criteria for selecting response prominences for endurance testing is as follows:

a. A transmissibility greater than 1.5 at any measurement location is sufficient to classify a maximum as a response prominence and include the corresponding frequency in the list of endurance test frequencies. However, the converse is not necessarily true, i.e., a response prominence whose transmissibility is less than 1.5 cannot be excluded solely on the magnitude of the transmissibility. Possible explanations as to why transmissibility maxima of magnitudes less than 1.5 may still represent real response prominences are:

   (1) The transducer may not be at the point of maximum response. If probing or some other means cannot be employed to locate the point of maximum response (e.g., due to inaccessibility), then all maxima displaying the classic characteristics of a resonance which cannot be attributed to instrumentation or numerical error must be identified as response prominences and their frequencies included in the list of endurance test frequencies.

   (2) The transducer may be at or near a response node point (location of minimal or low response in a vibration mode) at that frequency. The location of node points (as well as the locations of maximum response) can change location as changes in the drive frequency excite different modes of vibration.

   (3) The mass of the part and the amplitude of vibration of the mass that is in maximum response are not large enough to generate the forces necessary to cause structural responses of large enough magnitude at the location of the transducer.

   (4) The driving frequency is not exactly at the resonant frequency, thus the peak response is not obtained.

b. Without further investigation, the existence of a response prominence for the remaining maxima cannot be confirmed nor the possibility of the existence of a response prominence excluded. If practical, an attempt should be made to obtain further information to resolve this issue by probing for the maximum response location with movable transducers, listening, visually locating or feeling for the maximum response points.

c. If it can be shown that response prominences uncovered do not compromise equipment structural/functional integrity, then these response prominences do not have to be included in the endurance test. Justification should be provided in the test report as to why these response prominences have been excluded from endurance testing.

APPENDIX A

A.2.4 Guidance for specifiers. Carefully determine all functions of the equipment, which must be preserved under normal shipboard vibration. Determine the functional requirements that must be met during the vibration tests including the appropriate test acceptance criteria and include them in the procurement documents. A careful and thorough evaluation of the functional requirements will significantly reduce the potential for problems, define the basis for instrumentation selection and placement, and help in the interpretation of test results.

If possible, determine how and where to instrument the test article based on the functional requirements and expected responses or consider requiring the vendor to make this determination. If an area of concern cannot be directly instrumented, consider instrumenting to find alternate manifestations of this area of concern (e.g., voltage fluctuations, pressure variations, noise, contact closures). While analyses of the test and test equipment (if performed) can provide insights into possible test responses of some equipment, often neither extensive nor complicated analyses are needed and common sense alone can often be used to establish reasonable locations of instrumentation if the functional requirements are well known.

If the test vendor will determine the instrumentation scheme, depending on the equipment, consider requesting the instrumentation scheme for information or approval.

Depending on the equipment, consider requiring prior approval of frequencies used for endurance testing.

Custodians:
Army – EA
Navy – SH

Preparing activity:
Navy – SH
(Project ENVR-0052)

Review activity:
Navy – OS

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at http://assist.daps.dla.mil.