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MILITARY STANDARD

STRUCTUREBORNE VIBRATORY ACCELERATION MEASUREMENTS AND ACCEPTANCE CRITERIA OF SHIPBOARD EQUIPMENT

AMSC N4009 AREA HFAC

DEPARTMENT OF DEFENSE
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362-5101

Structureborne Vibratory Acceleration Measurements and Acceptance Criteria of Shipboard Equipment

1. This Military Standard is approved for use by Naval Sea Systems Command, Department of the Navy, and is available for use by all departments and agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE, PURPOSE, APPLICATION, IMPLEMENTATION, AND APPROACH

1.1 Scope. This standard prescribes instrumentation and procedures for the measurement and analysis of, and maximum acceptable level criteria for structureborne vibratory acceleration generated by shipboard equipment.

1.2 Purpose. Structureborne sound testing is conducted to demonstrate that equipment levels are within the limits specified herein.

1.3 Application. This standard supplements specifications and similar documents applicable to shipboard equipment.

1.4 Implementation. Implementation guidance is provided in section 6.

1.5 Approach.

1.5.1 Measurement. The basic method used in this standard to determine equipment acceptance is the measurement of the structureborne vibratory acceleration level (L_a) in decibels (dB). Measurements are required at the locations of 5.3.2 for use in guiding maintenance.

1.5.2 Acceptance criteria. Structureborne acceptance criteria are specified in 5.1.

1.5.3 Acceptability of equipment. Equipment is acceptable when none of the structureborne vibratory acceleration levels measured using accelerometers at the designated location exceed the applicable structureborne acceptance criteria.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified, the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

L-P-391 - Plastic Sheets, Rods and Tubing, Rigid Cast, Methacrylate (Multiapplication).
MMM-A-132 - Adhesive, Heat Resistent, Airframe Structural, Metal to Metal.

SPECIFICATIONS (Continued)

MILITARY

MIL-P-15024 - Plates, Tags, and Bands for Identification of Equipment.
MIL-M-17185 - Mounts, Resilient; General Specifications and Tests for (Shipboard Application).
MIL-M-17508 - Mounts, Resilient; Types 6E2000, 6E900, 6E900BB, 7E450, 7E450BB, 6E150, and 6E100.
MIL-M-19379 - Mounts, Resilient, Mare Island Types 11M15, 11M25, and 10M50.
MIL-M-19863 - Mounts, Resilient: Type 5B5000H.
MIL-M-21649 - Mount, Resilient, Type 5M10,000-H.

STANDARD

MILITARY

MIL-STD-1621 - Acoustical and Vibrational Standard Reference Quantities.

(Copies of specifications and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

S1.6 - Preferred Frequencies and Band Numbers for Acoustical Measurements.
S1.11 - Octave, Half-Octave, and Third-Octave Band Filter Sets.
S2.2 - Calibration of Shock and Vibration Pickups; Methods for.

(Application for copies should be addressed to Publication Sales, Dept. STD, American Institute of Physics, 335 East 45th Street, New York, NY 10017.)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Symbols. Symbols used herein are as follows:

a_o = Reference vibratory acceleration (see 3.2.3)
FFT = Fast Fourier Transform
f_c = Band-center frequency (see 3.2.8)
f_1 = Lower band-edge frequency (see 3.2.7)
f_2 = Upper band-edge frequency (see 3.2.7)
g_n = International standard acceleration of free fall (see 3.2.3)
L_a = Structureborne vibratory acceleration level (see 3.2.4)
DIM = Distributed isolation material (see 3.14.2)

3.2 Terminology.

3.2.1 Frequency. The frequency of a function periodic in time is the reciprocal of the period. The unit of frequency is the hertz (Hz). One Hz is equal to one cycle per second.

3.2.2 Level. The level of a vibratory quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level shall be indicated.

3.2.3 Reference vibratory acceleration (a_o). The reference quantity is 10 micrometers per second squared ($\mu m/s^2$) root mean square (rms) (10 $\mu m/s^2$ = 10^{-3} centimeters per second squared (cm/s^2) = 393.7 x 10^{-6} inches per second squared (in/s^2)). Units of the International System (SI) as specified in MIL-STD-1621 are prescribed for the measurement of vibrational quantities. The acceleration of 10 $\mu m/s^2$ is nearly one millionth of the international standard acceleration of free fall g_n = 9.80665 m/s^2 = 386.089 in/s^2. Therefore, for reporting in accordance with this standard, the reference vibratory acceleration may be described as a_o = 1 μg_n (rms). For calibration purposes use 1 g_n (rms) = 120 dB re a_o.

3.2.4 Structureborne vibratory acceleration level (L_a). L_a, in decibels (dB) is 20 times the logarithm to base 10 of the ratio of the measured structure-borne vibratory acceleration to a_o; that is,

$$L_a \text{ in dB} = 20 \log_{10}\left(\frac{\text{measured acceleration in } \mu m/s^2 \text{ (rms)}}{10\ \mu m/s^2 \text{ (rms)}}\right)$$

3.2.5 Band. A band is a continuous spread of frequencies.

3.2.6 Band level. Band level is the vibratory level in a particular band.

3.2.7 Band-edge frequencies. The upper (f_2) and lower (f_1) band-edge frequencies are those frequencies above and below the frequency of maximum response of a filter at which the response to a sinusoidal signal is 3 dB below the maximum response.

3.2.8 Nominal band-center frequency (f_c). The nominal band center frequency may be either the arithmetic or geometric mean between the band-edge frequencies of a band, the arithmetic mean being $f_c = (f_1 + f_2)/2$ and the geometric mean being $f_c = (f_1 \times f_2)^{1/2}$. The arithmetic mean is normally used when constant bandwidth filters, such as 50 Hz are specified. The geometric mean is normally used for filters of constant percentage bandwidth, such as one-third octave band filters.

3.2.9 Bandwidth. The bandwidth of a filter is the difference between f_1 and f_2. This difference may be expressed in Hz, as a percentage of the band-center frequency, or as the interval between the band-edge frequencies, in terms of octaves or parts thereof, such as one-third, one-fifteenth, etc.

3.2.10 One-third octave band. The one-third octave bands designated in this standard are those whose band-center frequencies are preferred one-third octave bands specified in ANSI S1.6. The width of a one-third octave band is approximately 23 percent of its band-center frequency.

3.2.11 Narrowband. Narrowband, when used in this specification, refers to that measurement bandwidth obtained with the use of a 400 line fast fourier transform. The preferred increments are zero Hz to 400 Hz, 400 Hz to 2000 Hz, and 2000 Hz to approximately 10,000 Hz. Other bandwidths, not to exceed 10 percent of the center frequency, may be used if approved by the contracting activity.

3.2.12 Equipment. The term "equipment", when used in this standard, refers to any equipment such as a system, subsystem, or part thereof which is being measured to determine compliance with the structureborne acceptance criteria.

3.2.13 Type. The term "type" is used to divide equipment into groups for the purpose of specifying structureborne noise criteria.

3.2.13.1 Type I. Type I designates reciprocating compressors and internal combustion engines.

3.2.13.2 Type II. Type II designates pumps, valves, and life support equipment.

3.2.13.3 Type III. Type III designates equipment not covered by types I, II and IV.

3.2.13.4 Type IV. Type IV designates vaneaxial fans.

3.2.14 Mounting.

3.2.14.1 Resiliently mounted equipment. Resiliently mounted equipment is equipment which is isolated from a support structure by Navy approved resilient mounts. For equipment which is not isolated by Navy approved resilient mounts, the criteria for solidly mounted equipment shall apply. Approved resilient mounts are mounts in accordance with MIL-M-17185, MIL-M-17508, MIL-M-19379, MIL-M-19863, or MIL-M-21649. For the purposes of this standard, DIM mounted equipment is considered to be solidly mounted equipment.

3.2.14.2 Compound mounts. A compound or two stage mount is a three element device consisting of an intermediate mass contained between resilient elements.

3.2.14.3 Solidly mounted equipment. Solidly mounted equipment is equipment which is attached directly to the supporting structure. For the purposes of this standard, DIM mounted equipment is considered to be solidly mounted equipment.

3.2.15 Contracting activity. Contracting activity, when used in this standard is the Government or its authorized representative.

4. GENERAL REQUIREMENTS

4.1 Equipment sampling. If sampling is called for by the acquisition specifications or the contract or order (see 6.3), selection of equipment for test shall be on the basis of conformance to the drawing requirements for that equipment, and shall not consider advance measurements, observations, or opinions about the acoustical performance of the particular equipment sample.

4.2 Equipment evaluation plan. When specified in the contract or order, an equipment structureborne vibratory acceleration measurement plan shall be prepared (see 6.4).

4.3 Testing. The Government shall have the option to witness all tests conducted to meet contractual requirements. Notification of tests letters shall be prepared in accordance with the data ordering document included in the contract or order (see 6.4) as specified (see 6.3).

4.4 Reporting standards.

4.4.1 Reference quantity identification. The applicable reference quantity shall be indicated on every table, figure, and graph, and at least once in the text. The reference quantity may be introduced by "re" which indicates that the level is "with reference to". For example, the 100 Hz one-third octave band level re 10 $\mu m/s^2$ is 85 dB.

4.4.2 Measurement bands. The bandwidths of the measurement bands shall be reported together with the measured levels. Normal procedure for reporting measured levels shall include the bandwidth and the band-center frequency with the level. For example: one-third octave 100 Hz band level was 85 dB re 10 $\mu m/s^2$; the 10 Hz bandwidth 100 Hz band level was 85 dB; or, the 6 percent bandwidth 100 Hz band level was 85 dB re 10 $\mu m/s^2$.

4.4.3 Plotting format. Plotting formats shall be in accordance with MIL-STD-1621. That is, all plots of data in which a level in dB is plotted against frequency on a logarithmic scale shall be made on graphs in which a factor of ten in frequency is equal in length to 25 dB (preferred) or 50 dB. Where the bandwidth of analysis is one-third octave or larger, one factor of ten in frequency shall be 50 mm (preferred) or 2 inches in length. The ordinate and abscissa of all graphs shall be labeled so that levels and frequencies can be readily understood without need to refer elsewhere in the report. Narrowband data shall be plotted using a linear frequency scale and the vibration level in decibels.

5. DETAILED REQUIREMENTS

5.1 Structureborne acceptance criteria. Structureborne acceptance criteria shall be in accordance with figure 2 for the type of equipment specified (see 3.2.13 and 6.3). The one-third octave band levels that must be compared to the specified levels shall be measured in accordance with 5.2 for the locations specified in 5.3.1. Equipment which fails to meet the acceptance criteria shall not be installed in the ship until the following have been accomplished:

(a) When specified in the contract or order, a sound test failure notification and recommendations report shall be prepared for each deficient equipment item measured (see 6.4).
(b) The Government or the contracting activity has accepted the deficient equipment or directed the specific course of action.

5.1.1 Figure 2 correction factors. Certain correction factors, shown in the notes on figure 2, apply only for some specific equipment, anticipated shipboard mounting and system connection configurations, or combinations thereof. For example, 15 dB shall be subtracted from the type II curve for solidly mounted non-sea connected pumps. No correction factor shall be applied for other than the specific conditions or combinations shown on figure 2. For example, no correction to the type II curve shall be made for resiliently mounted sea connected pumps.

5.2 Measurements. The measurements required by this standard are normally made using an accelerometer attached to the equipment or its supporting structure, as outlined in 5.3, which covers measurement locations, and 5.4, which covers the details of accelerometer attachment. These measurements are normally made during steady state operating conditions.

5.2.1 Required measurements. Unless otherwise specified (see 6.3), the following measurements shall be made:

5.2.1.1 General. Measurements in accordance with 5.2.2 shall be made at the specified locations in three mutually perpendicular directions, one of which shall be vertical. Additionally, for equipment with horizontally oriented shaft, one other direction shall be perpendicular to the equipment shaft. For valves, measurements in two directions are required; perpendicular and parallel to the flow for outlet flanges or nozzles, and three mutually perpendicular directions for other structural connections, except the inlets.

5.2.1.2 One-third octave band measurements. One-third octave band measurements in accordance with 5.2.2.1 shall be made at the locations specified in 5.3.

5.2.1.3 Narrowband measurements. These measurements may be required by the contracting activity and shall also be made whenever the equipment fails the one-third octave band criteria at the location and in the direction of the failure. When narrowband analyses are required they shall be made in accordance with 5.2.2.2.

5.2.2 Measurement procedures.

5.2.2.1 One-third octave band measurement procedure. One-third octave band L_a shall be measured for the ambient (nonoperating) condition and for the conditions specified in 5.8 using accelerometers, preamplifiers, meters, connecting cable, and actual or synthesized one-third octave band filters, a graphic level or X-Y recorder or digital printer, and connecting cables. The one-third octave band filters shall cover band-center frequencies over the range specified (unless otherwise specified (see 6.3), this range shall include the 10-Hz band or the fundamental forcing frequency of the equipment, whichever is lower through the 10,000-Hz band) and have rejection characteristics beyond the band-edges at least as good as those specified in ANSI S1.11, for class II filters. The recorder shall provide a permanent reproducible copy conforming to 4.3.3. The complete system shall have a flat response within plus or minus 2 dB over the specified frequency range. For every one-third octave band, the product of the analysis bandwidth in hertz times the sample time in seconds shall be at least 25. The complete frequency range of interest shall be analyzed and recorded. The correction factors required to convert recorded levels to actual L_a shall be indicated on the data.

5.2.2.1.1 Scanning rate. Continuous scan measurements that do not provide a time bandwidth product of 25 or greater are not permitted for one-third octave band measurements. If analyzer with automatic step advance is used, manual control of step rate for several of the lower frequency third-octave bands may be required to obtain a time bandwidth product of 25 or greater.

5.2.2.1.2 Amplitude adjustment. Instrumentation shall be adjusted so that the readout shows all levels within the frequency range of interest. Do not allow lower amplitudes to drop off the bottom of the data sheet.

5.2.2.2 Narrowband measurement procedure. Narrowband L_a measurements shall be made when specified by the contracting activity (see 6.3). The system used shall include the basic instruments of 5.2.2.1 (accelerometers, preamplifiers, meters, and connecting cables) with a narrowband analyzer (may be synthesized by FFT), in lieu of the one-third octave band analyzer, digital printer, a graphic level or X-Y recorder and connecting cables. The recorder shall provide a permanent reproducible copy.

5.2.2.2.1 Frequency response. Unless otherwise specified (see 6.3), the complete system shall have a flat response within plus or minus 2 dB over the frequency range from 9 Hz or the fundamental forcing frequency of the equipment, whichever is lower, through 11,225 Hz.

5.2.2.2.2 Time bandwidth product. The product of the analysis bandwidth in hertz times the total sample time in seconds shall be at least 25 at all frequencies. The complete frequency range of interest shall be analyzed and recorded. The correction factor required to convert recorded levels to actual L_a shall be indicated on the data. The bandwidth used for the analysis shall also be indicated. NOTE: As an exception, if swept analysis is used, a constant sweep giving a time bandwidth product of at least 25 at 40 Hz and above is acceptable.

5.2.2.2.3 Amplitude adjustment. Instrumentation shall be adjusted so that the readout shows all levels within the frequency range of interest. Do not allow lower amplitudes to drop off the bottom of the data sheet.

5.3 Measurement point locations. Unless otherwise specified (see 6.3), measurement point locations shall be as specified herein.

5.3.1 Primary locations. Accelerometers shall be attached to blocks either on the feet or flange locations selected as follows:

(a) For first article testing:

(1) For equipment with feet, measurements shall be made on the feet for both simple and compound mounted equipment.
(2) Measurements shall be made above all mounts and isolators, i.e., on the feet or base of the unit, for both simple and compound mounted equipment. No type of noise mount or isolator is permitted between the unit and the accelerometers.
(3) For valves, the measurement point locations shall be on all the outlet flanges or nozzles, and any other structural connections except the inlets (see figure 3).
(4) For equipment not having well defined points of attachment, measurement locations shall be as approved by the contracting activity.

(b) For follow unit testing:

(1) Measurement locations shall be as approved by the contracting activity. As a minimum, the accelerometer locations where the overall highest level was determined during first article testing and the diagonally opposite locations shall be measured, highest level being defined as that which has the highest level relative to the specifications.

5.3.2 Additional locations. For all rotating equipment, one-third octave band measurements at additional locations shall be made at the measurement point locations designated generally on figures 4 through 6. Specifically, for all fans and motor-driven pumps, accelerometers shall be oriented perpendicular to the machine's rotating shaft, one at each end of the auxiliary machine. These measurement point locations shall be designated "1" and "2" (see examples of these measurement point locations on figures 4 and 5). Also, motor driven pumps shall have an accelerometer mounted on the lower end bell, oriented perpendicular to the machine's rotating shaft. This measurement point location shall be designated "3" (see figure 5). In addition to locations "1" and "2", described above, all motor generator sets and motor-driven compressors shall have one accelerometer oriented parallel to the rotating shaft of the equipment. This measurement point location shall be designated "3" (see an example of these three measurement point locations on figure 6.) These additional measurements are for the sole purpose of guiding maintenance and diagnosing noise problems and are not to be used as a basis for acceptance of the equipment. Due to the uncertainties in the high frequency response characteristics of magnetically mounted accelerometers, analysis of data at frequencies above the 5 kHz 1/3 octave band at these locations is not recommended.

5.4 Accelerometer attachment.

5.4.1 Attachment at primary locations. Accelerometers shall be attached as follows:

(a) Accelerometers shall be attached to machined mounting blocks or directly to the equipment surface at all of the measurement point locations for the equipment to be measured. Blocks shall be oriented such that the most sensitive axis of each accelerometer is in the direction specified in 5.2.1.1. Accelerometers may be attached directly to the equipment being measured only where specified (see 6.3) or where there is insufficient space to accommodate a mounting block and the contracting activity has given specific prior approval for drilling holes in the equipment surface. When accelerometers are attached directly (that is studded to the structure) the point of attachment on the equipment shall be one having relatively high stiffness.

(b) Accelerometer mounting blocks shall be as small as possible and shall be of material compatible to the surface to which they are mounted, that is, steel blocks shall be used on ferrous housings and bronze blocks on bronze housings. Block surfaces shall be mutally perpendicular within one degree.

(c) Surfaces on which accelerometers are mounted shall be flat within 700 microinches rms and shall have a surface finish of 125 microinches rms or better.

(d) Stud holes shall be drilled and tapped to a depth of at least 1/4 inch with 10-32 national fine (NF) threads. Mounting holes, whether in mounting blocks or the equipment surface, shall be perpendicular to the finished surface within one degree. For the triaxial assembly of transducers, three holes which are mutually perpendicular shall be drilled and tapped in the mounting block. When studs longer than 1/4 inch are to be used, care shall be taken to assure that the block dimensions are adequate to permit the three studs to be arranged mutually perpendicular as required for the triaxial assembly of transducers.

(e) After drilling and tapping, all holes shall be protected with removable, reusable covers or inserts.

(f) Just before accelerometers are mounted, all mating surfaces shall be cleaned of all dirt, grease and other foreign matter in preparation for mounting. The surfaces of the attachment area shall be lightly covered with clean oil or grease. Interfering electrical ground loops shall be avoided by always using an insulated steel stud to attach accelerometers. To assure its effectiveness, care shall be taken to assure that the insulating stud material is not electrically shorted by a conductive lubricant on the material. Care shall also be taken not to damage the insulated stud by overtightening.

(g) Where specified by the contracting activity (see 6.3), mounting blocks shall be attached by brazing or electric arc welding, as appropriate. The welding process shall cause no heat distortion or other damage to either the block or machine surfaces. Before attaching the mounting blocks, the block shall be oriented in

the proper position to permit measurements in the directions specified in 5.2.1.1. These mounting blocks shall not be removed and shall be preserved with a rust inhibiting coating of grease after completion of measurements.

(h) If brazing or welding has not been specified (see 6.3), the mounting blocks shall be attached at the locations with a suitable noncompliant cement in accordance with MMM-A-132. Prior to cementing, surface contact areas shall be cleaned of all paint, grease, and loosely held contaminants, but shall not be polished. Blocks attached by cement shall be removed upon completion of the test.

(i) Unless otherwise specified (see 6.3), the measurement locations shall be permanently marked by suitable means when mounting blocks are not permanently attached.

(j) The use of magnetic clamps for attaching accelerometers is not permitted for measurements at primary locations.

5.4.2 Attachment at additional locations. Accelerometer shall be attached as follows:

(a) An accelerometer mount manufactured in accordance with figure 7 shall be attached at a location complying with requirements of 5.3.2 in the following manner:

(1) Clean the machine point locations to bare metal by scraping them free of all paint, primer, and rust. The surfaces need not be perfectly smooth, but shall be free of dirt, oil, water, and grease.
(2) Apply a two part epoxy mixture which is in accordance with MMM-A-132 to the clean surface according to manufacturer's instructions.
(3) Install the disk and secure in place until epoxy has cured so that the initial bond will support the disk.
(4) Paint the periphery of the measurement point locations.
(5) Torque (2 Newton-meters (N · m) (18 inch-pounds (in-lb)) an insulated stud to the accelerometer, and then torque (2 N · m (18 in-lb)) the accelerometer and insulated stud to a 1-inch diameter, 3/4-inch magnetic holding clamp. Attach the face of the magnet to the face of the steel disk for measurement purpose.

(b) The accelerometer mount shall not be removed from the machine after measurement and shall be protected by a protecting cap. The cap shown on figure 8 may be used.

(c) Both the accelerometer mounts and the protecting caps are available from the stock system.

5.5 External influences. Measured levels of equipment vibration shall not be adjusted to compensate for the effects of ambient magnetic, electrical, and acoustical fields. Ambient effects shall be at least 10 dB below the levels specified for the equipment. Corrective measures shall be taken to reduce the effects of external sources on the equipment's measured vibration level. In cases where pipes are connected to the equipment, a flexible connection shall be inserted in each pipe run between the equipment and any external piping. The flexible connection shall be within 1 meter of the equipment. Acoustical filters, damped piping, or similar devices shall be employed to reduce fluidborne pressure pulsation effects from external sources. The equipment shall be located away from other machinery items. If this is not possible, machinery which is not necessary for the test shall be shut down.

5.6 Mounting of equipment. Unless otherwise specified (see 6.3), mounting procedures shall be as specified herein.

5.6.1 Mounting methods. Equipment shall be oriented in its normal shipboard installation position. Equipment shall be resiliently mounted as described below regardless of how the equipment is to be mounted in service. Resilient mounts and subbases or bedplates shall normally be the same ones used for shipboard installation. The subbase used for the equipment evaluation shall not exceed the weight of the shipboard subbase (see 6.3). For the purpose of this standard, the terms subbase and bedplates refer to structure which is required for shipboard installations and which is necessary for purposes such as to hold one or more components within alignment or to provide a means for attachment to the ship. Resilient mounts used in such a case shall be loaded in accordance with the load range specified in the mount specification. The frequencies of the natural modes of vibration of the mounted equipment in the vertical direction shall not exceed 11 Hz or one-fourth of the lowest forcing frequency, whichever is lower. Resilient mountings conforming to MIL-M-17508, MIL-M-19379, MIL-M-19863, or MIL-M-21649, shall be used where possible. If these mountings cannot be used, commercial mounts for which data can be provided to show they meet the frequency requirements and which are otherwise suitable are acceptable if approved by the contracting activity. Where the above mounting requirements cannot be met, equipment mounting shall be subject to approval by the contracting activity. When used in Navy shipboard application, resilient mounts shall be in accordance with MIL-M-17185. The complete assembly shall be supported on a rigid and massive floor, preferably of reinforced concrete or cast metal to prevent interaction between the equipment and floor.

5.6.1.1 Foundations. Any foundation pedestals, cradles, etc., required to accommodate resilient mounts shall assure that the installed mounts provide the vibration isolation of the assembly from the foundation for which the resilient mount is designed. Foundations shall have a natural frequency of not less than 25 Hz and shall not have fixed base natural frequencies within plus or minus 0.4 (square root of 2, minus 1) times the fundamental rotational or other primary forcing frequency of the machinery or equipment. In addition, they shall not have natural frequencies within 0.4 times other machinery or equipment exciting frequencies between 0 and 500 Hz. Exciting frequencies shall include but not be limited to rotational, two times rotational, electrical frequencies and harmonics thereof, pump vane frequencies, pressure pulsations, ball bearing frequencies,

etc. For the purpose of this standard, the term foundation refers to support structure which is used below the resilient mounts and which may or may not resemble the shipboard structure.

5.6.2 Mounting fixture. Some equipment may be measured while solidly mounted on a mounting fixture. This equipment will normally consist of units which have a relatively light framework or structure (for example, controllers, control cubicles, nonrotation or nonreciprocating equipment) and which are to be solidly mounted on shipboard. For the purpose of this standard, the term mounting fixture refers to structure which is used solely for the purpose of resiliently mounting equipment for noise testing, is not used for shipboard installations, and is used above the resilient mounts. The contracting activity will specify whether a mounting fixture is required (see 6.3). Those items requiring attachment to a mounting fixture shall be attached at the normal points of attachment of the equipment. The fixture shall have a high rigidity to weight ratio. The fixture shall be stiff between points of attachment and shall not have a natural frequency within plus or minus 0.4 times the fundamental rotational frequency or other primary forcing frequency of the machinery or equipment. In addition, they shall not have natural frequencies within 0.4 times other machinery or equipment exciting frequencies between 0 and 500 Hz. If the equipment being measured contains internal sound isolation mounts, the weight of the fixture shall be great enough to permit these internal mounts to function properly. The weight of the fixture shall not exceed 30 percent of the total weight of the equipment. For equipment whose weight exceeds 2,000 pounds, use of the mounting fixture of figure 1 is recommended. It is preferred that equipment items be bolted directly to the fixture; however, the optional mounting pads and clamps shown on figure 1 may be used to attach the items. If, in specific cases, the mounting fixture of figure 1 cannot be used, the alternative mounting fixture shall be approved by the contracting activity. The combined assembly of equipment item and mounting fixture shall be resiliently mounted and oriented so that the item is in its normal shipboard installation position.

5.7 Calibration of instrumentation. Instrumentation used shall have been calibrated and have been found to meet the requirements specified herein.

5.7.1 Laboratory calibration. A laboratory calibration shall be made of all vibration measuring instrument components within 12 months prior to each use, or after exposure to mechanical shock or other unusual disturbance, or upon request by the Government inspector. All calibration instrumentation, including the accelerometer calibrator used for field calibration (see 5.7.3), shall have been calibrated within 6 months prior to each use traceable to the National Bureau of Standards. The laboratory calibration of the components shall be accurate within the instrument manufacturer's specifications or plus or minus 1 dB, whichever is more stringent.

5.7.1.1 Transducer calibration. Calibration of field transducers shall be performed by one of the methods specified in ANSI S2.2 within 12 months prior to each use. It is recommended that transducers intended for use with voltage amplifiers be calibrated with the particular cable and amplifier to be used in making the field measurement. When secondary transducers are used, they shall be kept under controlled conditions in the manufacturer's laboratory and used only for calibrating the transducers used for equipment measurements.

5.7.2 Electrical calibration for vibration measuring system. A calibration of the complete vibration measuring system including transducer or simulated transducer, preamplifiers, meter, analyzer, level recorder or plotter or digital printer, magnetic tape recorder, as applicable and so forth, shall be made by introducing known voltages and frequencies in series with the transducer. Cables and connectors shall have the same electrical characteristics (impedance, frequency response, capacitance, etc.) as those used during equipment measurement. Whenever any component of the measuring system is changed, a laboratory calibration shall be performed for the new component, and an electrical calibration shall be made with the new component in the system. The system calibration shall be accurate within plus or minus 1 dB.

5.7.2.1 Frequency response. Known voltages at known frequencies shall be introduced into the system such as to simulate the transducer output, and the level shall be recorded. The frequencies selected shall be:

(a) For analyzers with fixed filter sets, the band-center frequency of each filter in the specified frequency range.
(b) For analyzers with tunable filter sets used to scan continuously, a band of frequencies at the lower limit, upper limit, and at least two intermediate frequencies (including 500 Hz if within the scanning range) in each frequency range scanned.

5.7.2.2 Linearity evaluation. At a low frequency, at 500 Hz, and at a higher frequency, calibration shall be made at the following voltages:

(a) Equal to the lowest accelerometer output required by the applicable equipment specifications.
(b) 20 dB greater than that in (a).
(c) 40 dB greater than that in (a).
(d) 60 dB greater than that in (a).

5.7.3 Field calibration. For each work shift, prior to making measurements, an electrical calibration check shall be made of the vibration measuring system exclusive of the accelerometer by introducing a known calibration signal in place of the accelerometer signal and recording the level at the following frequencies (for field calibration, the accelerometer may be disconnected from the system):

(a) For analyzers with fixed filter sets, at 32, 125, 500, 2000, and 8000 Hz.
(b) For analyzers with tunable filter sets, at representative frequencies within each range of frequencies scanned.

In addition to system electrical field calibrations, the total vibration measuring system, including the accelerometer, shall be checked for at least one frequency using an accelerometer calibrator. This total system calibration using an accelerometer calibrator shall be conducted at the beginning of each day, and at the end of the equipment measurements. If measurements commence with one day on another unit, the final system calibration for the previous unit may serve as the initial calibration for the next unit. Also, whenever any component of the measuring system is changed, a field calibration shall be made with the new component in the system. Field calibration shall be accurate within plus or minus 2 dB.

5.8 Equipment operating conditions during measurements. Equipment operating conditions shall be as specified herein and the contract or order (see 6.3).

5.8.1 Normal conditions. Equipment shall be operated under normal energized operating conditions, including sufficient warmup time to reach normal operating temperatures. Multiple speed equipment shall be measured at each operating speed. Variable speed equipment shall be operated at maximum, 1/2, and minimum speed (5 percent of maximum if equipment can be operated down to zero speed) and shall be scanned over its entire operating range. Where equipment has pumps or fans as components, these components shall operate during measurements.

(a) Similarly, variable flow equipment, such as valves for throttling service, shall be operated at maximum, 1/2, and minimum flow (5 percent of maximum if equipment can be operated down to zero flow), and shall be scanned over its entire operating range. Equipment shall also be measured at other intermediate speeds or flow rates as recommended by the equipment manufacturer and approved by the contracting activity and where a resonance or noise peaking is detected.

(b) Where equipment operates as the result of a signal, a representative signal shall be used to energize the equipment during measurements.

5.8.2 Ambient measurement conditions. Ambient measurements shall be made with the equipment not operating for each transducer and location under the normal environmental conditions that will be present when the equipment noise measurement will be obtained.

5.8.3 Special operating conditions. If operating conditions other than those specified in 5.8.1 are required (see 6.3), such as during change of operating mode including stopping and starting of the equipment, these special requirements shall be specified in the equipment specifications.

5.9 Selection of units. Unless otherwise specified (see 6.3), measurements to determine compliance with structureborne acceptance criteria shall be made on every unit with the following exception: for nonrotating, nonreciprocating, type III equipment, if the first three units of a design are below the criteria by 10 dB or more at all frequencies, following units shall be selected for test in accordance with the sampling procedures for the applicable selective testing as specified in the equipment specifications.

5.10 Reports. When specified in the contract or order, a test report for each equipment measured shall be prepared (see 6.4).

5.11 Warning plate. All equipment which meets the criteria of this standard shall be prominently identified by affixing a warning plate bearing the legend "Quiet Design Equipment - Handle with Extreme Care". The plate shall be either type A or B of MIL-P-15024. Unless otherwise specified (see 6.3), this requirement applys only to rotating and reciprocating equipment.

5.12 Drawing and technical manual information. In addition to the information required on drawings by the applicable equipment specification, the assembly drawings shall contain specific notes as to assembly procedures, special tools, and tolerances to be maintained during overhaul so that machines may be restored to designed level of quietness. The location of all attachment points for accelerometers used in measuring structureborne vibration shall be shown on the drawings and suitable means shall be indicated for the protection and preservation of these attachment points. Maintenance information pertinent to quietness, including assembly techniques and procedures, shall be included in technical manuals required by the acquisition documents. The title block of assembly drawings of all electrical power equipment shall include the words "Special Quiet Design (controller or transformer, etc.) MIL-STD-740-2". Existing drawings are not required to be revised unless the drawings are required to be changed for other reasons.

6. NOTES

6.1 Intended use. This standard is intended for use for equipment acquisition testing.

6.1.1 This standard also prescribes certain warning plate requirements and drawing and manual information requirements for shipboard equipment (see 5.11 and 5.12).

6.2 Technical proposals. When this standard is invoked in acquistions which require technical proposals for evaluation, the following data should be included in those proposals:

(a) A list of recommended specification changes which will improve the quietness of equipment and assure meeting the acceptance criteria. An estimate of the amount of improvement in quietness, and the change, if any in other characteristics should accompany each proposed change to the equipment specifications.
(b) Outline of the facilities to be employed for structureborne measurements, and any additional features proposed for installation to comply with the test requirements of the equipment specifications.
(c) A list of features to be incorporated in the equipment design for reduction of structureborne levels.
(d) A list of actions that will be taken to assure achievement of specified levels.

6.3 Implementation guidance. When this standard is invoked, the following should be specified:

(a) Acceptance criteria. The structureborne sound acceptance criteria of figure 2 are provided for guidance and use only when other criteria are not specified. Either invoke figure 2, as applicable, or specify separate criteria. Acceptance criteria will be based on the design of the machinery and consideration of intended service, overall ship operational requirements, and prior experience with similar acceptable machinery. Acceptance criteria should be in terms of structureborne vibratory acceleration levels (L_a) expressed as one or more of the following:

(1) Maximum permissible narrowband L_a.
(2) Maximum permissible one-third octave band L_a.
(3) Maximum permissible narrowband L_a over a portion of the frequency range and maximum permissible one-third octave band L_a over the remaining frequency range.
(4) Maximum permissible narrowband L_a at specified frequencies such as rotational, twice electrical line frequency, gear mesh frequency, etc.

(b) Sampling procedures for equipment when sampling is desired (see 4.1).
(c) If an equipment evaluation plan is required (see 4.2).
(d) Whether the Government is to be notified of testing, and if so, which organization is to be notified and how long the advance notice time is to be (see 4.3).
(e) The type assigned to the equipment (see 5.1).
(f) Whether the Government is to be notified of failure, and if so, which organization is to be notified (see 5.1(a)).
(g) Measurement locations if the measurement locations are not to be in accordance with 5.2.1 and 5.3. If compound mounts or isolators are specified or anticipated it may be advantageous to take exception to 5.3.1(a)(2) and specify that additional measurements also be taken on the intermediate mass of the isolation system.
(h) The frequency range for measurements to be specified if the range of 9 to 11,225 Hz is not used (see 5.2.2.1 and 5.2.2.2.1).
(i) If narrowband criteria is to be invoked, the minimum analysis bandwidth to be specified (see 5.2.2.2). Measurement locations should also be specified, if other than those of 5.3.1.
(j) Whether the accelerometers are to be attached directly to the equipment rather than to a mounting block (see 5.4.1(a)).
(k) Whether the mounting blocks are to be welded or brazed to the equipment rather than cemented (see 5.4.1(g) and (h)).
(l) Whether specific methods and materials for permanently marking measurement locations are required (see 5.4.1(i)).
(m) Mounting procedure, if not in accordance with 5.6.
(n) The weight of the shipboard bedplate or subbase (see 5.6.1).
(o) Whether a mounting fixture is required (see 5.6.2).
(p) Equipment operating conditions during structureborne vibration test (see 5.8).
(q) Other operating conditions required (see 5.8.3).
(r) Whether an alternate selection of units plan is to be used and, if so, what the plan is to be (see 5.8).
(s) If a test report is required (see 5.10).
(t) If warning plate is required for equipment which is nonrotating or nonreciprocating (see 5.11).
(u) Technical proposal, if required (see 6.2).

6.4 Data requirements. When this standard is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of DoD FAR

Supplement, Part 27, Sub-Part 27.410-6 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard is cited in the following paragraphs.

Paragraph no.	Data requirement title	Applicable DID no.	Option
4.2	Equipment structureborne vibratory acceleration measurement plan	DI-HFAC-80273	----
4.3	Notification of tests	DI-T-23731	----
5.1	Sound test failure notification and recommendations report	DI-HFAC-80271	----
5.10	Equipment structureborne vibration acceleration measurements test report	DI-HFAC-80274	----

(Data item descriptions related to this standard and identified in section 6 will be approved and listed as such in DoD 5010.12-L., AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.5 Subject term (key word) listing.

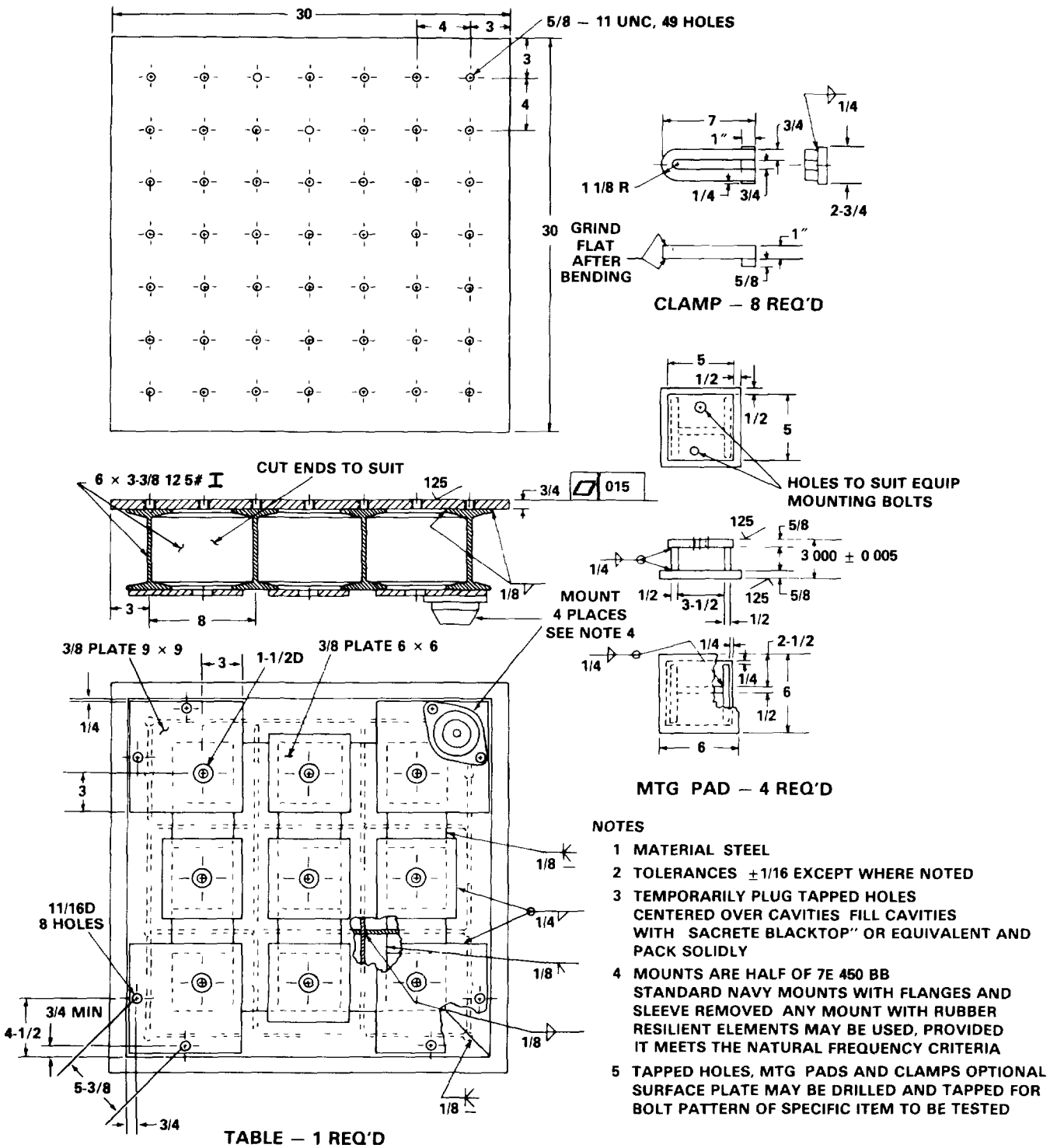
Distributed isolation material
Fast fourier transform
Reference vibratory acceleration
Structureborne vibratory acceleration measurements
Acceptance criteria, shipboard equipment

6.6 Supersession data. This standard covers structureborne vibratory acceleration measurements and acceptance criteria of shipboard equipment formerly covered by MIL-STD-740B(SHIPS).

6.7 Criteria equivalency. The criteria in this standard are equal to those in MIL-STD-740B(SHIPS), except that type IV is new and it is stated that valves are type II items.

6.8 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project HFAC-N004)



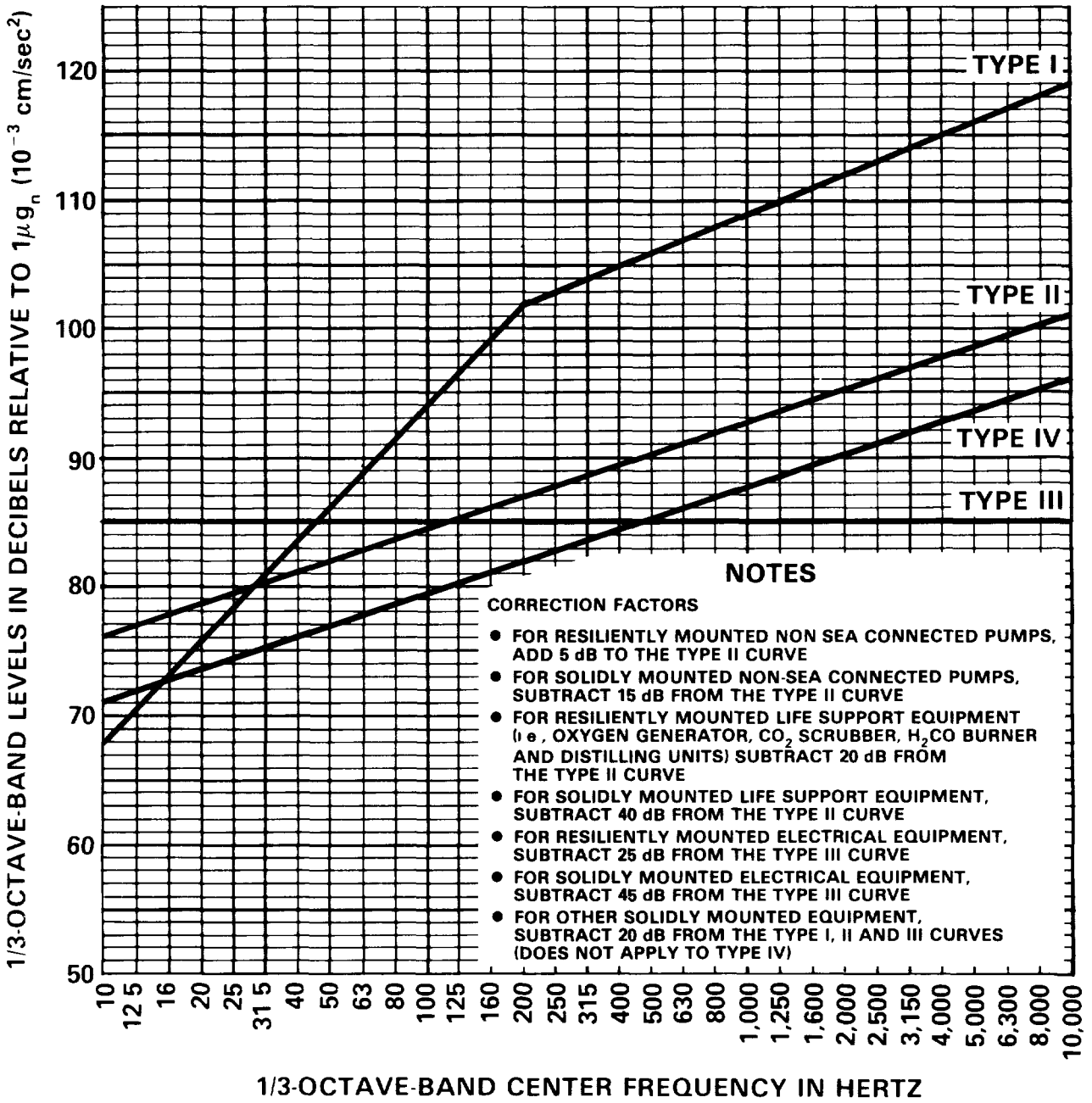
NOTES

1. MATERIAL STEEL
2. TOLERANCES ±1/16 EXCEPT WHERE NOTED
3. TEMPORARILY PLUG TAPPED HOLES CENTERED OVER CAVITIES FILL CAVITIES WITH "SACRETE BLACKTOP" OR EQUIVALENT AND PACK SOLIDLY
4. MOUNTS ARE HALF OF 7E 450 BB STANDARD NAVY MOUNTS WITH FLANGES AND SLEEVE REMOVED ANY MOUNT WITH RUBBER RESILIENT ELEMENTS MAY BE USED, PROVIDED IT MEETS THE NATURAL FREQUENCY CRITERIA
5. TAPPED HOLES, MTG PADS AND CLAMPS OPTIONAL SURFACE PLATE MAY BE DRILLED AND TAPPED FOR BOLT PATTERN OF SPECIFIC ITEM TO BE TESTED

All dimensions shown are in inches.

SH 131829

FIGURE 1. Standard test fixture.



SH 131830

FIGURE 2. Structureborne vibratory acceleration acceptance criteria.

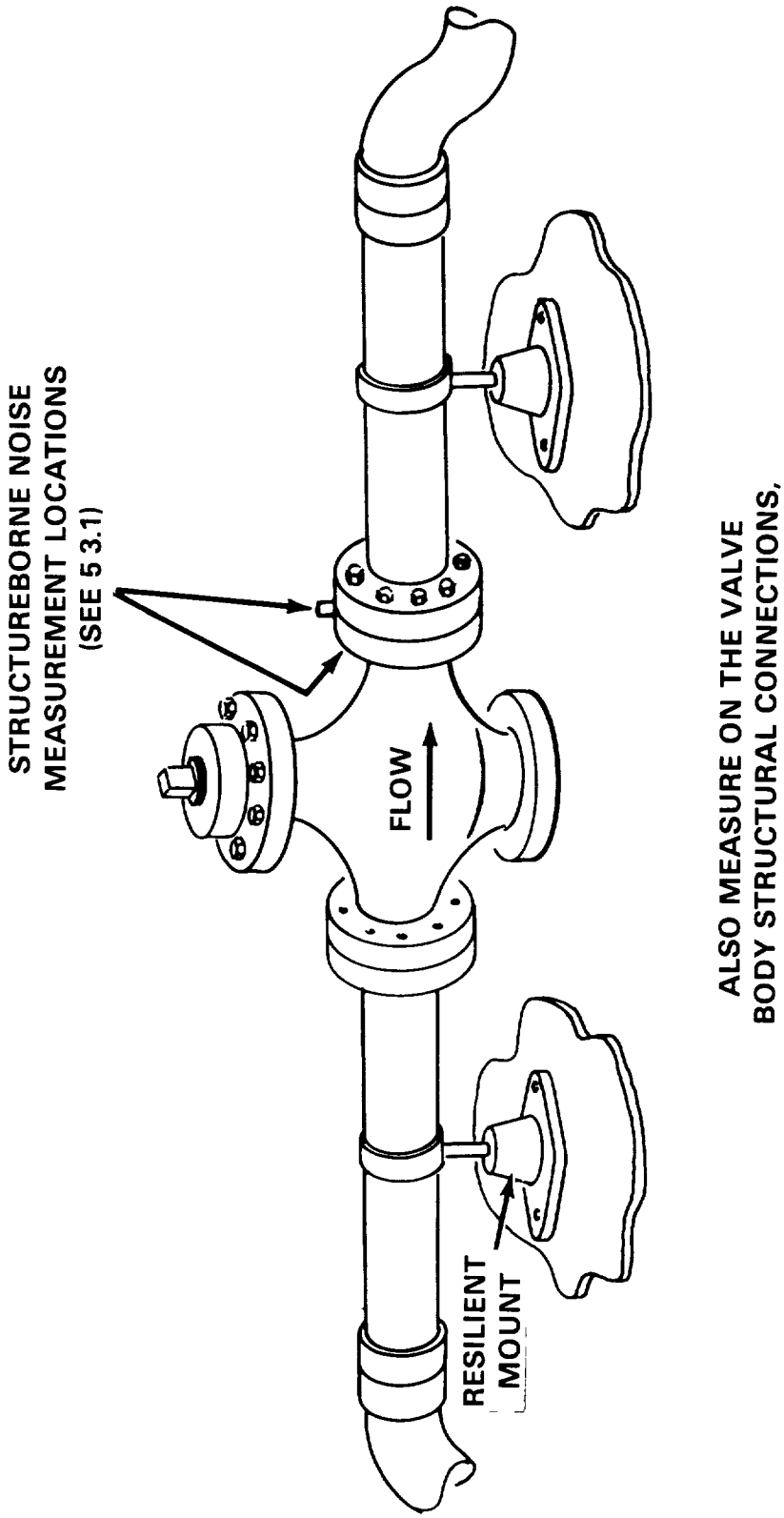
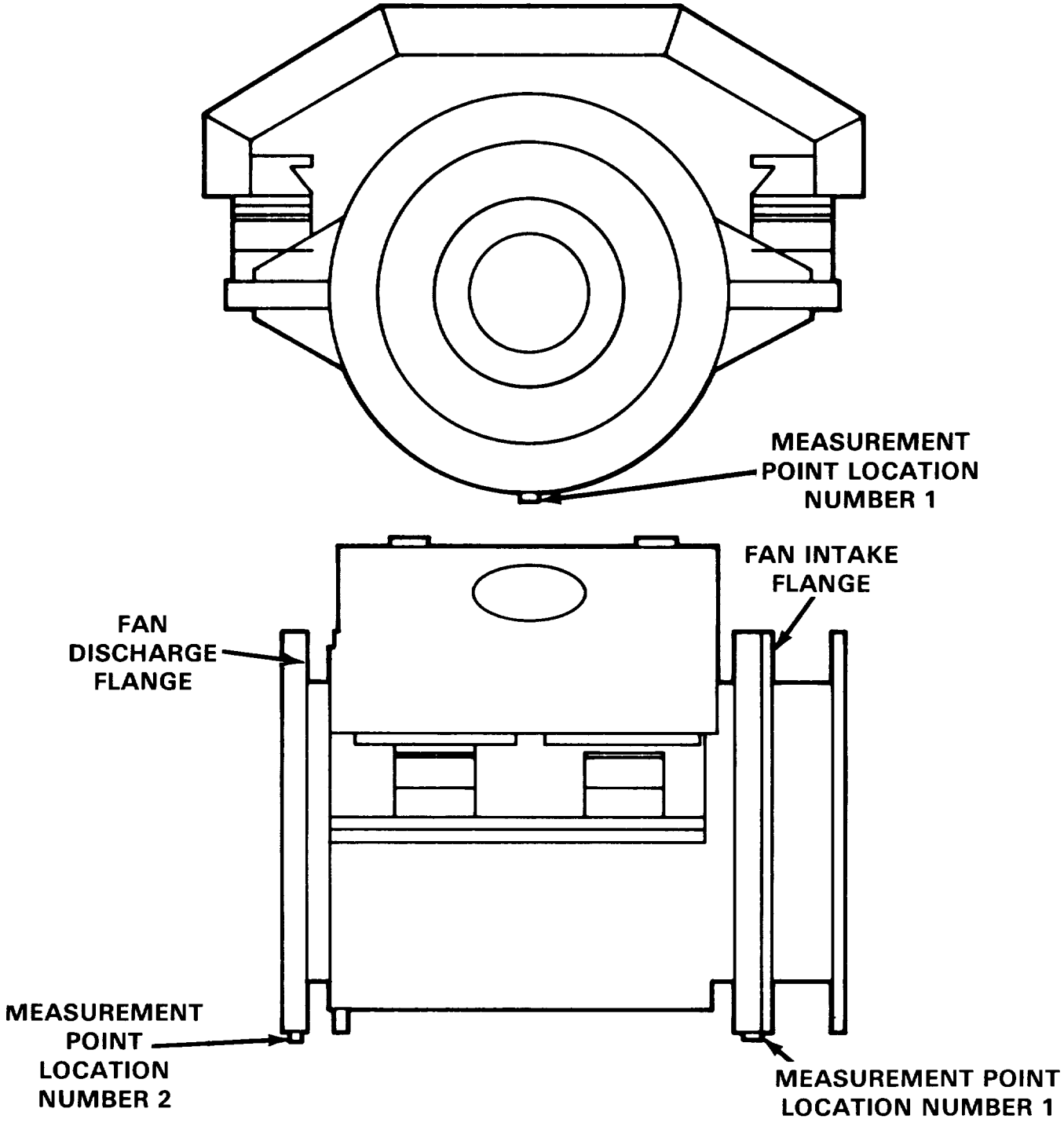


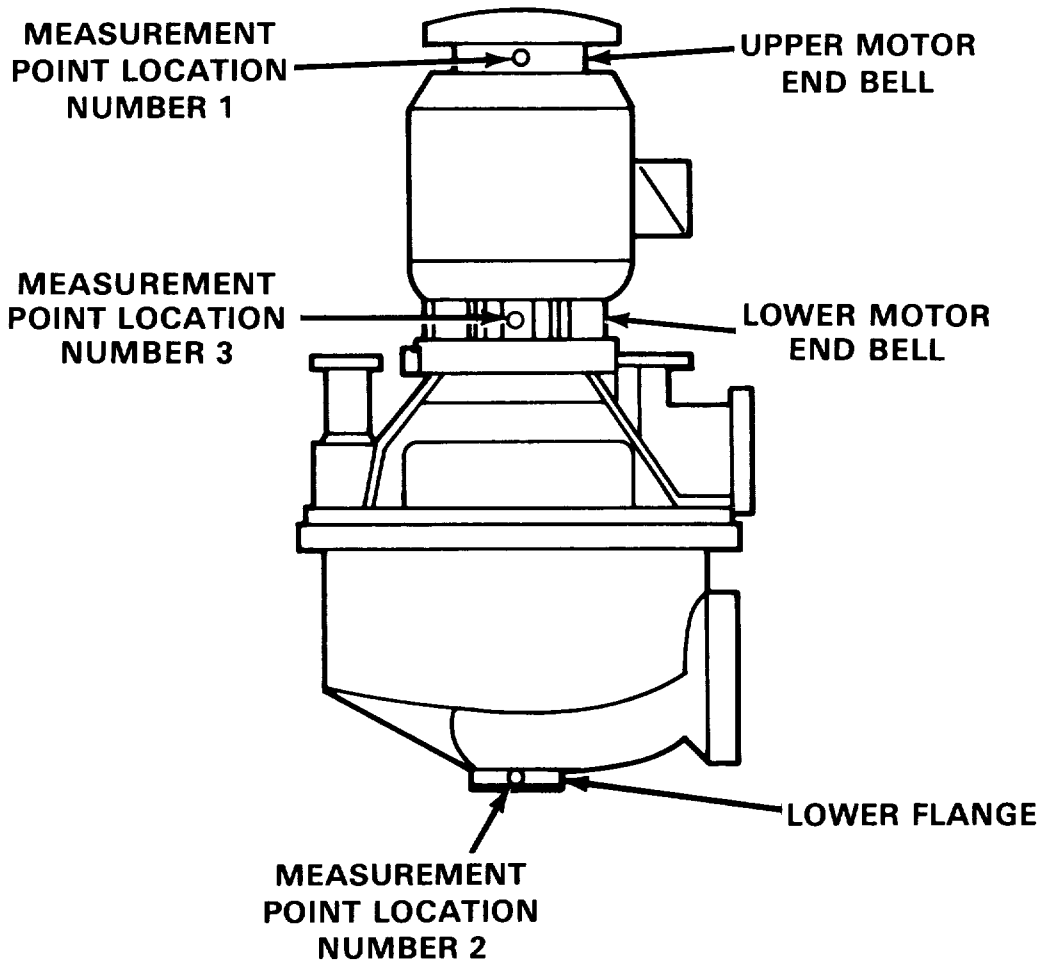
FIGURE 3. Valve measurement point locations.

SH 131831



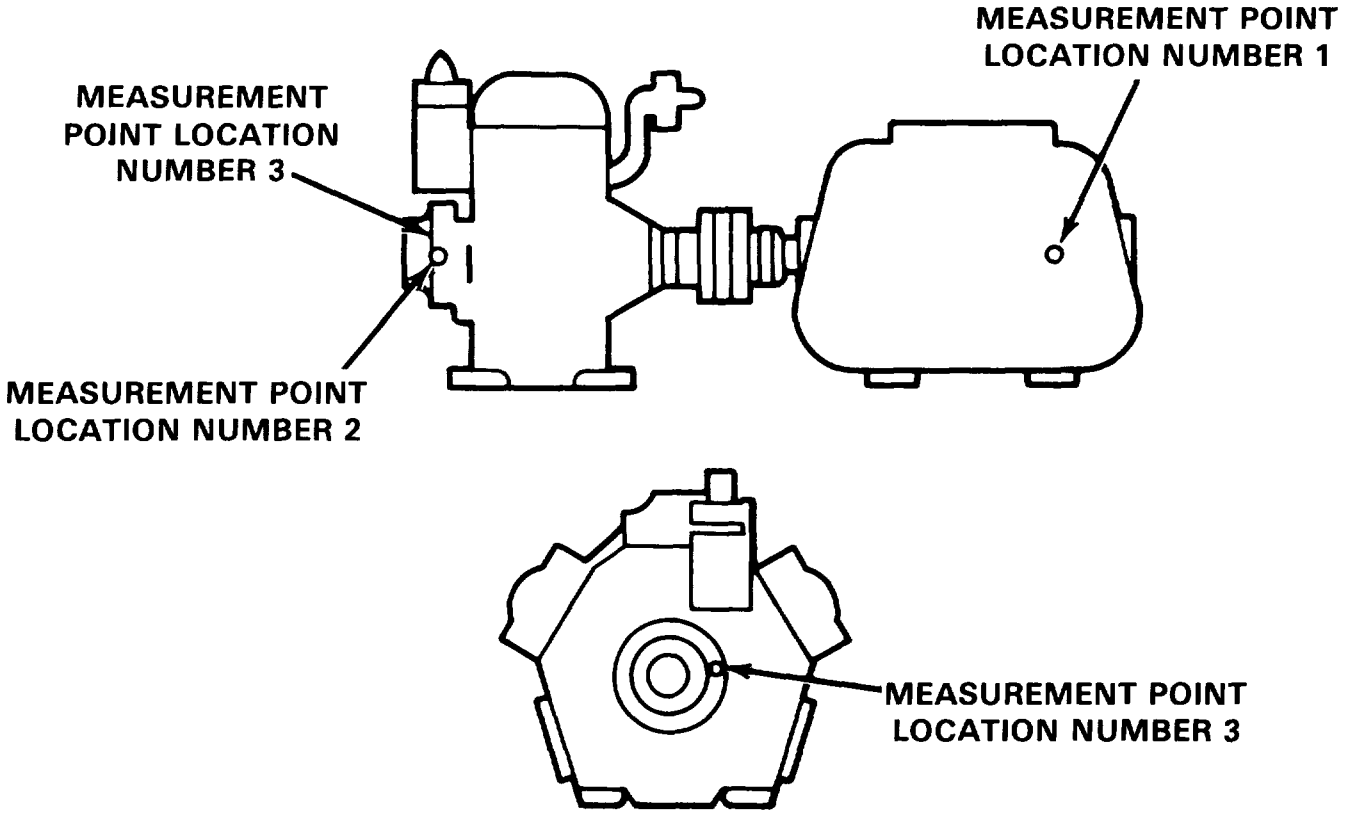
SH 131832

FIGURE 4. Vaneaxial fan measurement point locations.



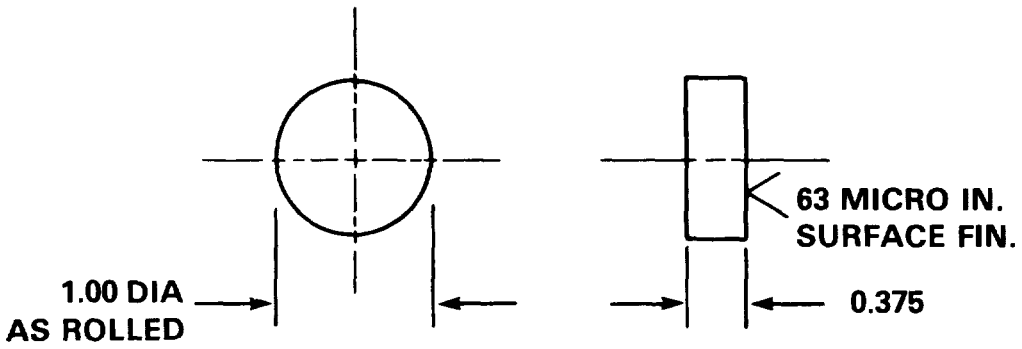
SH 131833

FIGURE 5. Motor driven pump measurement point locations.



SH 131834

FIGURE 6. Motor driven compressors measurement point locations.



ACCELEROMETER MOUNT
MATL COLD DRAWN STEEL
AISI TYPE 12L14

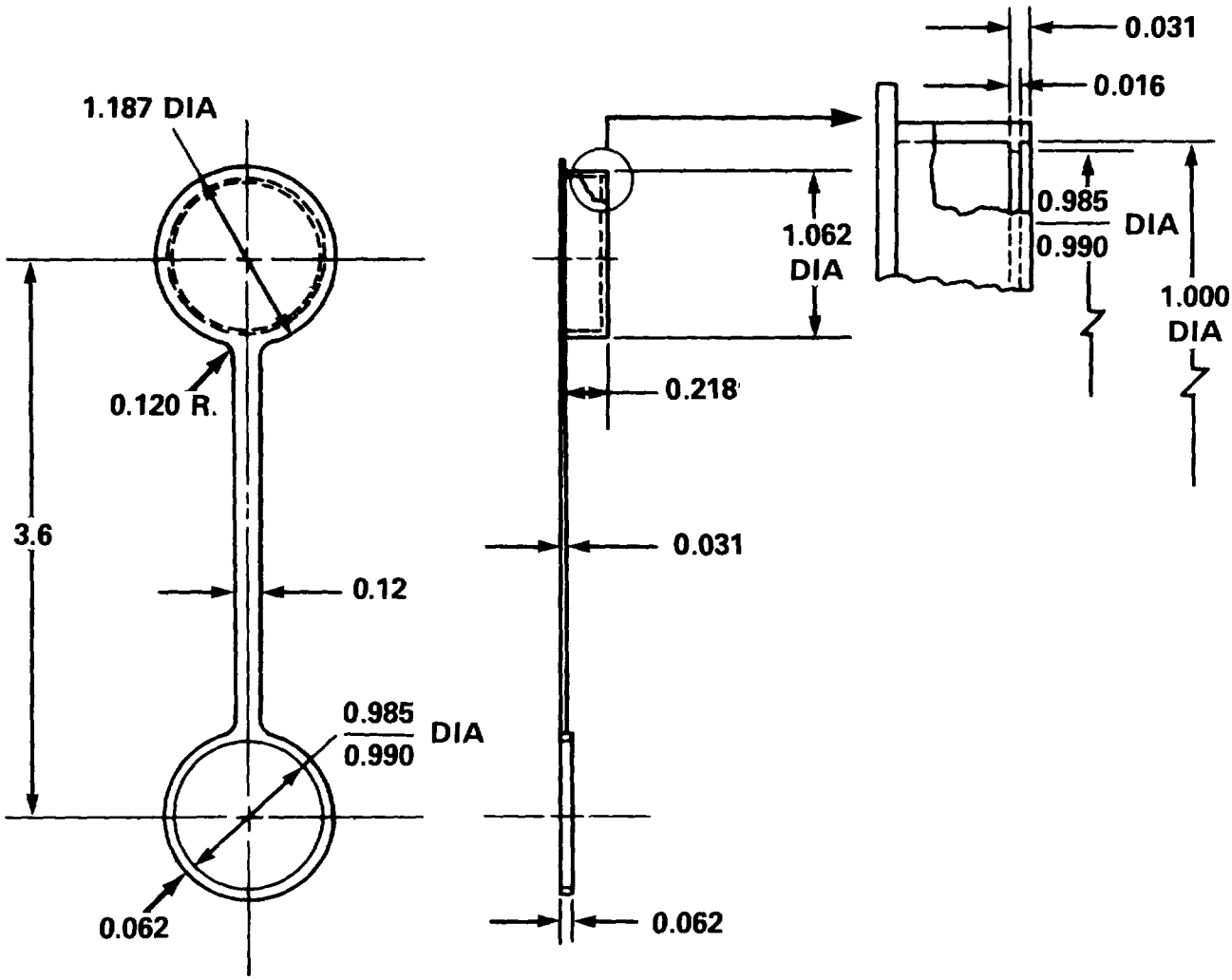
NSN 9Z5340-01-121-0176 APPLIES AS OF 1985

ACCELEROMETER MOUNT FOR USE FOR ATTACHMENT AT ADDITIONAL LOCATIONS WITH MAGNETIC HOLDING CLAMP, NSN 2H 6625-00-444-2499 WHICH APPLIES AS OF 1985

All dimensions shown are in inches.

SH 131835

FIGURE 7. Accelerometer mount.



PROTECTING CAP
MATL POLYPROPYLENE WITH RED DYE
FED L-P 391-C TYPE 1 (NATURAL TENITE 4231)

NSN 1H5340-01-127-5236 APPLIES AS OF 1985

All dimensions shown are in inches.

SH 131836

FIGURE 8. Protecting cap.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2 DOCUMENT TITLE
MIL-STD-740-2(SH)	STRUCTUREBORNE VIBRATORY ACCELERATION MEASUREMENTS AND ACCEPTANCE CRITERIA OF SHIPBOARD EQUIPMENT

3a. NAME OF SUBMITTING ORGANIZATION	4 TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ OTHER *(Specify)* _____

5 PROBLEM AREAS

a. Paragraph Number and Wording

b Recommended Wording

c Reason/Rationale for Recommendation

6 REMARKS

7a NAME OF SUBMITTER *(Last, First, MI)* – Optional	b WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8 DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426 PREVIOUS EDITION IS OBSOLETE

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NOTE This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document*(s)* or to amend contractual requirements.

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