METHOD 523.4

VIBRO-ACOUSTIC/TEMPERATURE

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METHOD 523.4

VIBRO-ACOUSTIC/TEMPERATURE

NOTE: Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4.2.2, and Annex C. Apply the general guidelines for laboratory test methods described in Part One, paragraph 5 of this standard.

1. SCOPE.

1.1 Purpose.

The vibro-acoustic/temperature procedure is performed to determine the synergistic effects of vibration, acoustic noise, and temperature on externally carried aircraft stores during captive carry flight. Such determination may be useful for, but not restricted to the following purposes:

a. To reveal and correct design weaknesses (Test, Analyze and Fix (TAAF) test).

b. To determine whether a design meets a specified reliability requirement (Reliability Demonstration test).

c. To reveal workmanship or component defects before a production unit leaves the place of assembly (Screening test).

d. To estimate the Mean Time Between Failure (MTBF) of a lot of units based upon the test item's time to failure of a small sample of the units (Lot Acceptance test).

e. To determine the relative reliability among units based upon the test item's time to failure of a small sample of the units (Source Comparison test).

1.2 Application.

For captively-carried stores, this method is intended primarily to test electronics and other electro-mechanical assemblies within the store for functionality in a vibro-acoustic/temperature environment. As an incidental part of the testing, thermal variation may induce changes in moisture exposure of the store and the effects of such exposure must be noted when interpreting the test result data. Typical applications include:

a. development of a more reliable store design prior to production.

b. assessment of the potential for satisfaction of the reliability requirement for a store.

c. manufacturer's internal testing to assure delivery of reliable units during production.

d. determination of the acceptance of a lot prior to delivery.

e. determination of the relative differences in quality from two sources for establishing production buy proportions.

1.3 Limitations.

This method is not intended to provide for:

a. An environmental design qualification test of a store or any of its individual components for functionality. (For such testing see Method 500 Altitude; Method 501 High Temperature; Method 502 Low Temperature; Method 503 Temperature Shock; Method 507 Humidity; Method 513 Acceleration; Method 514 Vibration; Method 515 Acoustic Noise; Method 516 Shock; Method 517 Pyroshock; and Method 520 Temperature, Humidity, Vibration, Altitude).

b. An environmental design qualification test of a store airframe or other structural components for structural integrity.

c. Any test to satisfy the requirements of the Life Cycle Profile except that for the combined vibration, acoustic, and temperature environments related to reliability testing.

2. TAILORING GUIDANCE.

2.1 Selecting the Vibro-Acoustic/Temperature Method.

After examining requirements documents and applying the tailoring process in Part One of this standard to determine where the vibro-acoustic/temperature environments are anticipated in the life cycle of the materiel, use the following to confirm the need for this method and to place it in sequence with other methods.

2.1.1 Effects of the Vibro-Acoustic/Temperature Environment.

Possible effects of a combination of vibration, acoustic noise, and temperature include all effects that these factors can cause separately (see Methods 514, 515, and 520). In addition, increased stress as a result of moisture from thermal change may produce possible effects seen in Methods 501, 502, 503, and 507. The combined vibration, acoustic noise, and temperature environments may interact to produce effects that would not occur in any single environment or a lesser combination of environments. Items in the discussion to follow point to significant effects of mechanisms applicable to this method.

2.1.1.1 Relative Importance of Environmental Stresses.

Not all environmental stresses contribute equally to materiel deterioration or failure. Analysis of service-use failures caused by aircraft environmental stress on the store (paragraph 6.1, reference a) has identified the following four most important causes of failure:

a. loading of the store through captive carriage,

b. temperature,

c. vibration, and

d. moisture.

2.1.1.2 Other Environmental Stresses.

Consider the inclusion of other environmental stresses that may be important for particular materiel. In general, it is not appropriate to include comparatively rare occurrences of extreme stress levels that are better quantified in single environment methods described elsewhere in this standard. A general guideline for this determination for an individual stress is that, if a stress has a “fraction of time of occurrence” (FTO) less than 0.1 (10 percent) of the total time specified for the store’s MTBF, the condition may be considered too rare to be included in a test described by this method. In evaluating FTO, consider all in-service use environments and use the more severe of the two. Note that the term FTO is used here in place of the more traditional probability of occurrence. FTO is defined for a level of stress as the ratio of the time the store is under the stress condition divided by the total time of observation, e.g., the store’s mean time between failures. Probability of occurrence relates to the chances a stress event will occur, and may not relate directly to a single specific time interval. FTO can be shown to provide an estimate of the probability distribution of the level of stress and is a more precise term. A simple example of this difference is as follows: If the stress condition is the absolute value of the acceleration at a point in the store that is above 5g’s, the FTO is easily established from an auto-spectral density (ASD) estimate over a specified time interval. This implies a stationary Gaussian time history with zero mean and standard deviation as the square root of the area under the ASD estimate. The probability of occurrence relates to the number of times the 5g level is exceeded, but the total time above 5g may vary from one occurrence to the next, depending on the difference in ASD estimates and on the associated duration of each of the stationary Gaussian ASD estimates.

2.1.1.3 Operation.

Operating any materiel item produces stress that can cause failure. In the case of external aircraft stores, operation generally means providing full electrical power that produces thermal, electromagnetic, and electrochemical stress. Duty cycles (on/off), low and high voltage, power ripple, and voltage spikes may also be significant stresses. Even when the stress of operation is negligible, it is necessary to operate the materiel under test to detect the presence of failure. Many failures induced by temperature and some vibration-induced failures are reversible, at least initially. As the test continues, reversible failures tend to become irreversible. Thus, it is important to conduct functional tests while the environmental stresses are present.

2.1.1.4 Temperature.

The most severe temperature shock to internal components may come from powering the materiel when it is cold. In order to induce all the stresses related to temperature in their proper proportion, use a thermal model of the store to predict the temperatures and rates of change at several internal points under service mission profiles.

a. Ambient temperature. The greatest variations in ambient temperature occur near the surface of the Earth. The low temperature extreme exposure by a store is, in many cases, due to low ambient temperatures immediately preceding flight. This is because there is ample time for temperature soak and there is no internal power dissipation or aerodynamic heating. Hence, it is important to consider on-the-ground temperatures in determining the initial captive flight temperature. The test temperature cycle may need to include a simulated on-the-ground period in order to normalize the temperature for the next simulated mission phase; otherwise an uninterrupted sequence of simulated missions may tend to drive the average internal temperature up or down relative to real missions. NATO STANAG 4370, AECTP 230, and MIL-HDBK-310 (paragraphs 6.1, references b and c) provide ground ambient air temperatures and their probability of occurrence for various regions. The temperatures that are cited in the two documents are those measured for meteorological purposes, and do not include the heating effects of direct sunlight or cooling due to radiation into the night sky. Hence, in determining preflight temperatures, consider the effects of radiation heat transfer, and remember to convert from probability of occurrence to FTO in application.

b. Aerodynamic heating. During captive flight, the high convective heat transfer rate will cause the surface temperature of an external store to be near that of the boundary layer. The recovery air temperature in the boundary layer depends primarily on the ambient temperature and the speed of flight. The functional dependence is:

$$T_r = T_o \theta \left(1 + r(\gamma - 1)\frac{M^2}{2} \right)$$

where:

T_r = boundary layer recovery air temperature, °K (°R)

T_o = sea level air temperature (standard day), 288.16 °K (518.69 °R)

θ = ratio temperature at altitude to sea level temperature (standard day)

(varies with altitude in two altitude ranges, see Method 514.8, Annex D, Table 514.8D-V)

r = 0.87, boundary layer temperature recovery factor

γ = 1.4, atmospheric ratio of specific heats

M = flight Mach number

Since flight at high altitude, where the ambient temperatures are lowest, is usually at higher Mach numbers (>0.80), the low temperatures are generally mitigated by aerodynamic heating. Because of the dominance of boundary layer heat transfer, radiation heat transfer can be neglected in captive flight.

c. Power dissipation. Although the high heat transfer rate will tend to keep the surface of a store at the boundary layer recovery temperature, internal temperatures may be considerably higher due to power dissipation of electronic equipment. For this reason the duty cycle of the materiel being tested must be tailored to reflect realistic operation and it must be coordinated with the external temperature to achieve a good reproduction of the expected temperatures.

d. Temperature gradients. The strongest temperature gradients will usually be those associated with powering the materiel when it is cold. Temperature gradients will also occur due to changes in flight speed and altitude that change the surface temperature more rapidly than internal temperatures.

2.1.1.5 Vibration.

Vibration may cause mechanical fatigue failure of parts, abrasion due to relative motion, dislodging of loose particles that can cause electrical shorts, and degradation of electronic functions through microphonics and triboelectric noise. Experiments (paragraph 6.1, reference d) and theoretical analysis (paragraph 6.1, reference e) have shown that the relative likelihood of various failure modes change with vibration level. In order to reproduce the service failure modes in proper proportion, it is necessary to test at several levels, keeping the fraction of time (FOT) in each level the same as predicted for the service use. The vibration spectrum may be considered to consist of two parts: the low frequency part that includes those vibrations that can be transmitted from the aircraft, through the store attachments, into the store (this is not the only source of low frequency vibration, but it is the major one), and the high frequency part that is driven almost entirely by pressure fluctuations in the boundary layer acting directly on the surface of the store. Generally, the mechanical impedance of the store attachment is such that the division between low and high frequency is between 100 Hz and 200 Hz.

a. Low frequency vibration. The low frequency vibration primarily stresses the structure, including brackets, large circuit boards, and electromechanical devices (e.g., gyros, relays). In most cases it is driven by transmission from the aircraft; hence, input excitation through the normal attachment points with a mechanical shaker best reproduces the low frequency vibration. Use Method 514 as a guide. Note that fluctuating aerodynamic forces may also act in the low frequency range. For control surfaces, wings, or other structure with a large area-to-mass ratio, the direct aerodynamic forces may be dominant. For this reason, the low frequency vibration of the test item cannot be regarded as a test of the structural fatigue life for wings, fins, or their attachments. In general, separate tests on components are needed to determine structural fatigue life of these components.

b. High frequency vibration. Above the frequency at which the store attachments can transmit vibration, the vibration is driven by the boundary layer turbulence (paragraph 6.1, reference f). This vibration does not contribute to failure of the basic structure, but is often a cause of failure in electronics. The characteristics of the pressure fluctuations in the boundary layer are well known (paragraph 6.1, reference g). The significant aspects for external stores are:

(1) The pressure spectrum is almost flat, out to the highest frequencies to which stores' component parts respond (the -3dB point is about 4000 Hz). Hence, the vibration spectrum of an external store is determined almost entirely by its natural frequency responses.

(2) The RMS level of the pressure fluctuations, and hence the vibration, is approximately proportional to the dynamic pressure, q, that is a function of flight speed and altitude:

$$q = \frac{1}{2}\rho_0 \sigma V_a{}^2 M^2$$

where:

q = dynamic pressure, kN/m^2 (lb/ft^2)

ρ_0 = sea level atmospheric density, 1.2251×10^{-3} kg/m^3 (2.3770×10^{-3} lb sec^2/ft^4)

σ = ratio of local atmospheric density to sea level atmospheric density (standard atmosphere)

(varies with altitude in two altitude ranges, (see Method 514.8, Table 514.8D-V)

V_a = speed of sound at sea level (standard atmosphere), 340.28 m/sec (1116.4 ft/sec)

M = flight Mach number

Modern aircraft flight speed is typically measured in terms of calibrated air speed or Mach number. See Method 514.7, Annex A, paragraph 2.6, and Annex D, Table 514.8D-V (Dynamic pressure calculation) for a more detailed explanation and calculation methods. Determine the proportionality between vibration level at particular points in the store and flight dynamic pressure by flight measurements. If flight data cannot be obtained, use similarity to other stores (paragraph 6.1, reference h), or Method 514.8, Annex D, Table 514.8D-V, and Figures 514.8D-5, -6, and -7 as guidance.

2.1.1.6 Moisture.

Moisture, in conjunction with soluble contaminants, can result in corrosion. In conjunction with electrical power it may result in shorts. Freezing of water in confined spaces may produce mechanical stress. The test cycle should provide for diffusion of water vapor and condensation. The amount of water is generally not important for inducing failures, so humidity need not be controlled in this test. This test is not a substitute for corrosion tests, such as the humidity test (Method 507) or the salt fog test (Method 509).

2.1.1.7 Shock.

Shock can cause failure through mechanical stress similar to that induced by vibration. Shocks that are more nearly transient vibrations (many zero crossings), such as aircraft catapult and arrested landing shock may be included in this test. Short duration shocks such as pyrotechnic shocks associated with store or sub-munition launch, flight surface deployment, etc., are generally too difficult to reproduce at the store level. Ensure that these events that are potentially destructive to electronics are accounted for in other analyses and tests (See Method 517, Pyroshock, and Method 516, Shock).

2.1.1.8 Altitude.

Barometric pressure is generally not a stress for external stores. However, variation in pressure may enhance the penetration by moisture. Reduced pressure may increase the temperature due to reduced power dissipation and there may be increased electrical arcing. Test separately for resistance to arcing. Moisture penetration will generally take place without pressure variation and, in most cases, the amount of water entrained is not important so long as it is enough to provide internal condensation. Reduced heat transfer may be realized by restricting air circulation rather than reducing ambient pressure. In general, altitude simulation is not needed in this test.

2.1.1.9 Other Environments.

Although this method is intended primarily to reproduce the environmental stresses associated with the captive flight of external stores, it can be extended to include other phases of a store's life cycle provided the relative duration of those phases can be related to captive flight. For example, periods of shock and vibration representing transportation and handling have been included in some tests. Do not use environments in this test that are not expected to produce failures randomly distributed in time. For example, corrosive atmospheres and fungal growth are environments in which failures, if any, will occur only after a considerable time lapse. Store ejection shock, sand and dust, and water immersion are examples of environments for which failure either occurs or does not; these failures are associated with the event rather than being distributed in time. These environments are not appropriate for this method. Care is required in deciding which environments to include. For example, consider the case of a store that ejects sub-munitions, flares, chaff, or other items. In this case there will be a series of shock events that may be an important part of the continuing operational store environment. This may also result in open cavities in the store's external surface resulting in high intensity cavity noise for long periods.

2.1.2 Sequence Among Other Methods.

a. General. Use the anticipated life cycle sequence of events as a general sequence guide (see Part One, paragraph 5.5).

b. Specific to this method. This method applies to environmental stress occurring in the final phases of the store's environmental life cycle. When a single test item is subjected to this test and other environmental tests of this standard, perform this test after the tests representing earlier phases of the life cycle, but before tests representing store ejection/launch, free flight, target impact, etc.

2.2 Selecting a Procedure.

This method includes one test procedure that may be tailored to many test requirements.

2.3 Determination of Test Levels and Conditions.

Having selected this method, complete the tailoring process by identifying appropriate parameter levels and applicable test conditions and techniques for this procedure. Base these selections on the requirements documents, the Life Cycle Environmental Profile (LCEP), and information provided with this procedure. Consider the following when selecting test levels. Unlike other methods in this standard, this method does not contain any default values for test conditions. The combinations of vibration, acoustics, temperature, and duty-cycle environment are too complex and the variety of materiel applications too great for such detailed instruction to be given here. Instead, this method provides guidance for writing a test procedure that will be more or less unique to the materiel and test item. Annex A provides a detailed example of the development of test levels and conditions. Before attempting to apply the method, study the example in the Annex. In determination of test levels and conditions, identify the following:

a. Mission characterization to develop a composite aircraft/store mission profile.

b. Mission analysis to develop:

(1) Mission temperature analysis for development of a mission temperature profile over time;

(2) Mission vibration spectra identification for development of a mission vibration profile over time[1];

(3) Mission operational duty cycle for functional performance of the store over time.

2.4 Test Item Configuration.

a. General. See Part One, paragraph 5.8.

b. Specific to this method. The configuration of the test item strongly affects test results. Use the anticipated configuration of the materiel in the life cycle profile. As a minimum consider the store captive carry service use environment.

3. INFORMATION REQUIRED.

3.1 Pretest.

The following information is required to conduct a vibro-acoustic/temperature test:

a. General. Information listed in Part One, paragraphs 5.7, 5.8, and 5.9; and Part One, Annex A, Task 405 of this standard.

b. Specific to this method.

(1) A written, step-by-step procedure for conduct of the test that implements the test plan. Include the recording and documenting of test events and measurements. It may include other existing procedures by reference; but explicitly include any procedures related to safety.

(2) Quantity of items to be tested.

(3) Composite mission profile. Include in the detailed environmental test plan (DETP) (either directly or by reference), information used in designing the composite mission profile. Include the following:

(a) The particular environmental and operational variables to be controlled in the test (a minimum set includes vibration level, vibration spectrum, skin temperature, and duty cycle).

(b) The mission profiles, including aircraft types, store load, and percentage of occurrence of different missions.

(c) The climatic region of operation and the distribution of ambient temperatures.

(d) Derivation of the composite mission profile; including captive flight vibration measurements, temperature measurements, and thermal models.

(4) Test cycle. The test cycle defines the time history of the controlled and monitored variables and the performance of functional tests. The environmental test cycle is the product of a composite mission cycle and a climatic offset cycle.

(a) Composite mission cycle. This is a time history of the environmental and operating stresses to be imposed repeatedly at different offset climatic temperatures. All functional tests and other events such as shocks are identified in this time history. The duration, level, and other characteristics of

[1] Specified mission vibration spectra will be spectra to be replicated during vibro-acoustic testing. In replicating the spectra, combined vibration and acoustic excitation will be employed. The specification of mission acoustic spectra is of nominal importance since the in-service acoustic environment is not replicated directly.

each stress are defined. Include in this cycle, transitional periods to normalize temperatures between climatic offsets.

(b) Environmental profile charts. Use a chart (either graph or table) for each of the environmental variables to be controlled or monitored during the test that shows the intended value for the variable during the composite mission cycle. These charts will be for the standard-day diurnal temperature condition.

(c) Climatic offset table. Prepare a table of the temperature offsets in their order of application to successive composite mission cycles. Explain in the DETP the origin of these offsets and their scope (e.g., 95 percent worldwide). Also, include any transitional temperature conditioning periods between composite mission cycles.

(d) Test control method. Include in the DETP, the method to be used in controlling environmental stresses, the location and type of sensors, the use of open-loop or closed-loop control, and the tolerances for variables.

(5) Test completion criteria. Specific statement of what constitutes a complete test (e.g., number or type of failures, number of test cycles completed, etc.).

(6) Test log. Use a test log for written information and recording unusual events and anomalies. As a minimum, include the following:

(a) Time that the test item(s) is installed in the test facility and the number of the first composite mission cycle thereafter.

(b) Calibration of instrumentation and apparatus.

c. Tailoring. Necessary variations in the basic test procedures to accommodate LCEP requirements.

3.2 During Test.

Collect the following information while conducting the test:

a. General. Information listed in Part One, paragraphs 5.10 and 5.12, and in Annex A, Tasks 405 and 406, of this standard.

b. Specific to this method.

(1) A chronological record of events. Record all events that affect the test or interpretation of test results.

(2) A continuous record of environmental levels. Running record of all ambient and test environmental factors and levels. For example, room temperature and humidity, acoustic horns and shaker levels, skin and component temperatures, buffet events, shaker shock events, etc.

(3) A record of deviations. Chronological record of all deviations from intended levels and/or durations of test environments.

(4) Failure interpretation/disposition. Procedures for operations after failures occur, including fix, repair, and test restart.

3.3 Post-Test.

The following post test data shall be included in the test report.

a. General. Information listed in Part One, paragraph 5.13, and in Part One, Annex A, Task 406 of this standard.

b. Specific to this method.

(1) Test chronology. Listing of events, test interruptions, and test failures.

(2) Failure interpretation/disposition. Definitions of failures and failure categories. Procedures for operations after failures occur including fix, repair, and test restart.

(3) Test item disposition. Location, condition, and planned uses of the test item (e.g., returned to the manufacturer, held for further tests, etc.).

4. TEST PROCESS.

Ensure that the apparatus used to conduct the vibro-acoustic/temperature test on a store, hereafter referred to as a "test item," includes the capability of inducing the required range of temperature and vibration while, at the same time, operating and monitoring the function of the test item. Include the following considerations.

4.1 Test Facility.

Ensure that the apparatus used to conduct the vibro-acoustic/temperature test includes the following:

4.1.1 General.

The capability to induce the required range of temperature and vibration while, at the same time, operating and monitoring the function of the test item.

4.1.2 Acoustic Chamber.

Combined application of mechanical vibration and acoustic noise is generally required to reproduce the specified vibration response of test items at the monitoring points. The mechanical input through a vibration shaker system generally supplies the energy at lower frequencies (below about 100 Hz). Acoustic pressures cannot be practically controlled at frequencies below 100 Hz where transmission of vibration energy by mechanical means is practical. Acoustic energy providing vibrational energy at monitoring points becomes the major source of such vibrational energy at higher frequencies (above roughly 300 Hz) where mechanical vibration transmission through complex mechanical connections becomes impractical. The range between these frequencies is driven by a mixture of vibration and acoustics. See Methods 514 and 515 for further guidance.

4.1.2.1 Acoustic Chamber and Acoustic Source.

Ensure the chamber shape and dimensions provide for a uniform distribution of the acoustic field at frequencies above 150 Hz (paragraph 6.1, reference i). The facility must be capable of producing the required levels of acoustic energy over the range 150 to 2500 Hz. While an acoustic level of 155 dB will sometimes suffice, much higher levels (up to 165 dB) are sometimes needed. This level must be attainable with the test item and other required equipment in the chamber. Because acoustic levels of these magnitudes are difficult to produce, careful planning is required to ensure that the chamber is capable of producing the required environment. Typical apparatus consists of electrically driven air modulators coupled to the chamber by exponential horns.

4.1.2.2 Vibration Equipment.

To induce the lower frequency part of the vibration and to simulate exceptional dynamic events, the test item may be driven by one or more electrodynamic or electrohydraulic exciters. Ensure attachment to the exciters does not interfere with the acoustic field or significantly change the natural frequencies of the test item. With large, complex shaped, or unbalanced test items (cruise missiles, electronic countermeasures stores, munition dispensers, etc.), this is likely to require multiple exciters driving a softly suspended store through rod-and-collar drive links. For small, slender test items (air-to-air missiles, etc.) this may sometimes be accomplished by driving the test item through its usual interface with an aircraft, e.g., launcher. However, even for such small, slender test items, a softly suspended test item driven through a rod-and-collar arrangement may be needed. Typically, electrodynamic exciters are used. In cases where there are high levels of vibration required at low frequency (e.g., buffet vibration), electrodynamic exciters may not be capable of producing the required amplitudes (particularly the high velocity and displacement amplitudes). In these cases electrohydraulic exciters may be the better choice. Electrohydraulic exciters are not capable of producing the high frequencies required in typical avionics vibration tests.

4.1.3 Temperature Equipment.

Ensure the range of temperatures and rate of change of the test item's skin temperature is adequate to achieve the test profile. A typical range is -40 °C to +85 °C (-40 °F to +185 °F); the rate of change may be as high as 4 °C/min (7 °F/min). Temperature conditioning of the test item must be compatible with the acoustic field. In order to isolate the test item from the air in the acoustic chamber and the chamber walls, the test item may be enclosed in a thin, flexible shroud through which temperature conditioned air is ducted. This increases the thermal efficiency and permits high rates of temperature change. The shrouds must be transparent to the acoustic field. Making the shroud close fitting so as to raise the air speed around the test item enhances the heat transfer rate. Rip-stop nylon cloth has proven to be a suitable shroud material. Injection of liquid nitrogen is useful for achieving high rates of cooling. Air temperatures more extreme than the desired skin temperatures may be used to increase the heat transfer rate, but care must be taken to avoid creating excessive gradients along the surface.

4.1.4 Electrical Stress.

The operation duty cycle and the functional testing of the test item will provide the basic electrical stress. Cycle the test item on and off as dictated by the mission simulation. Correlate voltage variation or other electrical parameters with temperature. Reproduce additional electrical stresses such as voltage spikes, dropouts, and ripples if they are known to occur in service.

4.2 Instrumentation.

To meet the test environment specification, acceleration, acoustic pressure, and temperature will be the measurement variables, with acceleration the primary response monitoring variable. On occasion other environment measurement variables may be employed, e.g., to measure moisture or humidity. In these cases special consideration will need to be given to the equipment specification to satisfy the calibration, measurement, and analysis requirements. All measurement instrumentation must be calibrated to traceable national calibration standards (see Part One, paragraph 5.3.2). In addition, instrumentation to measure test item function may be required. In this case, obtain and adhere to suitable calibration standards. The measurement device and its mounting will be compatible with the requirements and guidelines provided in paragraph 6.1, reference j.

a. Accelerometer:

(1) Frequency Response: A flat frequency response within ± 5 percent across the frequency range of interest is required.

(2) Transverse sensitivity should be less than or equal to 5 percent.

(3) Nearly all transducers are affected by high and low temperatures. Understand and compensate for temperature sensitivity deviation as required. Temperature sensitivity deviations at the test temperature of interest should be no more than ±5% relative to the temperature at which the transducer sensitivity was established.

(4) Base Strain sensitivity should be evaluated in the selection of any accelerometer. Establishing limitations on base strain sensitivity is often case specific based upon the ratio of base strain to anticipated translational acceleration.

b. Microphone:

(1) An amplitude linearity within 10 percent from 5 percent to 100 percent of the peak pressure amplitude required for testing.

(2) A flat frequency response within ±10 percent across the frequency range 10 – 10000 Hz.

(3) Microphone and its mounting compatible with the requirements and guidelines in paragraph 6.1, reference j.

c. Temperature gage:

(1) An amplitude linearity within 10 percent from 5 percent to 100 percent of the peak temperature amplitude required for testing.

(2) A flat frequency response capable of detecting temperature rates at 50°C/min (90°F/min).

(3) Temperature gage and its mounting compatible with the requirements and guidelines in paragraph 6.1, reference j.

d. Other Measurement Devices. Consistent with the requirements of the test.

e. Signal conditioning. Use only signal conditioning that is compatible with the instrumentation requirements on the test, and that is compatible with the requirements and guidelines provided in reference m. In particular, filtering of the analog voltage signals will be consistent with the time history response requirements (in general, demonstrable sharp filter rolloff at the bandpass filter cutoff frequencies for acceleration and acoustic pressure, linear phase from DC to the filter cutoff for temperature gage), and filtering will be so configured that anomalous data caused by amplifier clipping will not be misinterpreted as response data, i.e., input to the amplifier will be filtered, but not the amplifier output. For acceleration related to shock data, filtering will require a linear phase filter from DC to the filter cutoff.

f. Special monitoring instrumentation concerns. To control the test it is desirable to apply information from all active instrumentation in a feedback loop. Specifically, any information that indicates an out-of-tolerance test stress (e.g., temperature too high) or an out-of-tolerance test item response (e.g., excessive current draw) is cause to stop the test and initiate an investigation to determine the cause. Paragraphs 4.3.3 to 4.3.8 provide guidance for functional, vibrational (acoustic plus mechanical), temperature, humidity and power monitoring/control to ensure the test requirements are met.

  (1) Functional monitoring.

  (2) Vibration monitoring/control.

    (a) Air modulators.

    (b) Mechanical stimulus.

  (3) Temperature monitoring/control.

  (4) Humidity monitoring.

  (5) Power monitoring.

4.3 Controls / Tolerances.

a. Calibration. Ensure all environment measurement devices, e.g., accelerometers, microphones, thermal gages, have calibrations traceable as noted in Part One, paragraph 5.3.2. Verify calibration of the system with a calibration device before beginning the test procedure. If not available, provide a suitable method for verification of the appropriate response. After processing the measured response data from the calibration device and verifying that measurements are in conformance with the specifications, remove the calibration device and perform the test on the designated test item. Calibrate equipment to record the function of the test item according to the test item performance specification.

b. Tolerances. For test validation and control of the test, use the environment measurement tolerances specified under the test procedure, and guidance provided in Method 514, paragraph 4.2.2. In cases in which these tolerances cannot be met, establish and document achievable tolerances and ensure they are agreed to by the cognizant engineering authority and the customer prior to initiation of the test. In any case, establish tolerances within the limitations of the specified measurement calibration, instrumentation, signal conditioning and data analysis procedures. Establish tolerances on equipment to record the functional performance of the test item according to the test item performance specification.

4.3.1 Test Interruption.

Test interruptions can result from two or more situations, one being from failure or malfunction of test chambers or associated test laboratory equipment. The second type of test interruption results from failure or malfunction of the test item itself during operational checks.

4.3.2 Interruption Due to Test Facility Malfunction.

a. General. See Part One, paragraph 5.11 of this standard.

b. Specific to this method.

  (1) Undertest interruption. If an unscheduled interruption occurs that causes the test conditions to fall below allowable limits, note the immediate conditions of the test item (temperature, etc.) and the point in the composite mission cycle, and stop the test. Determine the root cause of the undertest condition (e.g., the store is not achieving the proper skin temperature because of a Temperature Conditioning Unit (TCU) failure, or the desired vibration response levels are not being met because an acoustic

modulator valve assembly has failed). Take corrective action to get all test equipment in proper working condition. Return the test item to the required conditions prior to the interruption, and continue the test from that point.

(2) Overtest interruption. If the test item is exposed to test conditions that exceed allowable limits, give the test item an appropriate physical examination and operational check (when practical) before resuming the test. This is especially true where a safety condition may exist such as with munitions. If a safety problem is discovered, the preferable course of action is to terminate the test and reinitiate it with a new test item. (If this safety problem is not so resolved and test item failure occurs during the remainder of the test, the test results may be considered invalid.) If no problem is identified, reestablish pre-interruption conditions and continue from the point where the test tolerances were exceeded.

4.3.3 Interruption Due to Test Item Operation Failure.

Failure of the test item(s) to function as required during operational checks presents a situation with several possible options.

a. The preferable option is to replace the test item with a "new" one and restart from Step 1.

b. A second option is to replace / repair the failed or non-functioning component or assembly with one that functions as intended, and restart the entire test from Step 1.

NOTE: When evaluating failure interruptions, consider prior testing on the same test item and consequences of such.

4.3.4 Functional Monitoring.

Monitor test item functions continuously during the test. This may consist of a simplified measurement of overall performance. If so, perform a full functional evaluation at least once per environmental cycle. Full functional evaluations are recommended at both the high and low temperatures and at maximum vibration. Failures may be intermittent, irreversible, or reversible with changes in the environment. Ensure procedures for dealing with indicated failures are clearly defined. Verify functions that cannot be verified in the environmental test chamber by removing and testing the store at short intervals as compared to its expected MTBF. Note that any statistical assessment of the store reliability must take into account the test interval (paragraph 6.1, reference k). Statistical test plans such as those in MIL-HDBK-781 (paragraph 6.1, reference l), usually assume continuous monitoring.

4.3.5 Vibration Monitoring and Control.

Vibration is induced both by the acoustic field and by mechanical shakers. Experimentally determine the vibration and acoustic inputs required to provide the required store response as in paragraphs a. and b. below. Once the required vibration input has been established, input control the vibration exciter(s) to this measured signal by closed loop automatic control system(s). This will provide greater test consistency than trying to control vibration exciters with feedback from response measurements. Monitor the response and when significant differences between measure and required responses are detected, stop the test and determine the cause. Looseness or wear in the vibration input train, problems with monitoring transducer mounting or wiring, and differences in response of nominally identical stores may significantly affect response (paragraph 6.1, reference m). In particular, instrumented stores that have experienced many hours of severe captive flight conditions and which are used to calibrate vibration tests may be considerably less responsive than a new test store.

a. Air modulators. The acoustic field may be generated by air modulators supplied with low-pressure 239 kPa to 446 kPa (20 to 50 psig) air. These modulators are coupled to the reverberant chamber through exponential horns. Considerable acoustic power is required, so several modulators may be needed for one chamber. Horns having a lower cutoff frequency of approximately 200 Hz may be used. The drive signal to the modulators is shaped random noise; it may be supplied from a noise generator signal that is shaped by filtering or from a pre-recorded signal. The shape of the acoustic spectrum is determined by adjusting it to produce (approximately) the same vibration response in an instrumented store as the vibration response measured in captive carry of that store. Microphones monitor the acoustic level and spectrum. Refer to Method 515 for microphone placement, test level tolerances, and further guidance.

b. Mechanical stimulus. The drive signal to the electrodynamic and electrohydraulic shakers is shaped random noise; it may be supplied from a noise generator signal that is shaped by filtering or from a prerecorded signal. Determine the shape of the vibration spectrum by adjusting it to produce the same vibration response in an instrumented store as the vibration response measured in the captive carry environment of that store. Adjust the acoustic input first and maintain it during compensation of the shaker drive signal. After the shaker drive signal has been compensated so as to reproduce the desired response vibration, record the vibration spectra and levels at the shaker attachments to the store as secondary standards to be used during the test. During the test, monitor vibration level and spectra with accelerometers at these points along with the store response control points. Monitor these signals throughout the test. For closed loop control of the shakers use the vibration as measured at the shaker/drive system interface. When the shakers are used only to provide the low frequency portion of the vibration spectrum, closed loop control may not be necessary. Refer to Method 514 for test level tolerances and further guidance.

4.3.6 Temperature Monitoring and Control.

The temperature that defines the temperature test cycle is the store skin temperature that is measured and used for feedback control during the test. The air temperature may be driven to more extreme values (as much as 20 °C (36 °F)) beyond the store range) in order to increase the rate of transfer. Monitor the air temperature separately in order to avoid values outside this range. In developing the temperature cycle, measure the store skin temperature at several points to ensure even distribution of the temperature.

4.3.7 Humidity Monitoring.

Although humidity is not a controlled variable for Procedure I, the ducted airstream may be monitored for moisture content, either by dewpoint or relative humidity sensing. Moisture can collect on a store's surface when it has reached and holds a cold temperature that is below the dewpoint of warmer air following in the mission cycle. This is a normal and expected condition.

4.3.8 Power Monitoring.

Continuously monitor all electrical and other power inputs (e.g., hydraulic, compressed air) whether or not they are modified to simulated mission conditions. This monitoring provides an immediate indication of many types of failures and, with automatic controls, may serve to limit secondary failures.

4.4 Data Analysis.

a. Use an analog anti-alias filter configuration on all digitized signals that will:

   (1) not alias more than a five percent measurement error into the frequency band of interest.

   (2) have linear phase-shift characteristics for the temperature gage and acceleration shock from DC to the upper band edge.

   (3) have a uniform passband to within one dB across the frequency band of interest (see paragraph 4.2).

b. In subsequent processing of the data, use any additional digital filtering that is compatible with the anti-alias analog filtering. In particular, additional digital filtering must maintain phase linearity for processing temperature gage data and any acceleration shock data.

c. Analysis procedures will be in accordance with those requirements and guidelines provided in paragraph 6.1, reference j. If anomalies are detected, discard the potentially invalid measured response time history data.

4.5 Test Execution.

4.5.1 Preparation for Test.

a. General. See Part One, paragraph 5.8.

b. Unique to this method. Verify that environmental monitoring and measurement sensors are of an appropriate type and properly located to obtain the required test data.

4.5.2 Pretest Checkout.

The following steps describe in detail the pretest set-up and cycle check procedure. The purpose of the pretest set-up is to provide a level of confidence that the test specification can be met on a test item. In general, this pretest checkout will require adjustment of the vibration sources to provide the best reproduction of the in-service vibration. Vibration response is subject to the following three sources of error: spatial, spectral, and amplitude. Since it may not be possible to minimize all of these errors simultaneously, compromises between the three kinds of error must be based on technical analysis and judgment. To better define and understand the cause behind the source of errors, each error will be described briefly along with potential corrective measures to reduce the error. It is important to note that both the in-service measured and laboratory replicated vibro-acoustic fields are spatially non-homogeneous and highly random.

a. Relative spatial acceleration amplitude. Because the in-service acoustic and vibration environment result from many sources that cannot be replicated in the laboratory, relative vibration levels at different locations within the test item may not correspond with measured relative vibration levels of the store at the same locations in service. Reduction of this error may require relocation of attachment shakers, use of multiple shakers, a reorientation with respect to the acoustic field (from directional horns), or selective application of acoustic damping material. In addition, the effectiveness of the acoustic field in inducing vibration may vary with the air temperature within the shrouds surrounding the test item. In general, the test set-up provides fewer degrees of freedom for exciting the test item than the degrees of freedom available for the store in service. It is important to note that cross spectra are not usually specified from in-service measured data, nor are they considered a control parameter for the test. To some extent, the input excitation from various sources is assumed to be uncorrelated.

b. Spectral shape error. Because the in-service acoustic and vibration environment comes from many sources that cannot be replicated in the laboratory, the spectral shape at different locations within the test item may not correspond with the spectral shape of the test item at the same locations in service. This may be corrected by changing the spectrum of the acoustic and/or shaker drive signals or it may require changing the method of supporting the test item. Since cross spectra are not usually specified from in-service-measured data and are not considered a control parameter for the test, only limited correction may be possible.

c. Amplitude error. For stationary random data, generally the amplitude distribution is assumed to be Gaussian. However, for in-service measured data, the distribution may be non-Gaussian – particularly for high-level maneuver events. The test setup should check the test item amplitude distribution to assure that it matches the in-service measured amplitude distribution. This means that particular care must be given to inherent shaker control system amplitude limiting; e.g., 3σ clipping. For replication of a given autospectral density estimate with Gaussian amplitude distribution, ensure the shaker control system truncation is at a value greater than three times the RMS level (because of the long test durations it is important to have accelerations that exceed three times the RMS level). In general, to replicate an autospectral density estimate with a non-Gaussian amplitude distribution, specialized shaker control system software is required.

4.5.3 Test Setup and Cycle Check Procedure.

Step 1. Using an instrumented test item (not necessarily operable), assemble the test item and environmental apparatus into the planned configuration. If the planned test is based on in-service measured values, it is important that the sensors and their locations be identical to those used in these measurements. It is highly desirable that the identical test item used in the in-service measurements, with its instrumentation intact, be used in the test setup.

Step 2. Install and calibrate all sensors. Concurrently, test the function of any automatic alarm or abort mechanisms.

Step 3. Apply and adjust the acoustic stimulus to the minimum level. Verify the levels and spectral shape. Apply higher levels in steps until the required maximum is reached. Adjust the spectral shape as required at each level.

Step 4. Apply the adjusted acoustic stimulus at the lowest required level. Apply an arbitrary, low-level vibration stimulus. Measure vibration response and iteratively adjust the vibration drive signal to achieve the required responses.

Step 5. Adjust both the acoustic and vibration stimuli to their maximum levels. Adjust the vibration drive signal and, if necessary, the acoustic drive signal until the highest required levels of vibration response are achieved.

Step 6. Adjust acoustic and vibration stimuli to each of the required intermediate levels and measure the responses. If the responses at each level are reasonably close (engineering judgement required) to the required levels, maintain the calibrations for the highest response level and iterate to the other levels by changing the overall levels of the drive signals (accuracy of the simulation is more important at the higher levels). If response variation is strongly non-linear with the stimulus level, establish calibrations for each level.

Step 7. Apply the maximum temperature stimulus to the store. Adjust the temperature controller and ducting to achieve the desired skin temperatures and rates of change. Ensure the distribution of temperature values over the skin is within tolerances as determined from the thermal model. Ensure that required temperature rates-of-change can be achieved.

Step 8. Conduct a composite mission profile cycle, including power on/off and operational tests. Measure skin temperatures and correct any problems. Ensure that temperature rate-of-change requirements can be met. Repeat as necessary.

Step 9. Run a composite mission temperature cycle and duty cycle at the highest offset and another at the lowest offset. Measure the skin temperatures and correct any problems. Repeat as necessary.

Step 10. Place an operable test item into the test setup. Repeat Steps 1 and 2 if this is a test item not previously subjected to those steps.

Step 11. Provide power to the test item as required and conduct a test of its function.

Step 12. Repeat Step 11 with vibration applied, under high temperature and then under low temperature.

4.5.4 Procedure.

The following general procedure will vary depending on the test type conducted as shown in Table 523.4-I:

Step 1. Prepare the test item in its test configuration as described in paragraph 4.5.3.

Step 2. Verify the functional status of the test item.

Step 3. Start the test using conditions specified in the test plan developed from test tailoring guidelines.

Step 4. Conduct the test and monitor the operational status of the test item per paragraph 4.5.3.

Step 5. If a test item failure occurs, refer to paragraph 4.3.3.

Step 6. If a test interruption occurs, proceed according to the procedure called out in paragraph 4.3.1.

Step 7. Continue the test until termination criteria are met according to the procedure called out in paragraph 3.1.b(5). Document the results for comparison with pretest data.

Table 523.4-I. Typical applications.

TEST TYPE	PURPOSE	APPLICATION	TYPE OF INFORMATION REQUIRED	
			FAILURE MODES	TIME TO FAILURE
Test, Analyze, and Fix (TAAF)	Reveal and correct design weaknesses	Development of a more reliable design prior to production.	Essential to induce potential service failures.	Not important
Reliability Demonstration	Show whether or not a design meets the specified reliability.	Start of production is usually based on a successful reliability demonstration.	Important only if the demonstration is unsuccessful.	Essential.
Screening	Reveal workmanship or component defects before a production unit leaves the factory, i.e., while repair is cheap.	Part of the manufacturer's internal testing to assure delivery of reliable units during production.	Essential to induce failures in defective areas; such failures should not then appear in service.	Not important.
Lot Acceptance	Estimate the MTBF of the lot units from the time to failure of a small sample.	Determination as to whether the lot is of acceptable quality.	Important only if the lot is rejected.	Essential that successive lot measures be consistent and comparable. Baseline similarity to service MTBF is desirable.
Source Comparison	Determine the relative reliability of units from the time to failure of a small sample.	Determination as to which of two sources should get the larger share of a production buy.	Important for improvements at the poorer source.	Only consistency comparability is essential.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraphs 5.14 and 5.17, and Part One, Annex A, Tasks 405 and 406, the following information is provided to assist in the evaluation of the test results. If the test item failed the test, consider the following categories during analysis of results of this method:

a. Stress. If a failure occurred, consider what the immediate failure may have been, e.g., fatigue, short circuit by particulate, etc.

b. Loading mechanism. Determine the physical loading mechanism that led to failure and the total time or number of cycles to failure (e. g., structural dynamic resonant modes, mode shapes, stress distribution, static deformation due to temperature distribution, incursion of moisture, etc.).

c. Responsibility. Whether or not the failure was in a contractor or government furnished part of the store; was the test being performed properly, or was there a test error, e.g., out of tolerance test conditions, that caused the failure.

d. Source. Whether or not the failure was due to workmanship error, a design flaw, a faulty part, etc. This is actually an inverted way of deciding what corrective action is appropriate, since extraordinary workmanship or high-strength parts can overcome design flaws and designs can be changed to eliminate workmanship errors and/or to work with weaker parts.

e. Criticality. Whether or not the failure would have endangered friendly forces, prevented tactical success, or required repair before delivering the store.

6. REFERENCE/RELATED DOCUMENTS

6.1 Referenced Documents.

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c. MIL-HDBK-310, Global Climatic Data for Developing Military Products. 23 June 1997.

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p. Sharon A. Ogden, "A Mathematical Method for Determining Laboratory Simulation of the Captive Flight Vibration Environment," Proceedings of the 48th Shock and Vibration Symposium, Huntsville, AL, 1977.

6.2 Related Documents.

a. Egbert, Herbert W. "The History and Rationale of MIL-STD-810 (Edition 2)," January 2010; Institute of Environmental Sciences and Technology, Arlington Place One, 2340 S. Arlington Heights Road, Suite 100, Arlington Heights, IL 60005-4516

(Copies of Department of Defense Specifications, Standards, and Handbooks, and International Standardization Agreements are available online at https://assist.dla.mil.

Requests for other defense-related technical publications may be directed to the Defense Technical Information Center (DTIC), ATTN: DTIC-BR, Suite 0944, 8725 John J. Kingman Road, Fort Belvoir VA 22060-6218, 1-800-225-3842 (Assistance--selection 3, option 2), http://www.dtic.mil/dtic/; and the National Technical Information Service (NTIS), Springfield VA 22161, 1-800-553-NTIS (6847), http://www.ntis.gov/.

METHOD 523.4, ANNEX A
PHILOSOPHY OF TESTING, VIBRO-ACOUSTIC/TEMPERATURE TEST PROFILE DEVELOPMENT

1. SCOPE.

1.1 Purpose.

This annex provides an example of the development of a Vibro-Acoustic/Temperature test profile.

1.2 Application.

Information in this annex is designed to provide some, but not necessarily all, of the details that must be considered in developing a Vibro-Acoustic/Temperature test profile. Information included here should allow the practitioner to develop the test profile for any of the possible test types provided in Table 523.4-I.

2. DEVELOPMENT.

2.1 Background.

In order to ensure that the failures occurring in a test are typical of in-service use, it is important to reproduce the service stress distribution. The service stress distribution is the set of stresses in the combinations, levels, and duration imposed by the in-service missions. The procedure reproduces the levels, durations, and combinations of temperature, vibration, and acoustic noise in the same relative proportions as the in-service missions.

2.2 General.

Military aircraft service use may be described by a set of missions and the relative frequency of occurrence of each mission as illustrated in Table 523.4A-I. Each mission is defined by the type of stores carried and a mission flight profile. The mission flight profile is an idealized mission history that describes altitude, speed, and various events (e.g., air combat, gunfire, refueling) as functions of time. From the mission profiles and climatic data, derive corresponding mission environmental profiles. Use data from instrumented flights in this derivation, if available. Once the mission environmental profiles are derived, they can be combined into a composite mission profile. The composite mission profile is a sequence of environments in which the various stresses and combinations of stresses occur in (approximately) the same proportion as in all of the mission environmental profiles weighted according to their relative frequency of occurrence. The composite mission profile also includes the effects of climatic temperatures according to their relative frequency. However, the composite mission profile must be short enough to be repeated many times (at least five times is recommended) within the expected time-to-failure of the store being tested. This may require that extreme environments (particularly extreme temperatures) not be included, since keeping them in proper proportion might result in too long a composite mission. Typically, the range of stresses included is between the 5th and 95th percentile.

Table 523.4A-I. Relative frequency of occurrence of mission types.

MISSION TYPE	AIRCRAFT TYPE	% OF SORTIES
1. Patrol Mission I	Fighter A Fighter B	50 30
2. Patrol Mission II	Fighter A Fighter B	20 20
3. Strike Escort Mission	Fighter A Fighter B	30 30
4. Strike Mission	Fighter B	20

2.3 Mission Characterization.

The first step in developing the composite mission profile is to determine the types of aircraft and mission flight profiles that will employ the store. The mission flight profiles may be described in terms of altitude and Mach number with annotation of events. A tabulated mission phase analysis or mission profile description is shown in Table 523.4A-II. A corresponding graphical representation of this mission is shown on Figure 523.4A-1. The relative frequency of occurrence of the various missions must also be determined. This may be tabulated as shown in

Table 523.4A-I. In determining the relative frequency with which the store will be carried on various missions, it may be necessary to consider some state of hostility. Experience has shown that weapons that would be expended on their first flight in conflict may be subjected to many flights during a time of high international tension in which there is no combat. Choose the most stressful, yet realistic, mix of missions for simulation. Generally, it is not desirable to average together relatively benign missions with relatively stressful ones if a store will experience only one or the other during its service life. For each aircraft type and mission, determine the carriage location of the store to be tested, as well as the location of other stores that may affect it. Stores located ahead of or adjacent to a given store will cause an increase in the turbulence-induced vibration of that store. Ejection of nearby stores may also induce dynamic loads. Also, note any geographic or other conditions that would influence the mission (e.g., a store carried only by carrier-based aircraft will not experience as wide a range of preflight temperatures as one carried by land-based aircraft).

Table 523.4A-II. Mission phase analysis (Fighter B, strike mission).

MISSION PHASE	MACH NUMBER	ALTITUDE (km)	DURATION (min.)	ADDITIONAL FACTORS	DUTY CYCLE OF STORE
Takeoff & Climb				Catapult Shock?	Off to Ready
Cruise					Ready
Refuel					Ready
Ingress					On (Radiate)
Attack				Buffet?	Ready
Return					Ready
Refuel					Ready
Descend & Land				Landing Shock?	Off

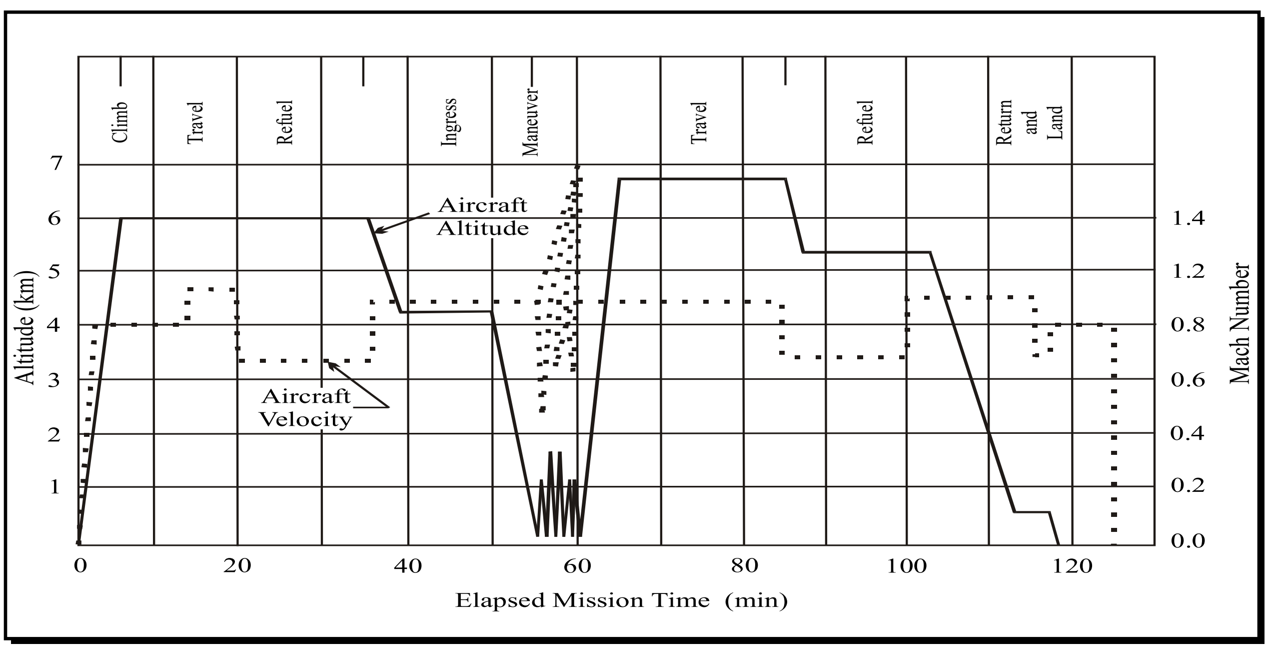

Figure 523.4A-1. Typical aircraft operational mission profile.

2.4 Mission Analysis.

Rather than deriving store environments such as vibration directly from the mission profiles, first recast the mission profiles in terms of the variables that directly affect the store, but which do not depend on the store's response.

These variables are initial temperature, recovery air temperature, and dynamic pressure. It is assumed that the store's temperature and vibration are a function of these primary variables.

2.4.1 Mission Temperatures.

Standard-day recovery air temperatures may be calculated from the equation in paragraph 2.1.1.4 and Method 514.8, Annex D, Table 514.8D-V, given the flight speed and pressure altitude (h) (standard atmosphere). Table 514.8D-V can also be used to convert various measures of air speed to Mach number. The temperature profile for a single mission type is provided on Figure 523.4A-2. For a composite mission, Figure 523.4A-3 displays the skin temperature versus the elapsed mission time.

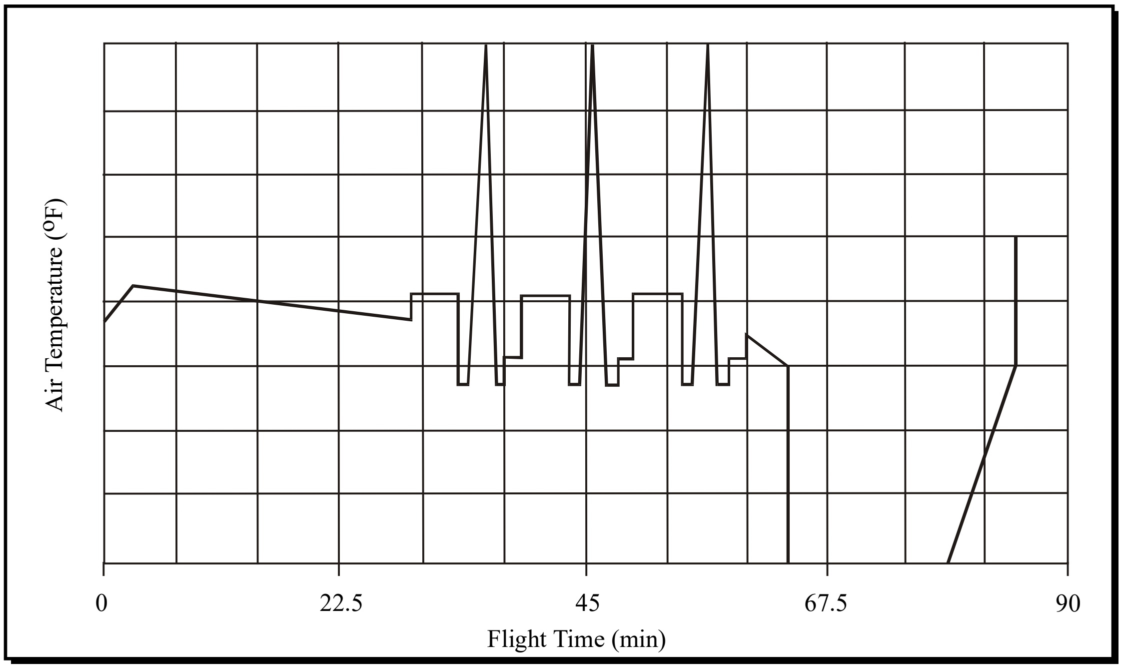

Figure 523.4A-2. Temperature profile for a single mission type.

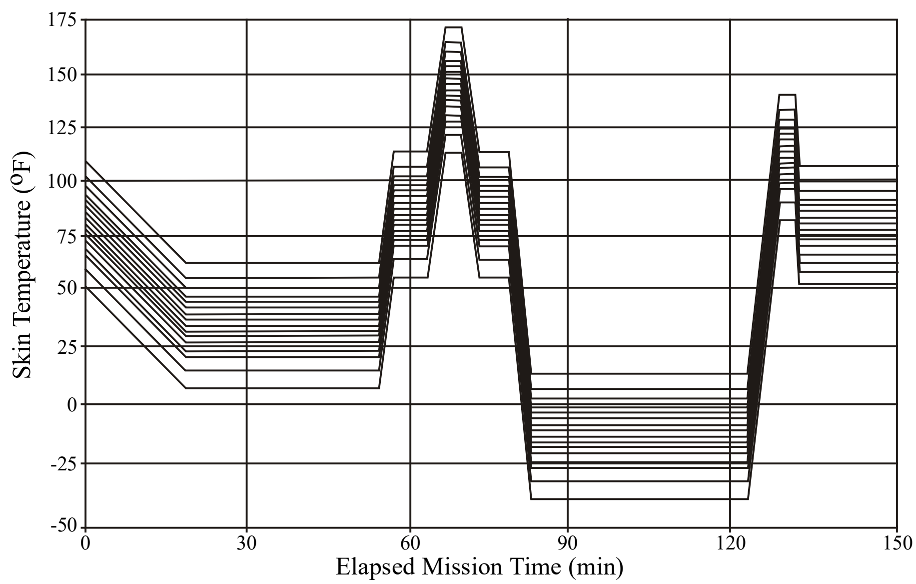

Figure 523.4A-3. Climatic set of temperature profiles for composite mission.

2.4.2 Mission Vibration.

a. Both the frequency spectrum shape and spatial distribution of store vibration in captive flight are almost independent of the flight condition. Exceptions are increased low frequency vibration during buffeting maneuvers and, in some cases, increased high frequency vibration in supersonic flight. In general, boundary layer fluctuating pressures are proportional to the dynamic pressure (q) of the flight condition. The store vibration is the dynamic response of the store to these pressures and is also proportional to q. The vibration spectrum rms level (grms) is proportional to q, and the acceleration spectral density (G) at any frequency is proportional to q^2. If vibration levels ($grms_{ref}$, G_{ref}) are defined for a single flight condition (q_{ref}), this proportionality can be used to approximate vibration levels throughout the flight envelope as follows:

$$\frac{grms}{grms_{ref}} = \frac{q}{q_{ref}} \quad \text{and} \quad \frac{G}{G_{ref}} = \left(\frac{q}{q_{ref}}\right)^2$$

where:
q = dynamic pressure, kN/m^2 (lb/ft^2)
grms = spectrum rms vibration level, g
G = acceleration spectral density, g^2/Hz
The area under the G(f) curve is the square of the grms level

b. Usually the reference condition is taken to be subsonic carriage on the least stressful aircraft station (wing pylon with no adjacent stores). Using this reference, determine the q versus time profile for each mission and construct a histogram representing the proportion of time the store is at a q level. This summarizes the expected vibration experience of the store. For stores for which measured vibration data are not available, the levels can be estimated by considering similar stores, with tailoring criteria provided in Method 514.8. Paragraph 6.1, reference g is a summary for various air-launched missiles.

c. For the missions where the store is carried on stations other than the least stressful station, adjustment factors may be needed. These factors typically account for cases where stores are carried side by side, behind other stores or in other special configurations. Measured data are the best source for these factors. Method 514.8 also provides guidance.

d. Vibration of a store is the dynamic response of the store to the fluctuating pressure and aircraft transmitted environments. This is broken down into definitions of the motions of key structural points of the store. The vibration environments of materiel located in the store are the local store vibration responses. The test consists of exciting the store with arbitrary levels of vibration and acoustics, and tailoring these inputs to achieve the defined store responses.

e. For the exceptional cases (aircraft buffet, catapult launch, arrested landing, gunfire, etc.), determine vibration/shock level, spectrum, and other characteristics. Quantify the occurrences of the exceptional vibration/shock conditions in terms of duration and mission time, so they can be reproduced in the proper proportions and at the proper times in the test cycle. Measured data are even more important here, but Method 514.8 contains guidance both for interpreting measured data and estimating levels when necessary. Method 519.8 contains guidance on estimating gunfire-induced shock.

2.4.3 Test Temperature Profile.

The test temperature profile will be the product of two parts: one that simulates the range and variation of temperature due to the missions, and another that simulates the climatic effects:

a. To determine the mission simulation part, begin with a sequence of skin temperatures corresponding to a few of the most common mission(s) strung together. Use a sequence that is no longer than one fortieth (1/40) of the store MTBF. It is usually convenient to make it a factor of 24 hours (e.g., 6 hrs or 8 hrs) since the test will be run around-the-clock. Use this skin temperature as an input to the store thermal model and determine the histograms of the internal temperature. These must be the responses after many cycles (the "steady state" responses). Compare these to the histograms for all the missions. Adjust the test sequence to achieve approximate agreement between the temperature histograms, both on the skin and internally. In this adjustment, keep the number and rate of temperature changes roughly the same as in the actual missions. It will usually be necessary to introduce a period of simulated on-the-ground time into the cycle in order that each simulated flight period start with the store at the appropriate uniform temperature. The temperature during the simulated on-the-ground time may be elevated or reduced in order to speed up the stabilization of internal temperatures. This initial temperature will be shifted each cycle to simulate the effect of climatic temperature variation.

b. Climatic effects are included by repeating the simulated flight cycle with temperatures shifted up or down by offset values that are constant over one cycle, but which differ from cycle to cycle (see Table 523.4A-III). Successive cycles have the temperature raised or lowered by an amount that represents a colder or hotter than standard day. Ensure the number of different offsets is at least eight. The upper bound on the number of offsets is determined by the requirement that the overall cycle must be shorter than one fifth of the MTBF. The value of the N offsets is chosen to be the midpoints of the N equi-probable intervals of the climatic temperature distribution as shown on Figure 523.4A-4. For worldwide, day and night operations, the climatic variation below 10 km is well approximated by a Gaussian distribution; at ground level; the mean is 12 °C and the standard deviation is 15 °C (paragraph 6.1, reference h). (This includes variation of location as well as season.) At altitude, the mean temperature is lower, but the standard deviation is about the same (paragraph 6.1, references h and n) over most of the globe. Near the poles and the equator, the variation at altitude is considerably less (paragraph 6.1, reference o). For eight offsets, the temperatures would be as shown in Table 523.4A-III. Stair-step the sequence of offsets in the test cycle up and down as indicated by the step number. Figure 523.4A-5 displays a climatic set plan where test item skin temperature is a function of elapsed test time. This reduces the duration required between offsets to normalize the store temperature for the next offset. It is desirable to minimize this duration since it does not count in measuring the store MTBF and hence decreases the test efficiency.

Table 523.4A-III. Temperature offsets.

STEP	PERCENTILE	OFFSET	GROUND TEMPERATURE
3	6.25	-30.8°C	-18.8°C (-2°F)
2	18.75	-13.3°C	-1.3°C (30°F)
4	31.25	-7.2°C	4.8°C (41°F)
1	43.75	-2.4°C	9.6°C (49°F)
5	56.25	+2.4°C	14.4°C (58°F)
8	68.75	+7.2°C	19.2°C (67°F)
6	81.25	+13.3°C	25.5°C (78°F)
7	93.75	+30.8°C	43.0°C (109°F)

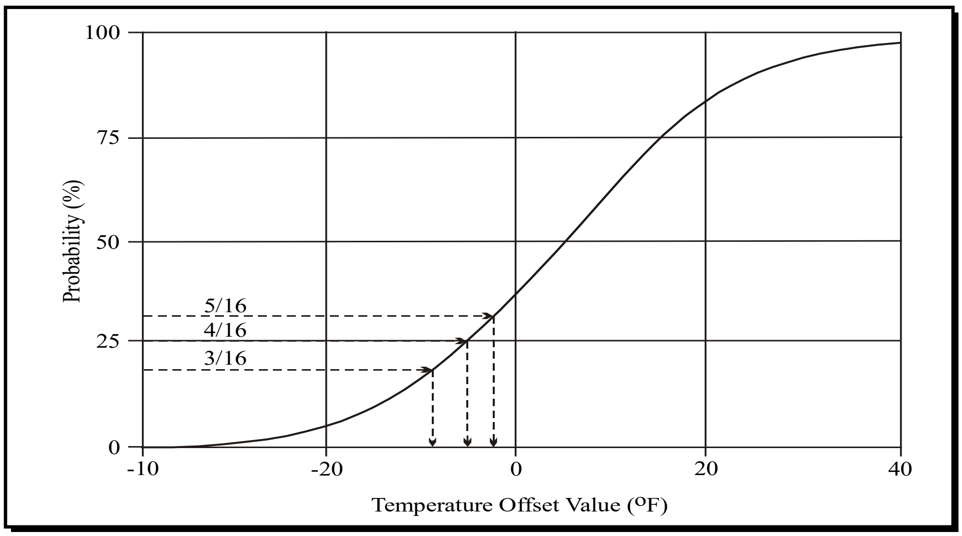

Figure 523.4A-4. Selection of equi-probable temperatures from the cumulative distribution of climatic temperatures.

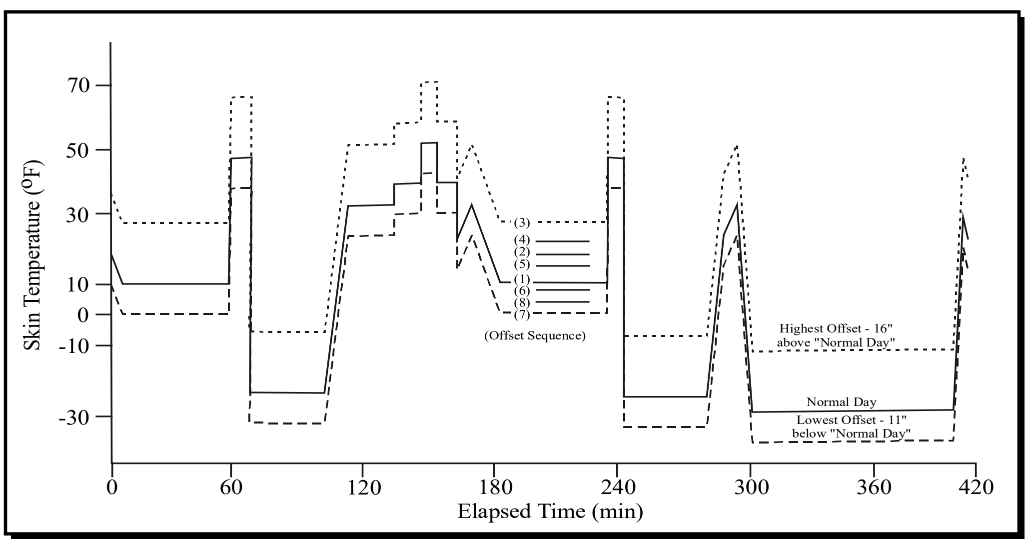

Figure 523.4A-5. Climatic set plan showing offset sequences.

2.4.4 Test Vibration Profile.

Ensure the test vibration profile produces the same histogram of store response levels as that derived from the mission analysis. Analyses assuming power function fatigue damage indicate that three to five different vibration levels are usually enough (paragraph 6.1, reference p). Use the same mission sequence used for the initial temperature cycle to generate a vibration level test cycle. This can then be adjusted to achieve the correct overall histogram. Maintain correlation between vibration and temperature (usually high vibration level goes with high temperature) as in the actual missions. Insert the exceptional vibration events into the test cycle with proportionate duration, and in realistic combination with the temperature and the straight and level vibration. Usually it is desirable to test the function of the store under the more severe part of the test environment, since that is the most likely to reveal reversible failures. In service, high levels of vibration, such as those due to buffet, usually occur over several very short time intervals, on the order of a few seconds. It may be desirable to conjoin all the high level vibration corresponding to a few mission-hours into a single interval in order to allow time for a complete test of the store's function during the high level vibration. Figure 523.4A-6 displays dynamic pressure, q, in terms of absolute pressure, P_a, versus elapsed mission time for a composite mission.

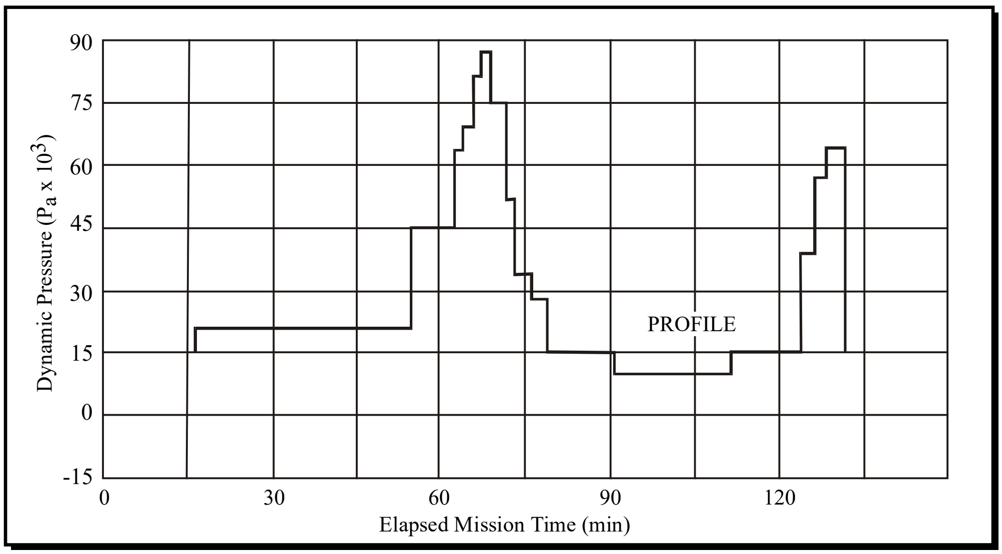

Figure 523.4A-6. Dynamic pressure, q, profile for composite mission.

2.4.5 Operational Duty Cycle.

Consider the operational duty cycle of the store in the temperature test design since power dissipation is a source of heat. Additionally, arrange it to allow functional test of the store during stressful parts of the cycle, as well as benign parts. If possible, test the store at low and high temperature extremes, during or immediately after high level vibration and at the beginning of each cycle.

3. TEST CONFIGURATION.

Figure 523.4A-7 is a schematic of the arrangements of a typical set of apparatus for performing a vibro-acoustic/temperature test. This arrangement consists of a control room that may be remotely located from a hardware test chamber termed an acoustic cell. The electrodynamic or electrohydraulic shakers are hidden under the test items.

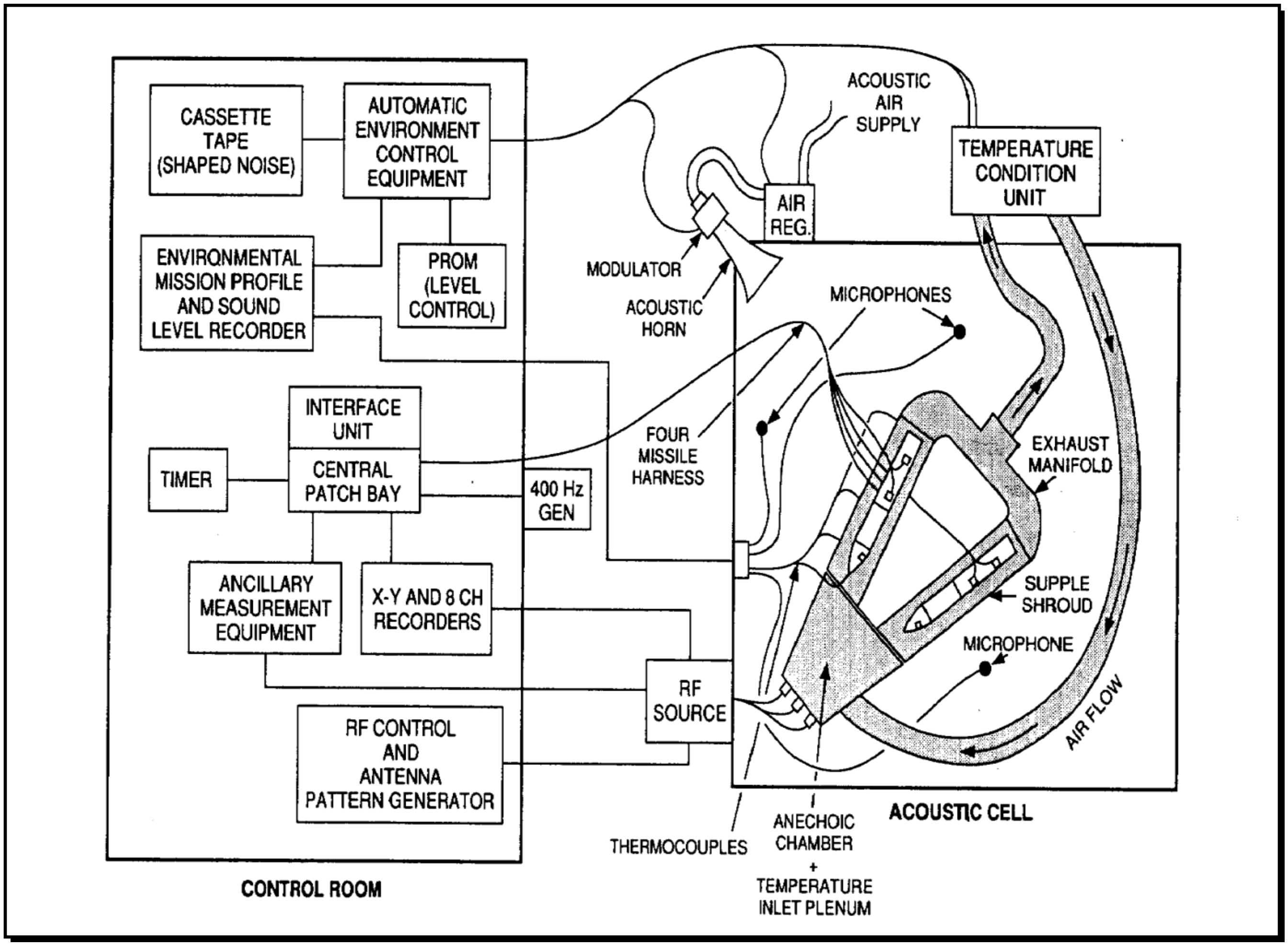

Figure 523.4A-7. Typical arrangement of test apparatus.