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DEPARTMENT OF DEFENSE HANDBOOK

ENVIRONMENTAL CRITERIA AND GUIDELINES FOR AIR-LAUNCHED WEAPONS

This handbook is for guidance only. Do not cite this document as a requirement.

AMSC N/A AREA ENVR

FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This handbook is converted from MIL-STD-1670A.

3. As air-launched weapons become more complex, the definition of the service environment and the attainment of high operational reliability become more complex and more critical. High operational reliability is directly dependent on how well the operational environment is defined and properly provided for during the equipment design and test phases. The past practice of qualifying weapons to arbitrary vibration levels and temperature extremes of standards and specifications without first investigating the weapon's expected life cycle environment has resulted in weapons severely deficient in reliability when used in the operational environment. This document provides a method for defining the weapon's expected total service environment early in the design phase and translating this environment into design criteria that is to be demonstrated prior to the weapon's operational use.

4. The research data presented in this handbook are based upon the AIM 7/7E weapons, which may be obsolete or no longer used. The test methods provided herein are intended for technical guidance and lessons learned information. It is recommended that weapon designers and contractors use these data as guidelines and tailor the data carefully to meet their specific weapon environmental requirements.

5. Soft metric units as shown are conversion of imperial units and presented as information only.

6. Comments, suggestions, or questions on this document should be addressed to the Naval Air Systems Command, Attention: Code 4.1.11, Highway 547, Lakehurst, NJ 08733-5100 or emailed to michael.sikora@navy.mil. Since contact information can change, you may want to verify the currency of the address information using the ASSIST online database at http://assist.daps.dla.mil.

CONTENTS

CONTENTS (continued)

CONTENTS (Continued)

APPENDICES

APPENDIX A ENVIRONMENTAL DATA AND CALCULATION TECHNIQUES

CONTENTS

PARAGRAPH PAGE

CONTENTS

APPENDIX B DESIGN USE OF ENVIRONMENTAL DATA IN DEVELOPMENT TEST PLANS

CONTENTS

PARAGRAPH PAGE

APPENDIX C DESIGN USE OF ENVIRONMENTAL DATA

APPENDIX D GUIDELINES FOR MEASUREMENT, ACQUISITION AND PROCESSING OF AIRBORNE WEAPON ENVIRONMENTAL DATA

CONTENTS

APPENDIX E OPERATIONAL USE DATA

APPENDIX F BIBLIOGRAPHY OF ENVIRONMENTAL DOCUMENTS

CONTENTS

FIGURES

FIGURES (Continued)

TABLES

1. SCOPE

1.1 Scope. This handbook establishes guidelines for the development of environmental engineering design and test requirements for air-launched weapons.

1.2 Purpose. The purpose of this handbook is to:

a. Provide acquisition activities with guidelines for the implementation of the required "most realistic environmental test" in addition to MIL-STD-810.

b. Provide guidelines for determining the environmental conditions to which air-launched weapons will be subjected during the factory-to-target sequence.

c. Describe the tasks involved in applying the essential environmental design criteria in all phases of weapon development.

d. Provide the developer with background environmental design and test data in the development of air-launched weapon.

1.3 Classification. The category of air-launched weapons include the following:

a. Air-to-air weapons.

b. Air-to-surface weapons including free-fall weapons.

c. Aircraft gun pods.

1.4 Limitations. The following environments are not considered in this handbook:

a. Nuclear environment.

b. Electromagnetic environment.

c. Short wavelength, coherent, electromagnetic environment (laser effects).

d. Munitions safety.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

INTERNATIONAL STANDARDIZATION AGREEMENTS

STANAG-2895	-	Extreme Climatic Conditions and Derived Conditions for use in Defining Design/Test Criteria for NATO Forces Materiel
STANAG-4325	-	Air-Launched Munitions Safety and Suitability for Service Evaluation
STANAG-4370	-	Environmental Testing

DEPARTMENT OF DEFENSE SPECIFICATION

MIL-S-901	-	Shock Tests, H.I (High Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-167-1	-	Mechanical Vibrations of Shipboard Equipment (Type I-Environmental and Type II -Internally Excited)
MIL-STD-167-2	-	Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System and Shafting) Types III, IV, and V (Controlled Distribution)
MIL-STD-331		Fuze and Fuze Components, Environmental and Performance Tests For
MIL-STD-810	-	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-967	-	Defense Handbooks Format and Content
MIL-STD-8591	-	Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase)

DEPARTMENT OF DEFENSE HANDBOOK

MIL-HDBK-310	-	Global Climatic Data for Developing Military Products

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

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein.

IRIG 106	-	Telemetry Standards
AFWAL-TR-80-3050	-	Weapon Bay Cavity Noise Environments, Data Correlation and Prediction for the B-1 Aircraft

(Copies of these documents are available from the Defense Technical Information Center (DTIC) 8725 John J. Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218 or online at http://stinet.dtic.mil.)

2.3 Non-Government publications. The following document forms a part of this document to the extent specified herein.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME-Y14.38 - Abbreviations and Acronyms (DoD adopted)

(Copies of this document are available from www.asme.org or ASME Information Central Orders/Inquiries, P.O. Box 2300 Fairfield, NJ 07007-2300.)

3. DEFINITIONS

3.1 Abbreviations and acronyms used in this handbook. The abbreviations and acronyms used in this handbook are defined as follows:

a.	CDD	-	Capability Development Document
b.	dB	-	Decibel
c	DETP	-	Detailed Environmental Test Plan
d.	EEMP	-	Environmental Engineering Management Plan
e.	EICL	-	Environmental Issues/Criteria List
f.	ESS	-	Environmental Stress Screening
g.	ETEMP	-	Environmental Test and Evaluation Master Plan
h.	ETR	-	Environmental Test Report
i.	ICD	-	Initial Capabilities Document
j.	LCEP	-	Life Cycle Environmental Profile
k.	OA	-	Overall
l.	OED	-	Operational Environment Documentation
m.	OEDP	-	Operational Environment Documentation Plan
n.	OEDR	-	Operational Environment Documentation Report
o.	RAT	-	Ram Air Turbine

p. SEMP - Systems Engineering Management Plan
q. SPL - Sound Pressure Level
r. TEMP - Test and Evaluation Master Plan
s. VTOL - Vertical Take Off and Landing

3.2 Dynamically induced environment. This is the induced environment where the forcing functions are dynamically activated to produce the environment.

3.3 Earth's albedo. This is defined as surface reflectivity of earth. This is expressed as the ratio of the amount of electromagnetic radiation reflected by the earth's surface to the amount of incident upon it. It is commonly expressed as a percentage.

3.4 Factory-to-target sequence. The sequence of events and situations in the life cycle of a weapon from the time it is accepted at the manufacturing plant until it has accomplished the required mission or reached its target.

3.5 Free flight. The flight phase of weapons, after separation from the launch platform.

3.6 Induced environment. A local environmental condition that is predominantly man-made or generated by the materiel platform. Also, refers to any condition integral to materiel resulted from the combination of natural environmental forcing functions and physical and chemical characteristics of the materiel itself.

3.7 Launch-to-target. Controlled flight path to get the missile from launch to target and ensure it performs properly during its flight.

3.8 Mach number. It is the ratio between the speed of an object and the speed of the sound in which the object is traveling in the medium.

3.9 Natural environment. A set of environmental conditions, static or dynamic, that occurs naturally such as temperature, wind, rain, solar radiation, sand and dust, and humidity.

3.10 Statically induced environment. This is the induced environment where the forcing functions are statically activated to produce the environment.

3.11 Special environment. Environments that are not covered in the above categories such as earthquake, building structural, water, flood and mud slide.

3.12 Tailoring. The process of choosing design characteristics and tolerances, test environments, methods, procedures, sequences and conditions, and altering critical design and test values, condition of failure to take into account the effects of a particular forcing function to which materiel normally would be subjected during its life cycle. The tailoring process also includes preparing or reviewing engineering task, planning, test, and evaluation documents to help ensure realistic weather, climate, and other physical environmental conditions are giving proper consideration throughout the acquisition cycle.

4. GENERAL GUIDANCE

4.1 General. A major task in the development of a weapon or a weapon system is to ensure that its design is compatible with the environment to which it will be subjected. This handbook provides guidelines for use by the weapon developing activity who is conducting the required environmental engineering tasks.

4.2 Environmental Engineering Management Plan (EEMP). The EEMP is the basic management schedule used to integrate environmental effects considerations into the Systems Engineering Management Plan (SEMP). This integration helps to ensure materiel will be prepared for all environmental conditions to which it will be subjected during its life cycle. The EEMP identifies manpower, dollar estimates, timing and points of contact necessary to complete the remaining tasks. There may be times that the program manager has valid alternatives, such as modeling and simulation or other analytic techniques, to testing actual materiel or working prototypes. These alternatives are scheduled and justified in the EEMP.

4.3 Environmental Test and Evaluation Master Plan (ETEMP). This plan is not a formal document, but is comprised of the products from three separate tasks: Life Cycle Environmental Profile (LCEP), Operational Environment Documentation (OED) and Environmental Issues Criteria List (EICL). Early in the acquisition process, initial work on these tasks helps build materiel need and performance requirements documents by identifying basic environments in which the materiel will operate, and fundamental issues to be addressed during the remainder of the acquisition process. These three tasks contribute to the Test and Evaluation Master Plan (TEMP) when they are completed. The ETEMP contains basic guidance and background information not to be confused with detailed test planning documents.

4.4 Life Cycle Environmental Profile (LCEP). The LCEP describes service-related events and environmental conditions that materiel will experience from its release from manufacturing to the end of its useful life. Fundamental progress is required on this task early in the acquisition process to influence the Initial Capabilities Document (ICP) and the Capabilities Development Document (CDD). The completed LCEP is needed later in the process to help system designers and evaluators build the TEMP. It is important to note that the LCEP does not specify design or test requirements. Rather, it serves as a tailored guide for deriving materiel designs and test parameters based on performance requirements.

4.5 Operational Environment Documentation (OED). The OED task entails producing two documents. One is a plan for obtaining data that will serve as the basis for design and test criteria development. The other is a report that contains those plans and the resulting data.

The plan, the Operational Environment Documentation Plan (OEDP), provides for two types of data. First, it contains plans for securing data that have been collected previously and are still valid for developing the materiel's design and test criteria. Second, it contains plans for collecting data not available currently, describing how to obtain those environmental data under realistic operating or field conditions using actual or closely related systems platforms. The OEDP and the resulting data (existing and new data) form the Operational Environment Documentation Report (OEDR).

4.6 Environmental Issues Criteria List (EICL). The EICL is developed from the LCEP and OEDR. It contains a list of tailored issues and criteria complete with appropriate criterion levels for the materiel being acquired. Also, it includes rationale and assumptions for how environmental effects issues and criteria were derived. This rationale aids designers, developers, and assessors as they revise criteria when materiel deployment concepts and designs change.

4.7 Detailed Environmental Test Plan (DETP). Developers, evaluators, assessors, and testers prepare detailed environmental test and evaluation plans in various levels of detail (e.g., Independent Evaluation Plans through Detailed Test Plans). These detailed plans serve as the primary means for calling out specific laboratory and field tests, test sites, instrumentation, procedures, and criterion levels for environmental tests. The DETP may stand alone as an environmental test planning document or may appear as a subset of a larger test plan. Quite often, the highest level of detail in these plans appears in standard test procedures referenced in those plans.

4.8 Environmental Test Report (ETR). Environmental test reports are produced at various points in the acquisition process. Specifications for conducting development and operational tests and formats for resulting reports are provided by development and operational test agencies. This task pertains mainly to the results of materiel tests performed in environmental testing laboratories. The ETR defines the test purpose, lists test issues/criteria, lists or describes test equipment/facilities/instrumentation, explains the test design/set-up, contains detailed test data/logs, provides failure analyses, and interprets test results.
The laboratory ETR is appropriate for design evaluation tests, operational worthiness tests, and qualification tests. Data from these laboratory tests serve as early warnings of unanticipated deviation from performance requirements. They support failure analyses and corrective actions related to the ability of materiel to withstand specific environmental conditions. These laboratory test data do not serve as substitutes for development or operational tests conducted in natural field/fleet environments.

5. DETAILED GUIDANCE

5.1 Documents. Detailed descriptions of the environmental documentation listed in section 4 are addressed in detail in Part One of MIL-STD-810. Refer to the specific task descriptions for guidance on the content and special considerations for the documentation.

5.2 Other documents. The following documents containing environment supporting data and test data are recommended for use as a guideline if needed in preparing the environmental documentation.

a. MIL-HDBK-310 and STANAG-2895. These are documents that describe regionalized climatic data and climatic extremes. These documents should be analyzed for use on a specific weapon.

b. STANAG-4370. This document provides descriptions of mechanical and climatic environments and corresponding test methods.

c. MIL-STD-331. This standard describes tests used to determine the safety, reliability and performance characteristics of weapon system fuzes and fuze components at any stage in their life cycle.

d. MIL-S-901. This specification covers shock testing requirements for shipboard machinery, equipment, systems and structures.

e. MIL-STD-167-1 and MIL-STD-167-2. These standards cover the requirements for shipboard mechanical vibrations Type I through Type V.

5.3 Environments. The major environmental conditions that may be encountered by the weapon in the factory-to-target sequence and, as a minimum, the conditions which should be addressed by the developing agency, are listed in the following paragraphs. Unusual system oriented environments, such as cosmic radiation and insects are excluded, but they should be included in the environmental profile plan and report if applicable.

5.3.1 Natural environments (see 3.9).

5.3.1.1 Wind. Wind is presented in terms of velocity. Wind shear and spatial variation of velocity with respect to a vertical axis should be presented wherever applicable.

5.3.1.2 Solar radiation. Solar radiation is presented as thermal units per square foot per hour (Btu/ft^2-hr) in conjunction with the temperature, wind speed and relative humidity at a given instant of time. Direct solar radiation is presented as one part of a many-part heating matrix. Some other radiation sources are:

a. Earth's albedo (see 3.3).
b. Hardstand albedo.
c. Reflection from other ordnance.
d. Sky brightness.
e. Re-radiation from clouds.
f. Re-radiation from liquid droplets or airborne solids.

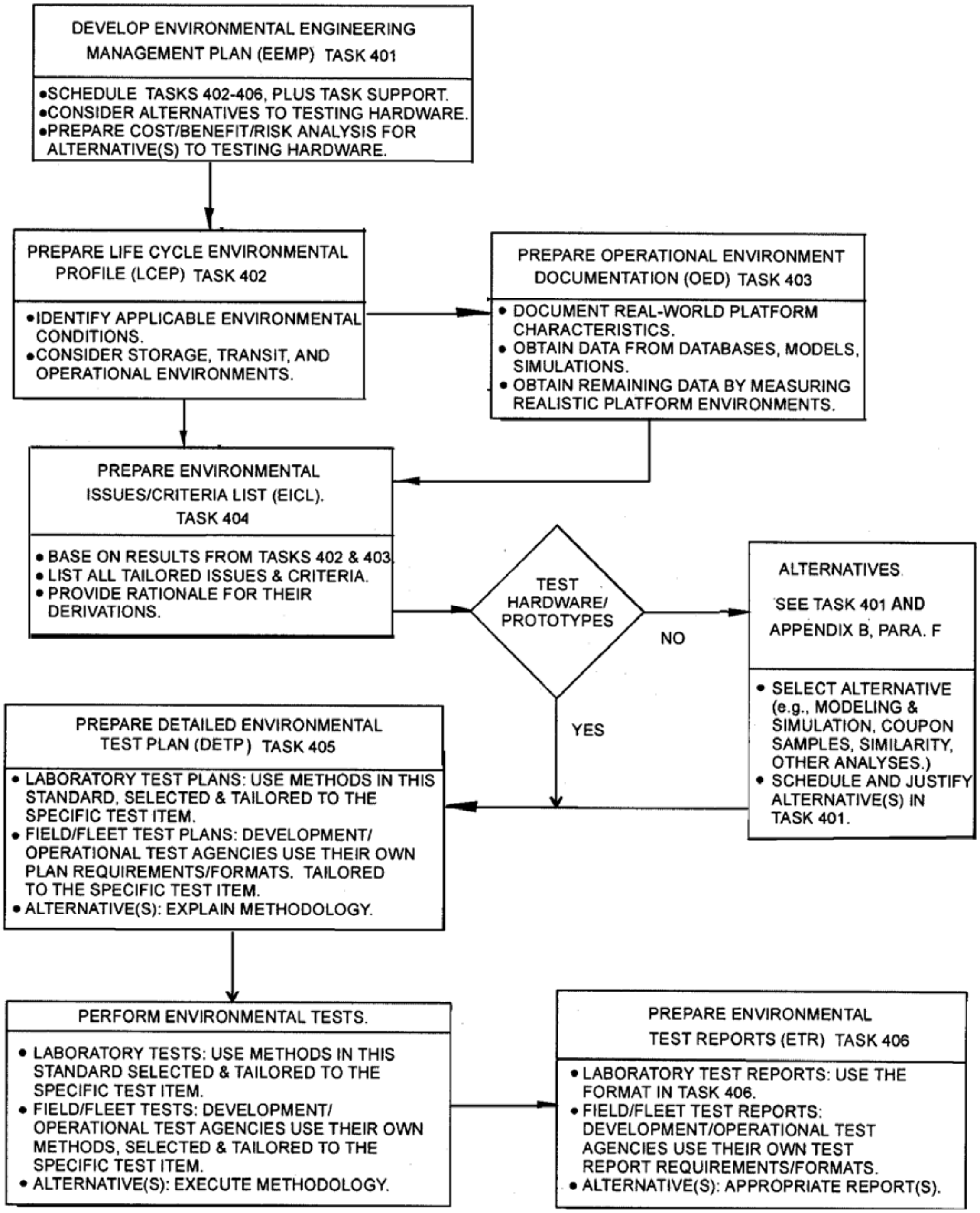

FIGURE 1. Documentation development sequence.

NOTES:

1. Reference Tasks 401 through 406 are described in MIL-STD-810. Complete task descriptions are in Appendix A.

2. Include EEMP and ETEMP with other systems plan and proposal to allow realistic cost estimating.

3. Make contract provision for the equipment supplier to update EEMP and ETEMP on a periodic basis as additional information becomes available.

5.3.1.3 Icing and freezing rain. Icing and freezing rain environments are endangering to the weapon systems. They are directly related to the temperature of the water vapor in the atmosphere and expressed as the density of water vapor per pound of water. The icing and freezing rain have a variety of effects on weapon systems; therefore, consideration should be given to the design of the weapon system to assure that the weapon is capable of operation with full performance.

5.3.1.4 Marine environment. The marine environment usually produces a highly corrosive environment. If the weapon system is designed for operating in the vicinity of an ocean, it should be protected against this environment through the use of materials insensitive to corrosion or protective coatings.

5.3.1.5 Heavy cloud. Heavy cloud reduces the visibility of aircraft and missiles. It is expressed as density of the gas vapor per pound of gas.

5.3.1.6 Fog. Fog reduces visibility and presents a danger to aircraft during landing and take-off, particularly to aircraft deployed on an aircraft carrier in the ocean. Weapon designers should consider the effect of this environment in their design.

5.3.2 Induced environment (see 3.6).

5.3.2.1 Statically induced environment (see 3.10).

5.3.2.1.1 Electrostatic and residual magnetism. Electric charge buildup is presented in standard electrical terms.

5.3.2.1.2 Water immersion. Water immersion is presented in terms of depth of immersion, temperature, and duration.

5.3.2.1.3 Explosive atmosphere. Electrical arc and energy discharge from electrical and electronic devices can easily ignite mixtures of fuel vapor and air. It is recommended during weapon system design that the entire arcing device be enclosed in an explosion proof container and hermetically sealed to protect from accidental explosion.

5.3.2.2 Dynamically induced environment (see 3.2).

5.3.2.2.1 Acceleration. The acceleration environment is expressed as sustained linear and angular load factors applied to the store and/or to items contained within the store. Although these load factors result from dynamic events (dives, turns, rolls, landing impact) the rate of load application and release is slow enough so that equipment items are not excited dynamically. Events with load application rapid enough to dynamically excite the store are classified as shock. Note that the acceleration environment applies to items wholly contained within the weapon but not to the assembled store. The assembled store must withstand the combined effects of accelerations and aerodynamic loads (see 5.3.2.2.5).

5.3.2.2.2 Transportation handling and maintenance acceleration. In order to be classified as acceleration, a load event must be sustained long enough to avoid dynamic excitation. Because of this, high levels of acceleration are highly unlikely in ground or sea environments. Instead, high load factor events such as drops and truck bounces are classified as shocks. Transportation aboard aircraft can result in acceleration events. However, equipment is generally much less vulnerable to acceleration when packaged for shipment and accelerations experienced on cargo floors of cargo aircraft or helicopters are much less than those experienced aboard combat aircraft. For these reasons, transportation, handling and maintenance do not contribute significantly to the acceleration environment.

5.3.2.2.3 Dynamic response. This environment is the result of flight loads acting on the aircraft and external store combination during normal flight maneuvers and events such as adjacent store release or aircraft buffet. MIL-STD-810 and MIL-STD-8591 provide preliminary values for initial sizing purposes, but final design and test load factors must be derived from the flight loads defined for the aircraft/store combination. MIL-STD-810 provides guidance for deriving and conducting tailored acceleration tests. Normal stress analysis or finite element techniques may be used to design or verify compliance with acceleration requirements. However, it should be noted that the degree of complexity of the analytical model required is determined by the complexity of the item analyzed, not by the size of the item. As a result, qualification by analysis is typically more expensive than qualification by test. The structural integrity of the store, the store suspension equipment, and the airframe must be verified for each case. It is usually assumed that the load application and release rates are slow enough so that the store is not excited dynamically. However, this is not always true, particularly in the case of aircraft buffet. Guidance for development of design loads and test methodology should be acquired through carrier aircraft programs.

5.3.2.2.4 Free flight and target impact acceleration. Free flight accelerations are based on the flight loads of the store in free flight and during launch. Target impact accelerations are very rapid and are classified as shocks. The acceleration values must be derived from a store's flight loads determination including consideration of launch and maneuvers. MIL-STD-810 provides tailorable test methodology.

5.3.2.2.5 Flight loads. The flight loads environment of a store is the combination of inertial (load factors) and aerodynamic loads acting on the aircraft/store combination and separately on the store during launch and free flight. Acceleration (load factor) loads acting alone are not sufficient. The total loads must be considered in store design and test. Further, the loads resulting from carriage on each carriage station of each specific aircraft are unique.

5.3.2.2.6 Shock. Shock is often defined as a rapid transfer of energy to a mechanical system, resulting in a significant change of the stress, velocity, acceleration, or displacement state of that system. Typically shock is characterized as a time dependent disturbance of short duration measured in milliseconds - the short pulse. The waveform or amplitude variation with time for a particular shock dictates the frequency content of the pulse which along with the magnitude of the disturbance is of major importance. The current paragraph identifies that shock causes the item to vibrate in its natural modes of vibration. While this can be true, shock can still force a response dictated by several modes or none of the natural modes.

5.3.2.2.6.1 Transportation handling and maintenance shock. There are many sources of shock loading associated with moving and handling of equipment prior to aircraft taxi for a mission. MIL-STD-810 and STANAG-4370 include data defining many such shocks along with sufficient background information to aid in developing shock requirements. MIL-STD-810 includes tests, which although arbitrary, have proven effective developing and qualifying equipment for these environments. It also includes test techniques, which can be tailored to most shock requirements such as packaged drops, general design and bench handling.

5.3.2.2.6.2 Captive carriage shock. In general, the shock environment aboard modern aircraft is mild. The vibration environment normally greatly exceeds the shock environment in effect on both function and durability of structures and equipment. Depending on location on an aircraft, there are possible exceptions such as snap-open and snap-shut of doors, ejection of small stores such as flares, low rate gunfire, and catapult and arrested landing shock. Most air-launched weapons are further protected by distance from the sources and by the shock isolation effect of low frequency wings and weapon pylons. Other events should be investigated individually.

5.3.2.2.6.3 Launch, free flight and target impact shock. The most likely mission related sources of shock for air-launched weapons are the pyrotechnic devices and snap-open and snap-closed devices used to eject or launch the store, to reconfigure the store for or in flight, and to launch warheads and or sub munitions from the store.

These shocks are typically high frequency, high acceleration, short duration events with numerous oscillations, which are poorly represented by standard shock criteria and shock tests. It is generally necessary to measure the shocks produced by the actual mechanisms on the actual structures in order to evaluate them properly. Such measurements can then be used to design and tailor tests for those items which may be sensitive to high frequency shock.

5.3.2.2.7 Vibration. Loading events occurring rapidly enough to dynamically excite an item and often enough to cause sustained dynamic motions of the item produce vibration. Thus response of a large airplane to atmospheric turbulence is vibration (typically called dynamic loads) to the airframe but acceleration to a store. The difference is the differing dynamic response frequencies (resonant frequencies) of the airplane and store. Vibrations of the store are driven by excitations from just below the lowest store natural frequency up to frequencies where vibration amplitudes become so small to be considered as no longer measurable or damaging. This upper limit is usually accepted as 2,000 Hz.

5.3.2.2.7.1 Environmental stress screening (ESS) vibration. Vibration screening is often used prior to delivery of an item and is sometimes used during repair or overhaul. Typically an arbitrary vibration level is applied for arbitrary periods of time. The usual assumption is that this screening does not contribute to life cycle damage accumulation. Also, if the screening results in rework, the unit is usually screened again, repeating the cycle until no failures occur. This combination of levels and screening cycles can use up significant portions of the useful life and should be accounted for in the environmental life cycle.

5.3.2.2.7.2 Transportation vibration. Vibration experienced by an air-launched weapon during transportation is driven by the mechanisms of the transportation systems and the surface over which the platform moves. Trucks, trailers and trains roll with imperfect wheels over imperfect surfaces at varying speeds driven by combinations of power plants, rotating shafts, gears. Ships transit varying seas also driven by complex propulsion systems. Aircraft experience these same sources as well as atmospheric turbulence, aerodynamic turbulence, acoustic noise, propeller and rotor effects. Because of the complexity of transportation vibration, broadband random vibration levels are typically used to encompass the known vibration data for each of these general categories. There can be exceptions such as helicopters, where specific sinusoidal elements may be used to represent known rotor generated vibrations. MIL-STD-810, STANAG-4370 and MIL-STD-8591 contain guidance, data, generalized criteria, and test methodology for transportation vibration. It is important to note that transportation vibration criteria are expressed as the environment at the interface between the transportation system and the item-shipping package. In order to evaluate the effect on the item, the dynamics of the item packaging and shipping configuration must be accounted for.

5.3.2.2.7.3 External captive carriage vibration. The vibration environments of captive carriage will typically be the most demanding dynamic environments for air-launched weapons. There are contributions of vibration transmitted mechanically from the carrier aircraft. However, an aircraft store is effectively vibration isolated from aircraft vibration by the low frequency suspension provided by aircraft structure, pylon, rack and launcher. Thus the primary sources of store vibration are the fluctuating pressures of airflow, acoustics, gunfire blast, oscillating shocks. The vibration resulting from all sources has been evaluated as a set based on flight test and laboratory work. This is the basis of the tailored criteria and test methodology contained in MIL-STD-810 and STANAG-4370 covering jet and propeller conventional fixed wing airplanes and helicopters. MIL-STD-8591 provides a considerable database and vibration prediction methodology based on several modern U.S. combat aircraft, including a vertical takeoff and landing (VTOL) aircraft. The following is a set of lessons learned, which should be considered in defining external store vibrations or in testing for these vibrations.

5.3.2.2.7.4 Test methodology. Assembled stores should never be mounted directly to a vibration exciter and driven to input criteria as are typical of smaller equipment items. A store responds to the fluctuating pressure field of aircraft flight quite independently of the vibration occurring at the store and suspension equipment interface. The criteria provided by MIL-STD-810, STANAG-4370 and MIL-STD-8591 define the motions of the store at points within the store. The vibration input to the store must be tailored to achieve the prescribed vibration at these points. In general, the store should be suspended separately from the vibration exciter(s). The vibration is input to the store at location(s) chosen to achieve the required response. This method is provided in MIL-STD-810.

5.3.2.2.7.5 External fins, wings and blades. The above discussions do not apply to elements, which are wing-like and extend into the airflow around the store. A "blade" responds directly to the local airflow and can amplify airflow pressures in the same way a wing produces lift and drag. When the local airflow contains significant pressure content at a low order bending or torsion resonant frequency of the blade, violent vibrations may occur leading to rapid failure. When the local airflow contains significant pressure content at a low order bending or torsion resonant frequency of the blade, violent vibrations may occur leading to rapid failure. Local airflow is not predictable, particularly in regions around grouped stores and under the wings and fuselages of combat aircraft. Thus each separate store location and store mix on each airplane has the potential of causing blade problems. In general the best course is to avoid extended "blades" in captive carriage as much as possible. Barring that, try to place "blades" as logically as possible to avoid airflow turbulence (e. g., place a "blade" on the bottom of the store away from the wake of the pylon). Experience has shown that stores with cruciform fins tend to have less trouble if the fins are at 45° rather than directly behind the store and rack interface. There is a known case where a vortex originating at the corner of an engine inlet under specific flight conditions wiped over a "blade" of a fuselage mounted missile and caused rapid failure.

5.3.2.2.7.6 Aircraft buffet. Buffet of an airplane may occur which involves higher frequency airframe modes. Depending on the frequencies of the lowest store modes, this motion may be an acceleration load (see 5.3.2.2.1 and 5.3.2.2.5), flight or a vibration with respect to the store. In either case, the frequency will be low enough so that the vibration isolation effect of the airframe will not be effective. In fact, the store, pylon and airframe combination can be acting as a system amplifying the motion of the store. Buffet levels are potentially very high and must be accounted for in store design and test. MIL-STD-810, STANAG-4370 and MIL-STD-8591 provide rudimentary preliminary buffet criteria. However, buffet criteria and test methods must be obtained through the specific aircraft program.

5.3.2.2.7.7 Gunfire vibration. Gunfire vibration may be transmitted mechanically from the weapon mount. However, that source is generally small compared to the effect of gun blast pressure impinging on lightweight aircraft or store structures. The resulting motion of the structure may be in the form of shocks for a very low fire rate, but usually it is experienced as vibration. Such vibrations are very difficult to predict. The recommended procedure is to subject the structure to the gunfire blast and to measure the results. In lieu of this, MIL-STD-810 and STANAG-4370 contain methods for developing estimates and tests.

5.3.2.2.7.8 Open cavities. All holes or cavities in the external skin of the store are subject to high-level acoustic resonance excitation and resulting vibration levels. There is no general method to derive vibration criteria for acoustic resonance cases. It should be handled as an acoustic load problem and is discussed in the acoustics section below.

5.3.2.2.7.9 Miscellaneous sources. Stores may include elements producing substantial vibration. Some examples are rotating equipment (e. g., electric motors, hydraulic pumps) producing rotating unbalanced loads, ram air turbines (RAT) adding aerodynamic pressure pulses to airflow turbulence, and ram air scoops adding to general flow turbulence and possibly resulting in oscillating shock waves. Any equipment, which produces continuous or rapid intermittent mechanical motion, any significant discontinuity in store external contours, and all openings in the skin should be evaluated. Methods for evaluation might include analysis, flight and/or laboratory measurement and wind tunnel test. Predictions for this type of vibration are not included in MIL-STD-810. However, the test methods of MIL-STD-810 can be tailored and utilized based on the results of the evaluation.

5.3.2.2.7.10 Internal equipment. As noted above, a store vibration criterion applies to the motions of the entire store. Internal equipment, which forms a part of store structural load paths, cannot be effectively tested except as part of the assembled store. Other equipment can be tested separately using the defined store motions as inputs to the equipment. However, when the assembled store is tested all equipment should be installed. Substitution of mass simulators for real equipment can greatly influence store response and can invalidate test results.

5.3.2.2.7.11 Internal captive carriage. When a store is carried inside a weapons bay, it is protected from the vibrations of external carriage. However, when the bay opens in flight, high acoustic levels are likely to occur. This is due to high-level broadband random turbulence, and, more importantly, extremely high-level narrow band acoustic peaks caused by acoustic resonance of the air volume in the bay as driven by the turbulent flow over the bay. Spoilers or other devices are sometimes used to suppress the acoustic spikes resulting in higher broadband random levels. There is no general database or analytical basis for predicting either the bay closed or the bay open store vibrations. Methods for defining acoustic levels are discussed in the acoustics section. Measurements of acoustic levels in current aircraft with weapons bay spoilers have shown levels to be roughly the same as fluctuating pressure levels measured on externally carried stores (see 5.3.2.2.8). Stores properly qualified for external carriage do not seem to experience problems when exposed to this high level but short duration environments.

5.3.2.2.7.12 Launch, free flight and target impact. Generally, vibration levels should decrease as the store moves out of the complex flow field of the carrier aircraft. This should be true for rocket powered and jet engine powered weapons if the engine exhaust is in the weapon aft end. MIL-STD-810 provides rudimentary preliminary criteria for these cases. Exceptions, which should be evaluated for significant vibration increases include acceleration to higher flight dynamic pressures than the worst-case carrier aircraft case, violent maneuvers, open cavities and miscellaneous sources as discussed in 5.3.2.2.7.5 and 5.3.2.2.7.6. Open cavities can be particular problems where sensor covers open or where sub munitions are dispensed.

5.3.2.2.8 Acoustics. The term acoustics applies to sound waves transmitted through air. However, in this case, the definition is broadened to include the sum of all atmospheric transmitted or conducted fluctuating pressures acting on the store. This includes flow turbulence, oscillating shocks and blast pressures as well as acoustic pressures.

5.3.2.2.8.1 Environmental stress screening (ESS) acoustics. Acoustic screenings are sometimes applied to assembled (all-up-round) stores. Levels and duration are derived in various ways and are often considered as not contributing to damage accumulation. This is a dangerous assumption. Any loading, which is sufficient to exercise the store, is likely to contribute to fatigue damage somewhere in the store. ESS, including the maximum number of ESS cycles, should be included in the environmental life definition.

5.3.2.2.8.2 Transportation handling and maintenance acoustics. These environments should not reach acoustic levels of sufficient severity to damage equipment. This threshold is usually taken as 135-decibel (dB) overall (OA) sound pressure level (SPL). In any case levels should not approach those typically encountered by external stores carried on modern combat aircraft (160 dB OA SPL or higher). Thus acoustics is not a consideration except in special cases. If sensitive equipment is developed for low performance aircraft or helicopter carriage, it could be sensitive to SPLs encountered on a flight deck, hangar deck, or combat aircraft hard stand area. No general criteria are available for such cases. Evaluation will require obtaining data or measuring the environment and applying these data to testing of the equipment. MIL-STD-810 and STANAG-4370 provide tailorable test procedures.

5.3.2.2.8.3 External captive carriage acoustics. The dominant factor in the acoustic environment of external stores are high-speed carriage airflow turbulence on modern combat aircraft. Other sources such as aircraft engine acoustic noise, propeller passage pressures, and gunfire blast pressures require consideration for specific cases. MIL-STD-810 and STANAG-4370 provide rudimentary estimates of various environments and test methodology.

5.3.2.2.8.4 Internal captive carriage acoustics. During bay-closed periods, acoustic levels should be very low compared to external carriage levels. When a bay is open in flight, high levels of broadband fluctuating pressures occur and extremely high narrow band spikes of acoustic noise are possible. This is due to broadband random flow turbulence, and more importantly, narrow band acoustic resonance peaks as the air volume in the bay is driven by the flow over the bay. Spoilers or other devices are usually used to suppress the acoustic spikes but also result in higher broadband random levels. AFWAL-TR-80-3050 provides further estimation methodology and a useful introduction to cavity resonance studies, including analysis wind tunnel test and flight measurement. The best sources for information on current aircraft are the aircraft program offices. New aircraft will require wind tunnel studies and in-flight measurements of actual environments. In general, weapons bay levels on weapons in current aircraft with effective spoilers have proven to be generally equal to worst case external carriage levels.

5.3.2.2.8.5 Launch, free flight (see 3.5) and target impact acoustics. The primary contributor to this environment is typically turbulent boundary layer. Other potential contributors are propulsion system noise and open cavities. Propulsion system noise is usually not a factor because jet or rocket engines typically drive weapons from the extreme tail. Thus the acoustic noise source is well behind the weapon. Open holes in the skin may be the result of sensor covers' openings or sub munitions expulsion. Other sources, which should be included when applicable, are ram air turbines, ram air scoops and other devices extending into the air stream. MIL-STD-810 includes tailorable test procedures and provides general open cavity criteria. Evaluation of other sources might include analysis of flight and/or laboratory measurement during wind tunnel tests, etc. Predictions for these sources are not included in MIL-STD-810.

5.3.3 Situation dependent environments. See Appendix A for environmental data and calculation techniques that may be applied to this section.

5.3.3.1 Temperature. Temperature should be presented in degrees Fahrenheit and Celsius (°F and °C) as a function of time. Steady state or soak conditions should be supported with written evidence of applicability.

5.3.3.2 Humidity. The humidity environment is presented in one of the following forms. Each steady-state relative humidity value should be supported by written evidence of applicability.

a. Percent relative humidity at a corresponding dry bulb temperature (see figures 2 and 3).
b. Pounds of water (H_2O) per pound of dry air.
c. Clearly labeled combinations of (a) and (b).

5.3.3.3 Precipitation. The precipitation environment should be presented in terms of fall rate in millimeters per hour (mm/h), change in fall rate, relative velocity, and particle size and distribution. Forms of precipitation include rain, snow, sleet, hail, ice and freezing rain.

5.3.3.4 Small particulate water. Small particulate water should be presented in pounds of water per pound of dry air. Precipitate of small particulate water should be presented in pounds of water per square foot of projected surface area. Small particulate water considerations should address clouds, fog, frost, and dew.

5.3.3.5 Sand and dust. The sand and dust environments are presented in the following form:

a. Chemical composition of the sand and dust (includes Fe_2O, Al_2O_3 and SiO_2).
b. Particle size distribution.
c. Relative particle velocity.

5.3.3.6 Pressure. Pressure is presented in terms of force per unit area (lb/in^2) or ($dynes/cm^2$). Pressure or pressure differences are associated with changes in altitude, meteorological characteristics, water submersion and thermal expansion. Blast pressure should be considered as applicable pressure.

5.3.3.7 Corrosion. Corrosion is considered in terms of the effects of reaction kinetics and oxidant interface. Typically corrosion is produced by the action of acid gas, salt spray, and moisture and by galvanic and microbiological processes.

5.3.3.8 Dissociated gases. The dissociation of oxidant gases and halogen compounds are given as parts of the oxidizing radical per million of air. When the possibility of exposure to oxides of chlorine, fluorine, bromine, iodine, nitrogen or ozone exists, the potential for dissociation should be considered. The most prominent dissociated gas is ozone.

5.3.3.9 Fungus. The fungus environment is presented with reference to temperature, humidity, nutrient supply, time and exposure. It is an inseparable condition of the hot, humid tropics and mid-latitudes, and must be considered in the design of all standard general-purpose materials. Consideration should be given to any situation in which water or hydrocarbon liquids stand in metal structures. The OED should call attention to the hazards of adding fingerprints, labels, inspection stamps, or organic substances to materials that are non-nutrient to fungus wherever applicable.

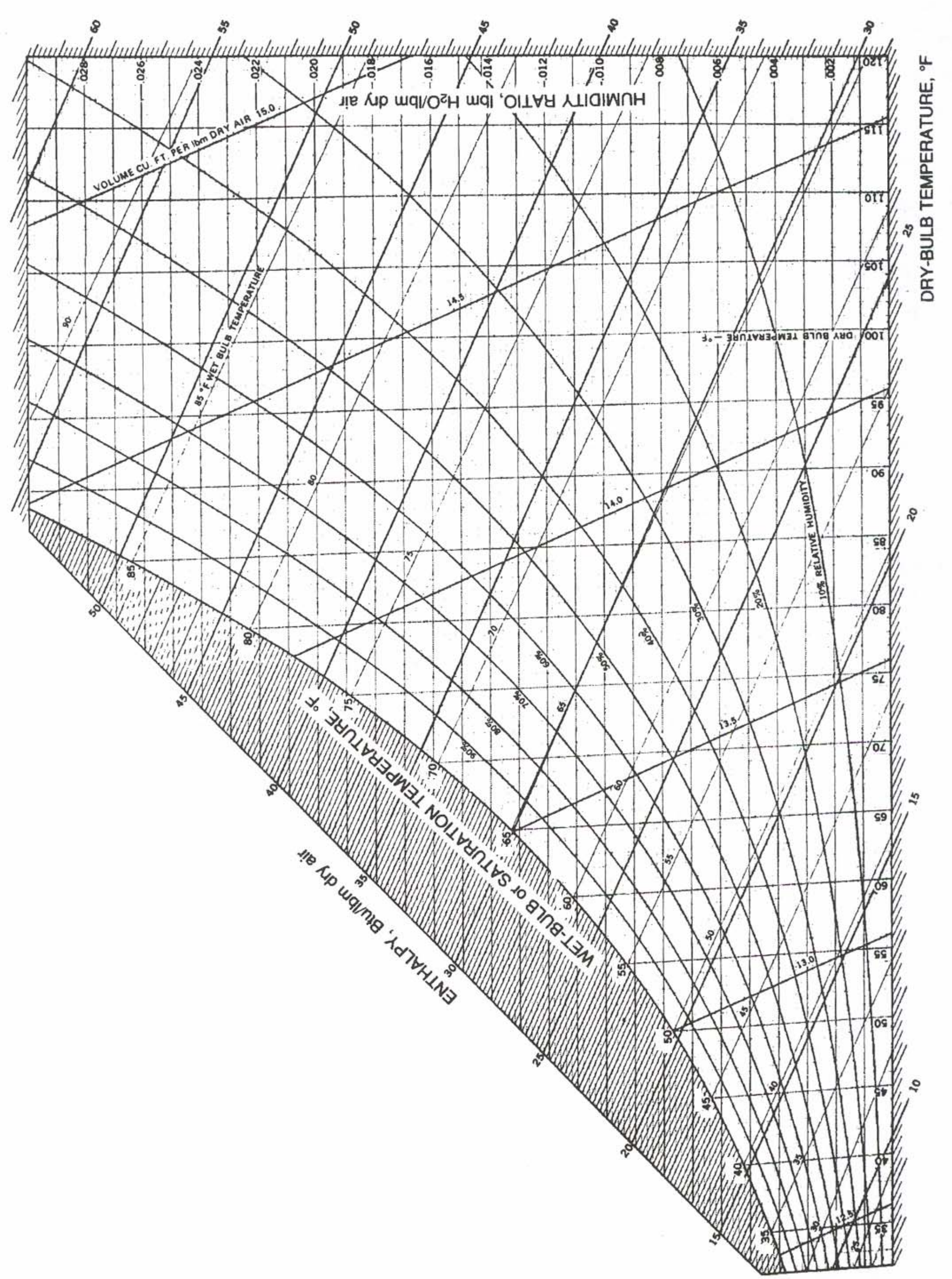

FIGURE 2. Humidity chart for normal temperature.

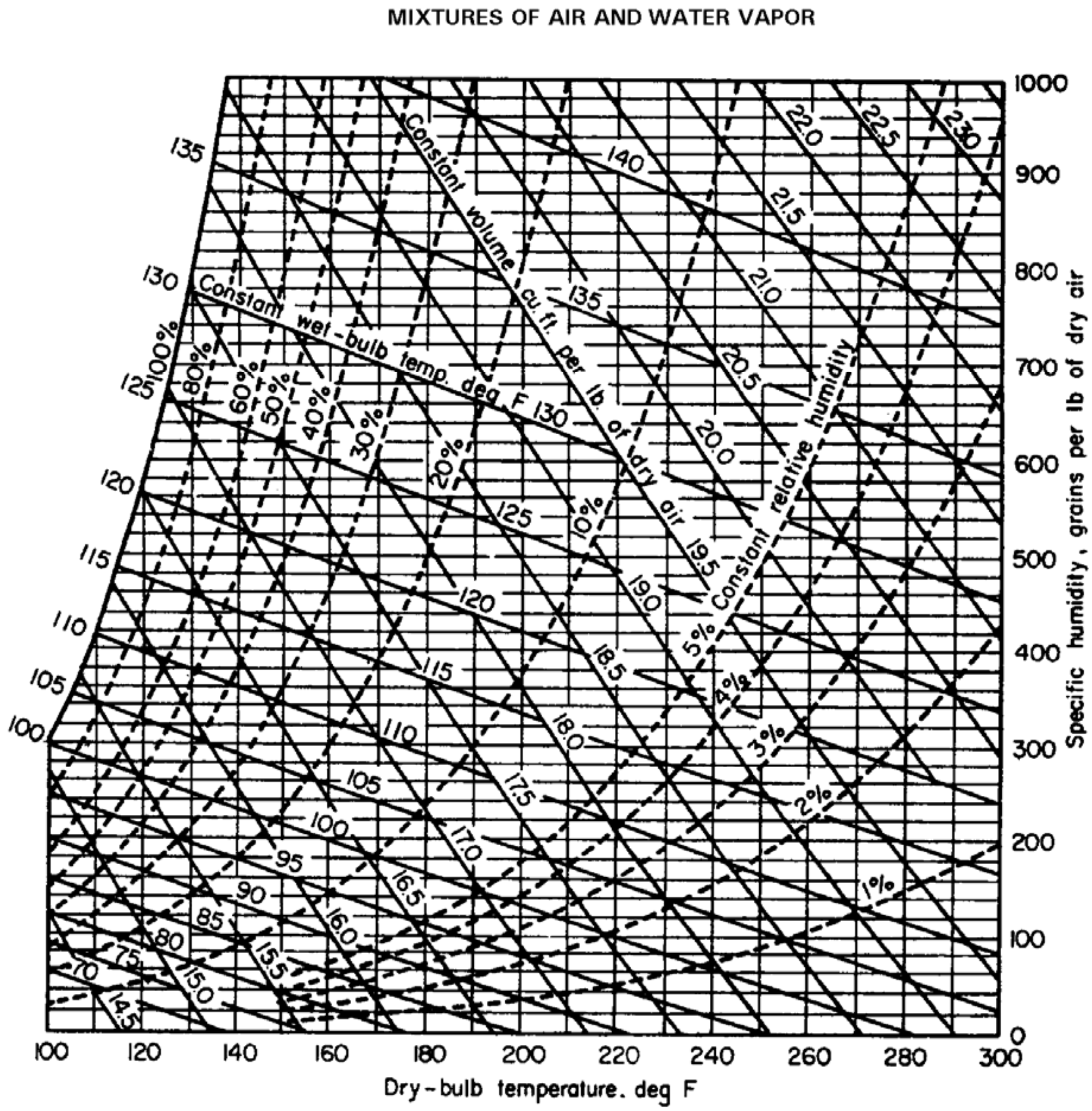

FIGURE 3. Humidity chart for high temperature.

5.3.3.10 Situations. The following situations are considered in specifying the environments of 5.3.3.l through 5.3.3.9.

(1) Transportation and handling:

a. Wheeled vehicles
b. Tracked vehicles
c. Rail vehicles
d. Watercrafts
e. Ships including aircraft carriers

(2) Storage and handling:

a. Igloo-magazine
b. Un-insulated sheet metal building
c. Roofed structure with no sidewalls
d. Dump storage, exposed
e. Dump storage, revetment
f. Railroad siding
g. Aircraft carrier main deck
h. Aircraft carrier hangar deck
i. Wood structure with sidewall
j. Aircraft's hangar

(3) Operational handling and storage:

a. Maintenance test site
b. Maintenance shop
c. Aircraft carrier main deck
d. Weapons handling equipment
e. Unsheltered ordnance assembly table

(4) Aboard aircraft:

a. Catapult lineup
b. Aircraft in a revetment
c. Aircraft on the runway
d. Vertical takeoff and landing (VTOL) jet blast
e. Jet blast (from other aircraft)
f. Bomb bay
g. Store station of aircraft
h. Rocket exhaust impingement
i. Aircraft in flight

(5) Launch-to-target

5.3.4 Situation independent environments.

5.3.4.1 Leakage. Penetration, seepage, immersion of water into equipment or weapon enclosure can cause material corrosion, formation of electrical conductivity and diminishment of the heat quality of propellant. The leakage should be presented in terms of fluids or gas or gases and measured in cubic inches per second (in^3/sec) or liters per second (ℓ/sec). The amount of leakage should be minimized, depending upon the chemical and mechanical properties of the materials.

5.3.5 Special environments (see 3.11).

5.3.5.1 Structural. The weapon designer should consider the safety and reliability of the weapon systems during storage and transportation to the final destination. The structural environments are directly related to the materials, strength, mechanical and chemical properties and stress. Consideration should be given as whether the structural materials are capable of resisting corrosion, high temperature extremes, strong wind and heavy rain. Consideration should also be given to the selection of the transportation equipment which will safely deliver a weapon to a final destination.

5.4 Synergistic effects. Synergistic effects result from exposure of the weapon to a combination of concurrent environments whose effects on the weapons are more damaging than the cumulative effect of each environment acting singly. They may include such combinations as:

a. Humidity and acid gas during ground storage, transportation, and handling operation.

b. Temperature, humidity, shocks, and vibration during transportation.

c. Aerodynamic heating, altitude variations, humidity, shocks and vibration, and acoustics during aircraft carriage. The weapon's factory-to-target sequence should be examined for this effect.

5.5 Tailoring process. The tailoring (see 3.12) process is an ability to apply common scientific and engineering methods to the environmental life cycle focusing on realistic materials, design, and test criteria. To execute a tailoring process, it is necessary to give proper consideration to environments that occur throughout the life cycle. Data given in Appendices A through F are for guidance only to help program managers and environmental engineering specialists develop tailored design and test criteria.

6. NOTES

6.1 Intended use. This handbook provides acquisition activities the guidelines for the development of environmental engineering design and test requirements specifically for air-launched weapons.

6.2 Subject term (key word) listing.

Aircraft systems, fixed wing, rotary wing
Aircraft carrier, surface ships, and ship systems,
Bomb, Missiles, Ordnance, weapon systems
Delivery, transportation,
Document preparation
Environments, static, dynamic, natural

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

6.4 Environmental engineering points of contact.

a. US Army Topographic Engineering Center
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Commander
US Army Developmental Test Command
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Aberdeen Proving Ground, MD 21005-5055

b. Air Force-22-AAC/EN,
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Air Force 11 - ASC/ENFS
Attn: Faustino Zapata
2530 Loop Road West, Building 560
Wright-Patterson AFB, OH 45433-7101
Email: Faustino.Zapata@wpafb.af.mil

c. Naval Air Systems Command
Naval Air Warfare Center Weapons Division
Attn: Brian Haugen, Code 476300D
1900 N. Knox Road Stop
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ENVIRONMENTAL DATA AND CALCULATION TECHNIQUES

A.1 SCOPE

A.1.1 Scope. The environmental data and calculation techniques presented herein may be used to provide preliminary data before hardware becomes available for field acquisition of data.

A.1.2 Introduction. The data presented herein are sample values or calculation methods for each environment discussed and always include consideration of the operational status of the weapon system. For example:

a. The weapon container is exposed to the environments during transportation and storage. The weapon is not required to function during this exposure but must function after removal from the container.

b. The weapon is exposed to the environments during airfield and aircraft carrier handling but may be containerized during underway replenishment. The weapon must function following exposure to these environments.

c. The weapon mounted in its use configuration is exposed to the environments on board the carrying aircraft and must function during and following exposure to these environments. Several environments cannot be adequately defined because of the complexity of the problem of definition or lack of knowledge about the environment. Some of the environments that fall in this category are those involving rainfall at altitude. These environments are not detailed herein, but their effects on the hardware are to be described in the OED.

A.2 APPLICABLE DOCUMENTS

MIL-STD-167-1
MIL-STD-167-2
MIL-STD-810
MIL-STD-8591
STANAG 4370
MIL-S-901 and
MIL-HDBK-310 listed in section 2 of this handbook applies to this appendix.

A.3 DEFINITIONS

A.3.1 Air-delivered ordnance. Ordnance such as a rocket or bomb (either free fall or self propelled) delivered by means of fixed wing or rotary wing aircraft.

A.3.2 Captive flight. The flight mode of aircraft with weapon(s) attached.

A.3.3 Covered storage. Ammunition or ordnance stored under cover protected from natural environments such as sunlight, heat, and rain.

A.3.4 Design maximum. The theoretical value of maximum temperature used in the design when calculating the cumulative probability.

A.3.5 Dump storage. Open storage of ordnance with no, or minimum, protection (tarps) from natural environments.

A.3.6 High altitude intercept. A target intercepted at altitude above 35,000 feet (10,668 meters).

A.3.7 Laminar regions. A fluid region where the Reynolds number is less than 100,000. In this region, the flow of air is smooth, the instantaneous point of fluid velocity is the same and the fluid obeys Newton's law of viscosity.

A.3.8 Reynolds number (R_e). R_e defines the flow characteristics of air: laminar, transition, or turbulent. For laminar flow, the R_e is less than 100,000, for turbulent, the R_e is greater than 1,000,000 and for transition flow, the R_e is in between 100,000 and 1,000,000.

A.3.9 Shock spectrum. A set of peak responses of damped mechanical systems, each tuned to a different un-damped natural frequency when subjected to a shock transient.

A.3.10 Thermal forcing function. The natural or induced thermal environmental stress condition acting on the weapon that may affect its ability to function reliably during its service life.

A.3.11 Three sigma. A process standard deviation from the root mean square value.

A.3.12 Turbulent region. Thin regions of fluids in the form of boundary layer (free shear layer). In this region, the Reynolds number is greater than 1,000,000, the flow of fluid is well mixed and instantaneous point velocities are unequal.

A.3.13 Underway replenishment. A method of transferring fuels, munitions, supplies, and personnel from one vessel to another while the vessel is underway.

A.3.14 Vortex shedding. At a low Reynolds number, the flow around the cylinder is steady and symmetric upstream and downstream and there is no vortex shedding. However when the flow increases, the vortex shedding appears, resulting in an increase of the pressure drag.

A.3.15 Abbreviations and acronyms used in Appendix A. The abbreviations and acronyms used in this appendix A are defined as follows:

a. AE - Ammunition Ship
b. AOE - Fast Combat Support Ship (underway replenishment)
c. BPH - British Thermal Unit per Square Foot Per Hour
d. LPH - Langley Per Hour
e. MHU - Munitions Handling Unit
f. SIDNA - Systems Improved Differencing Numerical Analyzer

A.4 GENERAL GUIDANCE

A.4.1 Temperature. The thermal environment of air-delivered ordnance (see A.3.1) during the factory-to-target sequence is divided into two basic categories:

(1) Transportation, storage, and handling, and

(2) Captive flight (see A.3.2) and free flight (launch-to-target).

The first category accounts for the major part of the factory-to-target sequence; the second category generally provides the thermal extreme situations. The weapon's response to temperature in both of these categories must be considered in the weapon design.

A.4.1.1 Storage and transportation temperature computations. Computation of weapon temperature profiles during storage and transportation requires determination of:

a. The appropriate thermal forcing functions (see A.3.10).

b. Weapon response to these forcing functions.

During dump storage, the primary forcing functions are:

a. Direct and reflected solar and atmospheric radiation.

b. Convection from ambient air.

During covered storage (A.3.3) and transportation, the dominant forcing functions are:

a. Convection from the surrounding air, and

b. Radiation exchange with compartment walls.

Once the thermal forcing functions have been determined, a weapon's response may be computed using appropriate heat transfer theories and techniques. An energy balance that describes the system must be developed and the appropriate set of equations solved. This involves consideration of natural convection, conduction, and radiation heat transfer. To construct an accurate thermal model configuration, surface emissivities and properties such as thermal conductivity, density, and specific heat must also be known. A typical example is dump storage of a solid propellant rocket motor in a container. The parameters involved in this situation are as follows:

a. Radiation and convection between the container and its surroundings (unless the container temperature profile is provided as an input).

b. Conduction through the container wall (often negligible).

c. Radiation exchange between the inner wall of the container and the surface of the motor.

d. Natural convection in the air gap between the container and the motor.

e. Conduction through motor, liner, and propellant grain.

A.4.1.1.1 Sample problem (dump storage). Predict the temperature response of an 8-inch diameter solid rocket motor in a container subjected to the daily cycle of temperature and associated solar radiation, relative humidity, and wind speed given in MIL-HDBK-310.

A.4.1.1.1.1 Basic assumptions.

a. Motor in 6-foot-long container aligned parallel with wind direction.

b. Thermal forcing functions: solar radiation, atmospheric radiation, and convection with ambient air.

c. One dimensional radial heat transfer through 30 degree segment of top of container and motor system (giving conservative results since the top receives maximum solar radiation).

d. System initially soaked at 100 ^{o}F (38 ^{o}C).

e. Constant thermal properties (temperature dependent properties may be included).

A.4.1.1.1.2 Method of solution.

a. Develop thermal model of weapons system, see figure A-1 and table A-I for dimensions.

b. Define input conditions of thermal properties from table A-II.

c. Write energy balance for each thermal node.

d. Solve resulting system of energy balance equations to obtain temperature response of each mode.

TABLE A-I. Thermal model construction and dimensions.

Node (see fig A-1)	Part	Thickness (inch)	Thickness (mm)
1	Case	0.0625	1.588
2	Liner	0.025	0.635
3	Air gap	0.150	3.810
4-8	Shell grain	0.825	20.955
9	Air gap	0.5	12.700
10-14	Inner grain	1.7	43.180
15	Air gap	4.0	101.600
16	Container	0.1	2.540

TABLE A-II. Thermal properties.

Material	Density		Thermal conductivity		Specific heat	
	lb/ft^3	Kg/m^3	Btu/hr-ft-^oR	W/m-^oK	Btu/lb-^oR	KJ/kg-^oK
Container	483.80	7749.73	25.00	1657.43	0.12	231
Motor case	483.80	7749.73	25.00	1657.43	0.12	231
Liner	108.90	1744.41	0.19	12.60	0.28	539
Grain	105.20	1685.14	0.22	13.26	0.29	558

Note: Thermal mass of air gaps neglected.

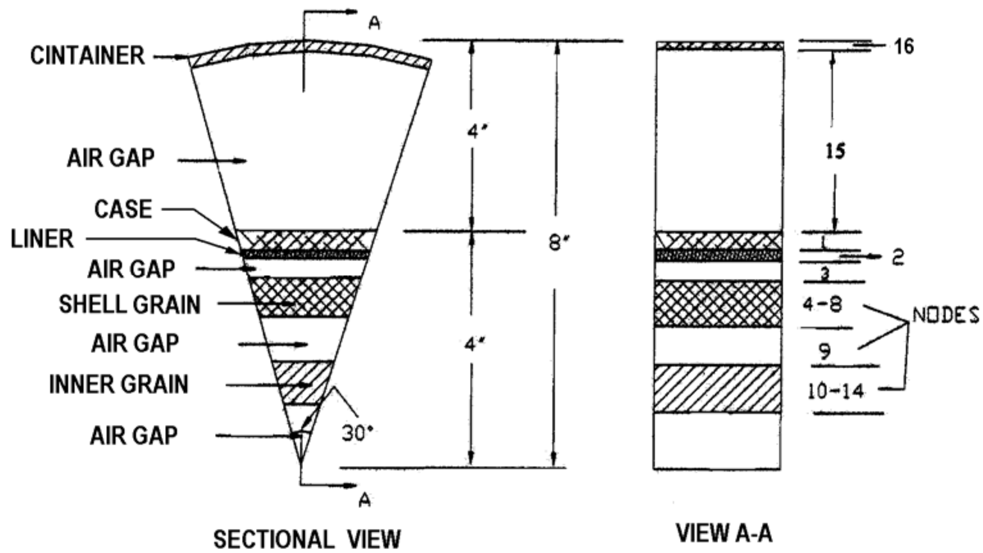

FIGURE A-1. Thermal model of 30° segment of the rocket motor.

A.4.1.1.1.3 Input conditions. The data shown in table A-III is used as an input condition for evaluation of environmental data.

Atmospheric radiation (q_{atm})

$$q_{atm} = \sigma T_{air}^4 (a + b\sqrt{e}) \text{ Btu/ft}^2\text{-hr}$$

where

σ = Stefan-Boltzmann constant

σ = $0.1714 \text{X} 10^{-8}$ Btu/hr-ft^2-°R^4 ($5.67 \text{X} 10^{-8}$ W/m^2-°K^4)

T_{air} = Ambient air temperature, ^{o}R (^{o}K)

a = 0.5 (constant factor)

b = 0.06, $\frac{1}{\sqrt{mb}}$

e = Relative Humidity (RH) X saturation vapor pressure in millibar (mb)

Average Convective Heat Transfer Coefficient ($\bar{h}_c$)

$$\bar{h}_c = \frac{0.036 \times k}{L \times P_r^{.33} \times R_e^{.8}} \quad \text{Btu /hr -ft}^2\text{-}^{o}\text{R (W/m}^2\text{-}^{o}\text{K)}$$

where

k = Thermal conductivity of air, Btu /hr-ft-^{o}R (W/m-^{o}K)

L = Length of container, ft

$P_r = \frac{C_{pa}\mu}{k}$ Prandtl number

C_{pa} = Specific heat of air, Btu/lb-^{o}R (W/kg-^{o}K)

μ = Viscosity of air, lb/ft -hr (kg/m-hr)

$R_e = \frac{VL\rho_a}{\mu}$ Reynolds number (see A.3.8)

V = Wind velocity, ft/hr (m/hr)

ρ_a = Density of air, lb/ft^3 (kg/m^3)

Air properties are evaluated at film temperature where:

$$T_{film} = \frac{T_{air} + T_{cont}}{2} \quad {}^{o}R\ ({}^{o}K)$$

Where

T_{film} = Film temperature in ^{o}R (^{o}K)

T_{cont} = Container temperature ^{o}R (^{o}K)

A.4.1.1.1.4 Energy balance. An energy balance, which equates the heat stored to the difference between heat in and heat out is required for each thermal node of the system. The energy balance per unit area of the top of the container is as follows:

Heat Stored = Heat In — Heat Out

Heat stored in the container = Heat in to the container — Heat out from the container

Heat stored in the container = $\rho_c \times C_{pc} \times b \times DT/dt$

where

ρ_c = Density of container wall, lb/ft^3 (kg/m^3)

C_{pc} = Specific heat of container wall, Btu/lb-^{o}R (W/kg ^{o}K)

b = Thickness of container wall, ft (m)

DT/dt = Rate of change of container temperature (T) with time (t)

Heat in to the container = Solar Radiation + Atmospheric Radiation + Convection with ambient air

Heat in to the container = $\alpha_s \times q_{solar} + \alpha_L \times q_{atm} + \bar{h}_c (T_{air} - T_{cont})$

where

α_s = Absorbtivity to solar radiation ($\simeq$0.6)

q_{solar} = Solar radiation heat flux, Btu/ft^2-hr (W/m^2)

α_L = Absorbtivity to long wavelength atmospheric radiation ($\simeq$ 0.9)

q_{atm} = Atmospheric radiation heat flux, Btu/ft^2-hr (W/m^2)

T_{air} = Ambient air temperature, °R (^{o}K)

T_{cont} = Container temperature, °R (^{o}K)

Heat out from container = Radiation Emitted + Convection with air gap + Radiation Exchanged with Motor Skin

$$= \sigma \times \xi \times T_{cont}^4 + \bar{h}_{isc}(T_{cont} - T_{airgap}) + \sigma \times \xi \times (T_{cont}^4 - T_{motor}^4)$$

where

σ = Stefan-Boltzmann constant, Btu/ft^2-hr-^{o}R^4 (W/m^2-^{o}K^4)

ξ = Emissivity of container surface ($\simeq$ 0.9)

$\bar{h}_{isc}$ = Convective heat transfer coefficient on internal surface of container
= $\simeq$0.6 Btu/hr-ft^2-^{o}R ($\simeq$ 19.85 W/m^2-^{o}K)

T_{airgap} = Temperature of air gap between motor and container, ^{O}R (^{o}K)

T_{motor} = Temperature of motor case, ^{O}R (^{o}K)

Therefore:

$$\rho_c \times C_{pc} \times b \times DT/dt = \{\alpha_s q_{solar} + \alpha_L q_{atm} + \bar{h}_c(T_{air} - T_{cont})\} -$$

$$\{\sigma \times \xi \times T_{cont}^4 + \bar{h}_{isc}(T_{cont} - T_{airgap}) + \sigma \times \xi \times (T_{cont}^4 - T_{motor}^4)\}$$

Similar expressions are developed for each thermal node equating to heat transfer to and from adjoining nodes by conduction, convection, and radiation.

A.4.1.1.1.5 Solution of equations. The resulting system of equations may be solved numerically with a typical thermal analysis program; the energy balance equations may be developed within the program, using the geometry and properties of the thermal model, and the required boundary conditions as input (see figure A-2). For this particular problem, the Systems Improved Differential Numerical Analyzer (SIDNA) thermal program is used and the systems of equations are solved by implicit "forward-backward" finite differencing (Crank-Nicholson method).

A.4.1.1.1.6 Results of typical solution. The results of a typical thermal analysis are provided in figure A-2.

A.4.1.2 Cumulative probability for dump storage (limited data). Where the data from MIL-HDBK-310 is not appropriate for calculating container wall temperatures, usable values for container wall maximum and minimum temperatures can be obtained from figures A-3 to A-5. Cumulative probability is plotted as a continuous function from 0 to 1. A management decision on "design maximum" (see A.3.4) temperatures may be made utilizing cumulative probability, keeping in mind that three sigma (see A.3.11) is 0.997. Figures are each based on 8,760 hourly samples per year from a given thermocouple.

A.4.2 Air temperature profiles for transportation and storage. Air temperature profiles for selected transportation and storage situations are shown on figures A-6 to A-11. For information on transportation and storage, see the references listed in Appendix F.

A.4.2.1 Captive and free flight temperature computation. Analysis of the aerodynamic heat transfer (heating or cooling) of weapons involves:

(1) Developing an accurate thermal model of the weapon.

(2) Defining the environment (input) in terms of flight profiles and atmospheric conditions.

(3) Calculating the aerodynamic heat transfer coefficients over the external surfaces of the weapon.

(4) Writing an energy balance for each thermal node.

(5) Solving the resulting network of equations.

Some of the above may not be necessary in all cases. The greatest uncertainty arises in the definition of the environment.

The flight conditions and atmospheric temperature determine the recovery temperature, which is the forcing function in the aerodynamic heating of a body. Realistic mission profiles must be used, with consideration given to the effect on aircraft performance of nonstandard day conditions and external stores. Extreme atmospheric temperature profiles are obtained from MIL-HDBK-310. These values, however, cannot be used in applications involving the changes in altitude indicated in mission profiles and air-to-air and air-to-surface missile trajectories. Until a family of consistent hot and cold model atmospheres is developed, such applications should be handled using the U.S. Standard Atmosphere, 1976, or the Standard Atmosphere Supplement, 1966. Techniques for calculating the aerodynamic heat transfer coefficient are generally well developed. An important exception is interference heating, caused by control surfaces and other surface protrusions that can result in heating rates several times the undisturbed values. In speed regimes and configurations where this problem exists, it must be treated using the best engineering techniques available. Development of adequate thermal models can range from a fairly simple process to a very complex process. In a simple process, such as a case-bonded rocket motor, only heat conduction through a symmetrical shape is involved. In a complex process, such as a guidance section, the effects of natural convection, radiation between components, contact resistance and internal heat sources must be considered.

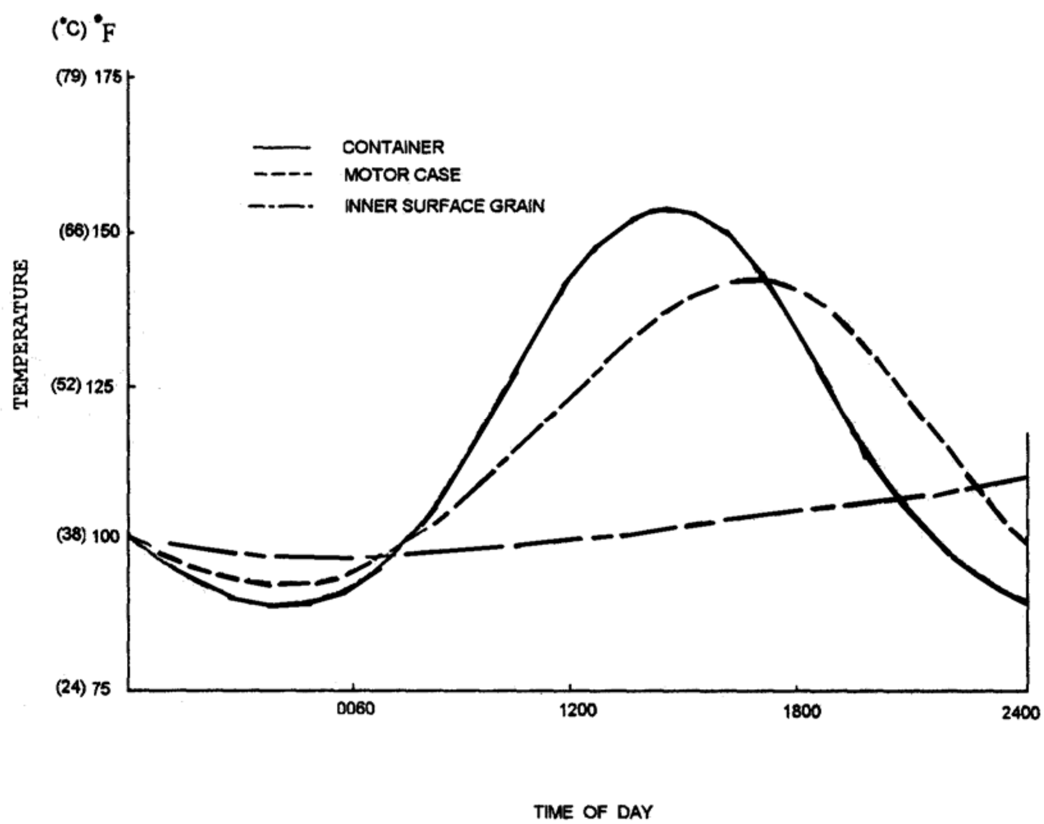

FIGURE A-2. Results of typical solution of thermal analysis.

TABLE A-III. Daily cycle of temperature and other elements associated with the high temperature extreme for ground operations.

Local standard time, hours	Temperature		Relative humidity percent	Wind speed		Solar radiation	
	°F	°C		ft/sec	meters/sec	BPH 1/	LPH 2/
0100	95	35	6	9	3	0	0
0200	94	34	7	9	3	0	0
0300	93	34	7	9	3	0	0
0400	92	33	8	9	3	0	0
0500	91	33	8	9	3	0	0
0600	90	32	8	9	3	18	5
0700	91	33	8	9	3	85	23
0800	95	35	6	9	3	160	43
0900	101	38	6	9	3	231	63
1000	106	41	5	14	4	291	79
1100	110	43	4	14	4	330	90
1200	112	44	4	14	4	355	96
1300	116	47	3	14	4	355	96
1400	118	48	3	14	4	330	90
1500	119	48	3	14	4	291	79
1600	120	49	3	14	4	231	63
1700	119	48	3	14	4	160	43
1800	118	48	3	14	4	85	23
1900	114	46	3	14	4	18	5
2000	108	42	4	14	4	0	0
2100	105	41	5	14	4	0	0
2200	102	39	6	14	4	0	0
2300	100	38	6	14	4	0	0
2400	98	37	6	9	3	0	0

Notes:
1/ BPH - British thermal units per square foot per hour.
2/ LPH - Langleys per hour.

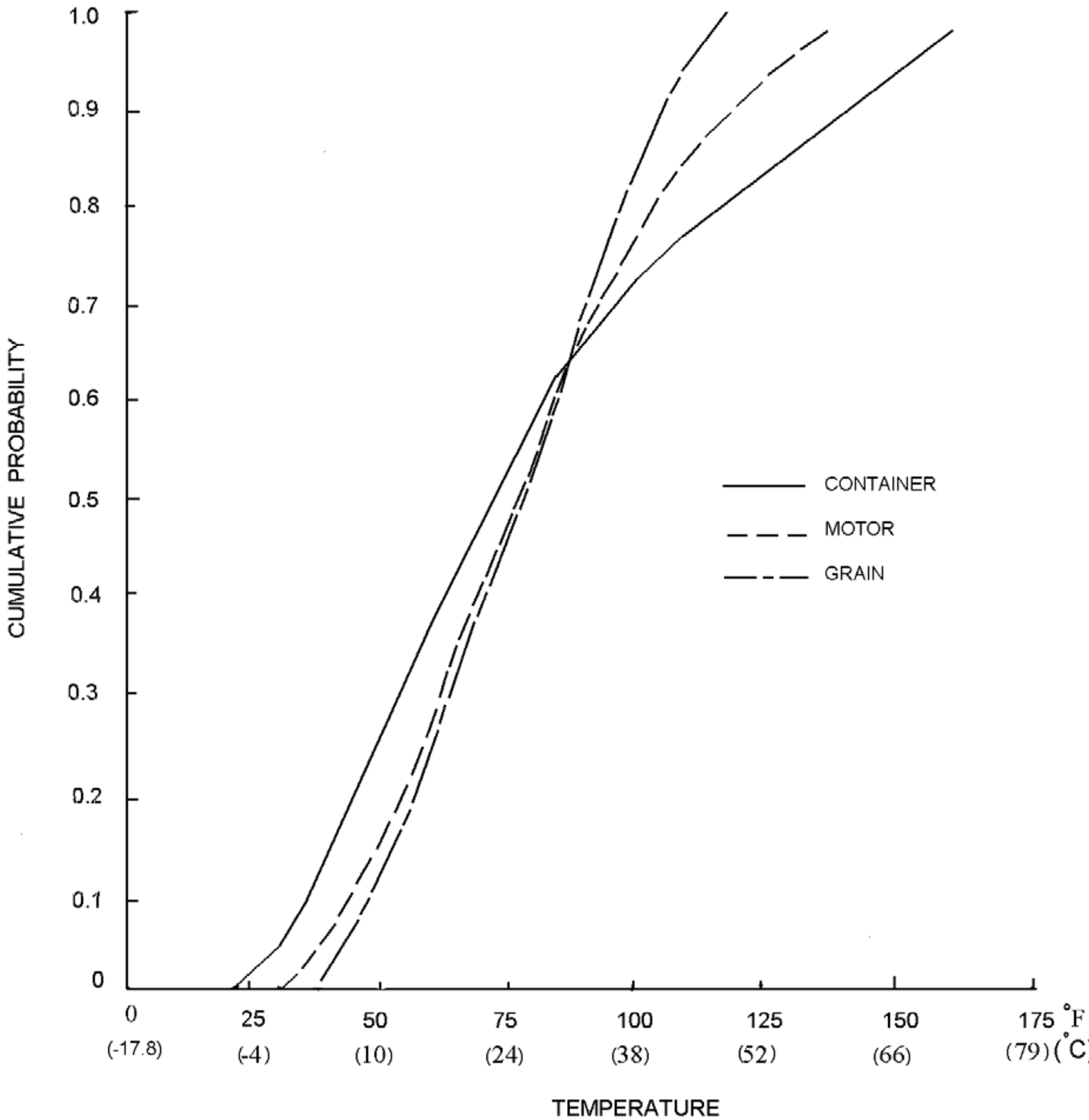

FIGURE A-3. Cumulative distribution summary of desert dump stored 12-inch diameter rocket motor temperatures for the period June 1970 through May 1971.

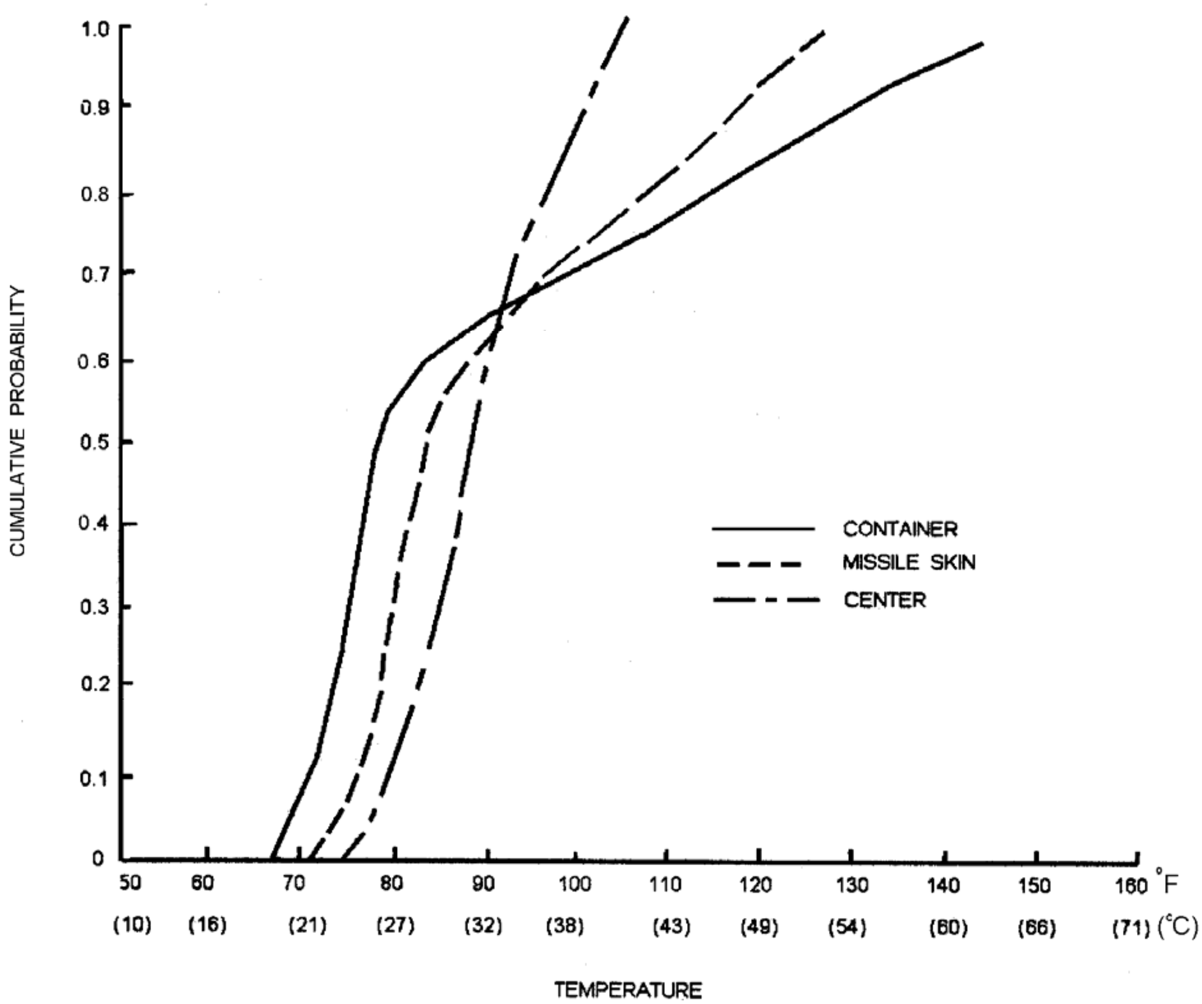

FIGURE A-4. Cumulative distribution summary of dump stored 12-inch diameter rocket motor temperatures at Subic Bay for 1970

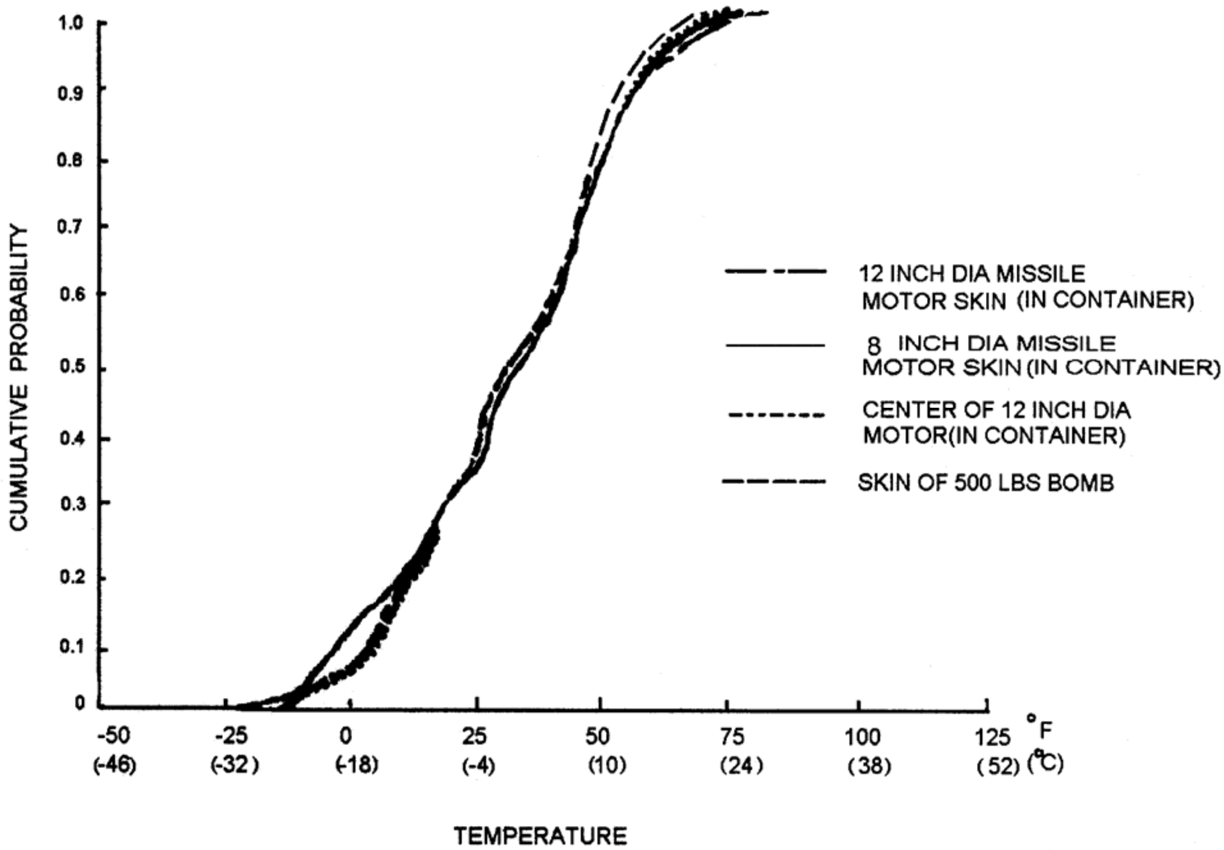

FIGURE A-5. Cumulative distribution summary of dump stored ordnance temperatures at Fort Richardson for 1970.

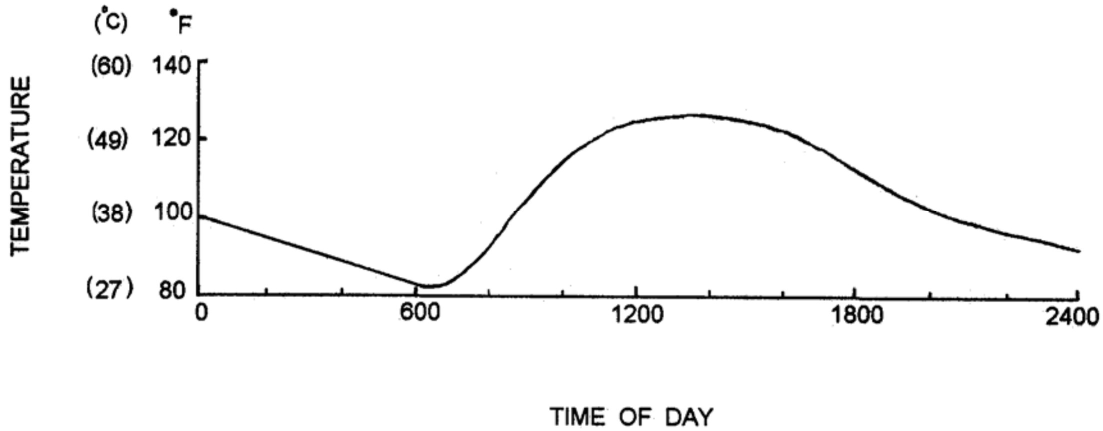

FIGURE A-6. Truck, van, rail and covered storage high temperature profile.

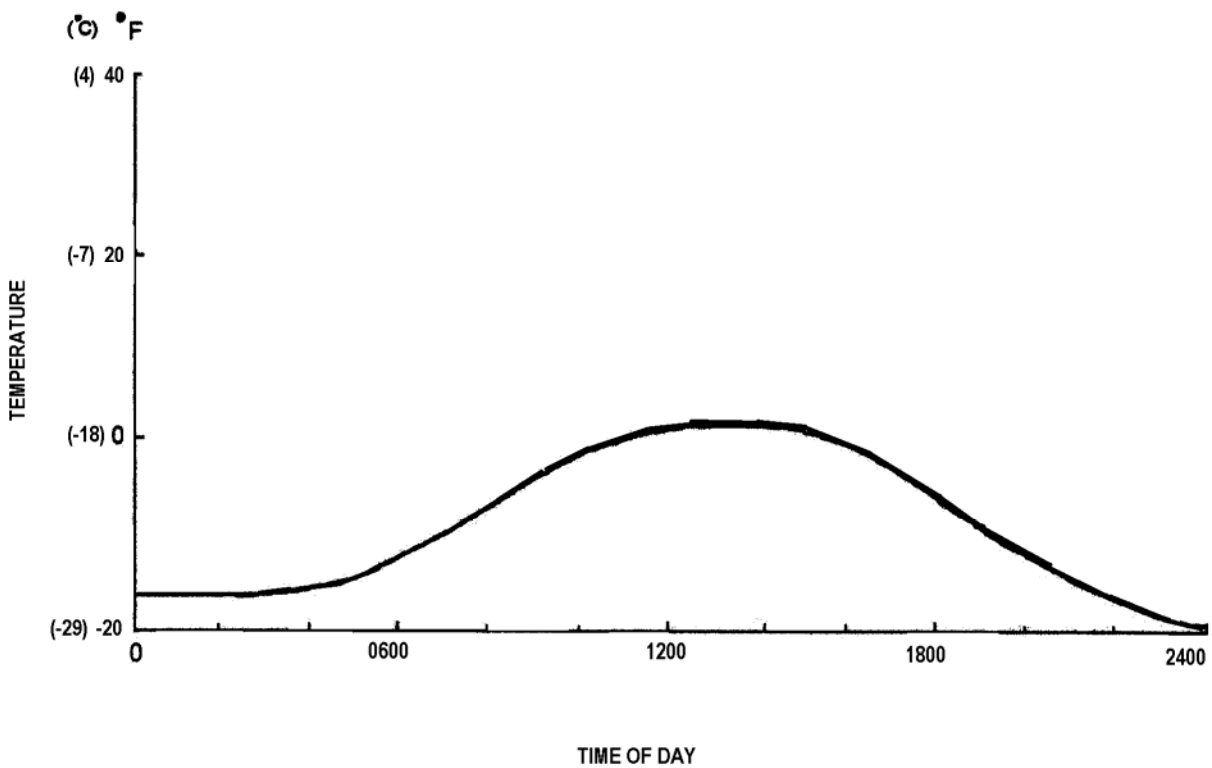

FIGURE A-7. Truck, van and rail low temperature profile.

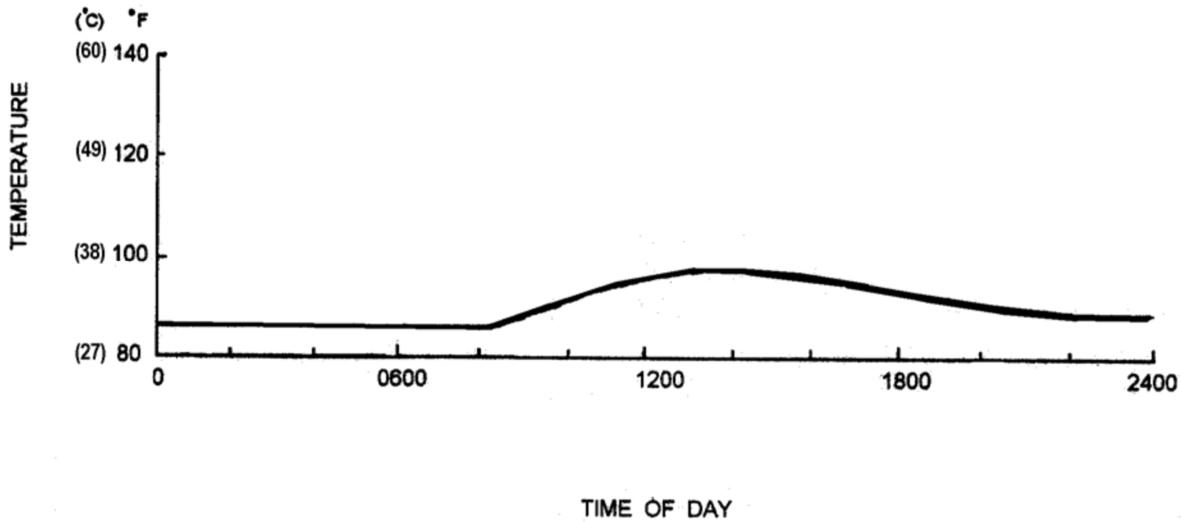

FIGURE A-8. Ship and aircraft carrier storage high temperature profile.

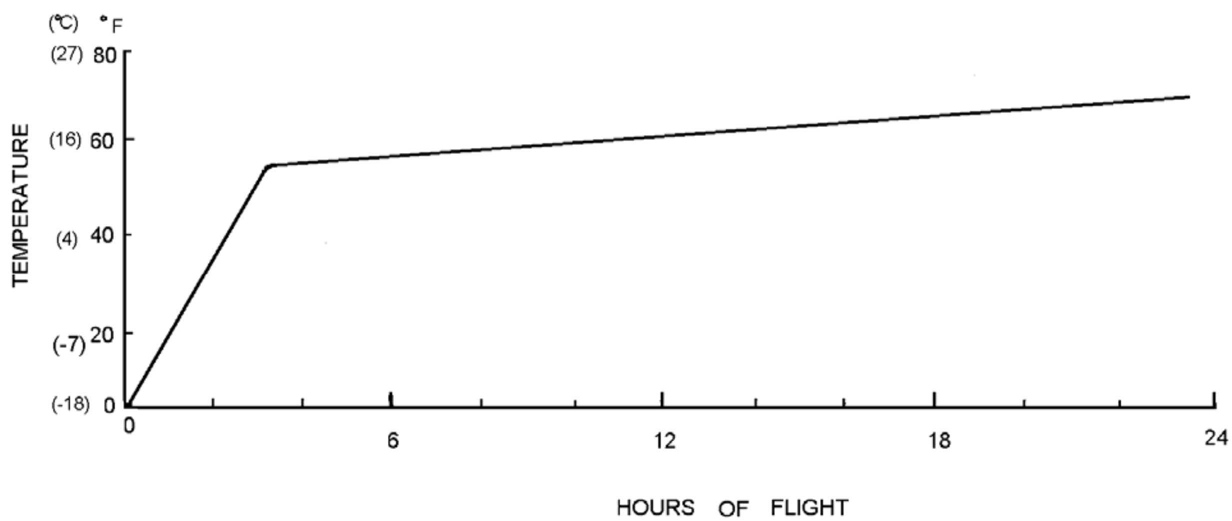

FIGURE A-9. Air cargo compartment low temperature profile.
Note: At end of flight, compartment temperature will again approach ambient.

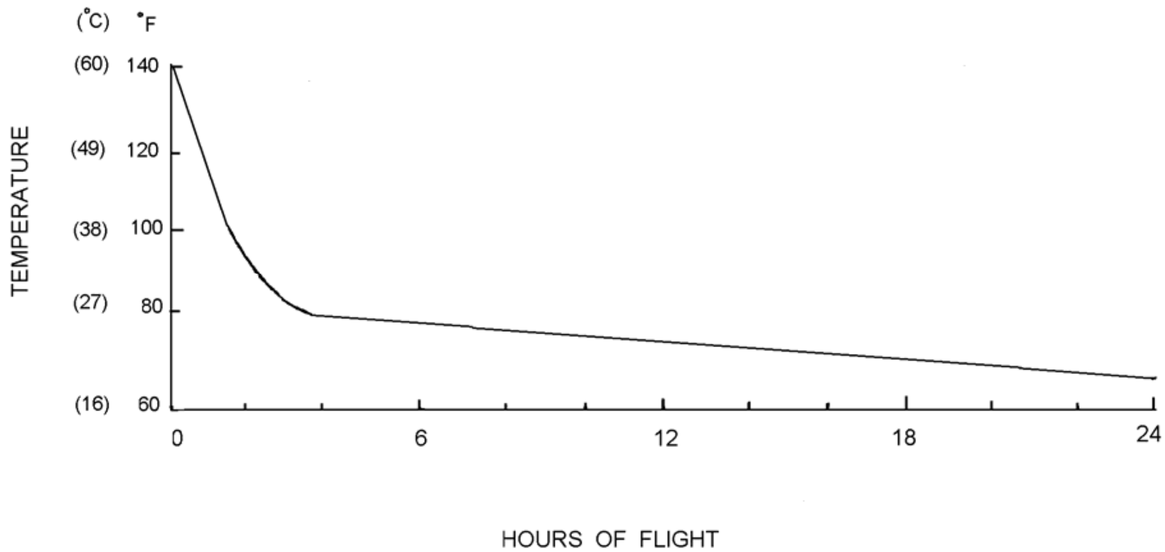

FIGURE A-10. Air cargo compartment high temperature profile.
Note: At end of flight, compartment temperature will again approach ambient.

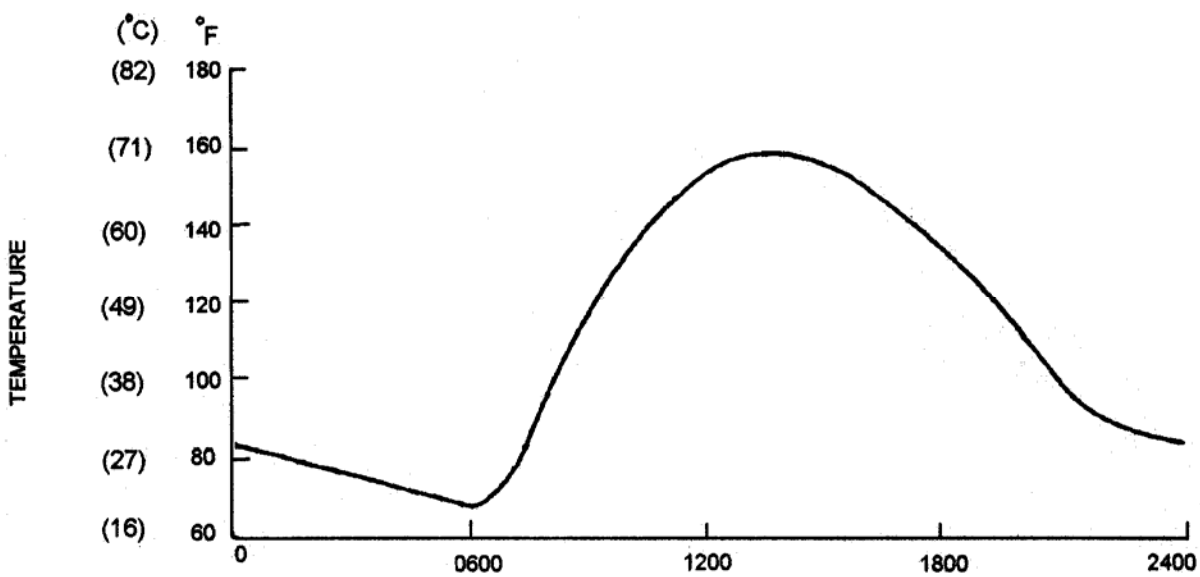

FIGURE A-11. Airfield and dump storage container inner wall high temperature profile.

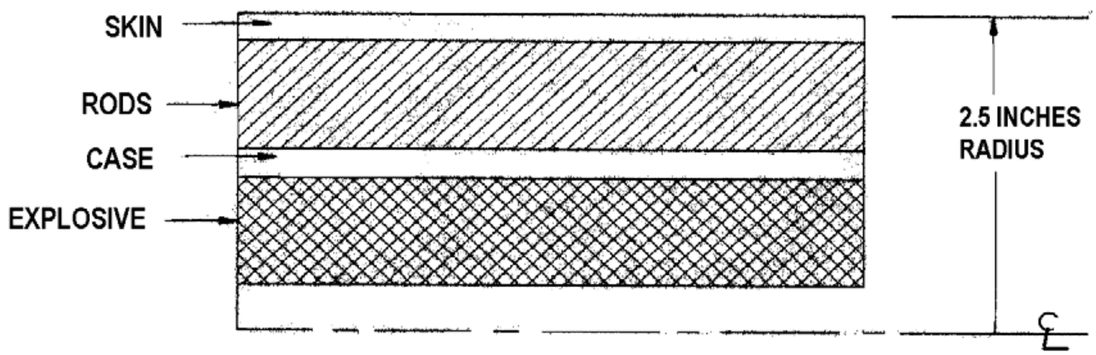

FIGURE A-12. Thermal model construction.
(Sectional view of 5 inches diameter weapon warhead)

A.4.2.1.1 Sample problem. Predict the temperature response of a 5 inch-diameter weapon warhead during aerodynamic heating and cooling.

A.4.2.1.1.1 Basic assumptions.

a. One-dimensional heat transfer (radial direction only).

b. Aircraft/missile interference effects neglected.

c. Radiation neglected.

TABLE A-IV. Thermal properties.

Materials	Thermal conductivity		Density x specific heat	
	Btu/hr-ft-^{o}R	W/m-^{o}K	Btu/ft^{3}-^{o}R	KJ/m^{3}-^{o}K
Skin	30	.1128	55	7.5
Rods	12	.045	35	4.8
Case	80	.301	35	4.8
Explosive	0.19	.0071	29	3.95

A.4.2.1.1.2 Aerodynamic heating rate.

The equation governing heat flow to or from a body in flight is:

$$q_{body} = \bar{h}_a (T_R - T_B)$$

where

q_{body} = Heat flow per unit area, Btu/hr-ft^2 (W/m^2)

$\bar{h}_a$ = Aerodynamic heat transfer coefficient, Btu/hr-ft^2-^{o}R (W/m^2-^{o}K)

T_R = Recovery temperature, ^{o}R (^{o} K)

T_B = Temperature of body, ^{o}R (^{o} K)

The following expressions give the heat transfer coefficients and recovery temperatures for laminar regions (see A.3.7) and turbulent regions (see A.3.12) on a smooth flat plate in a perfect gas with constant specific heat. The transitional Reynolds number is assumed to be 500,000.

(1) For laminar regions on a flat plate, the recovery temperature and heat transfer coefficient are computed from the equations:

$$T_{RL} = T_\infty (1 + 0.17 M_\infty^2)$$

where

T_{RL} = Recovery temperature of plate at laminar region

T_∞ = Free stream temperature, ^{o}R (^{o} K)

M_∞ = Free-stream Mach number

and

$$\bar{h}_{pl} = \frac{0.332 \times k^*}{L \times R_{el}^{*.5} \times P_r^{*.33}} \quad \text{Btu/hr-ft}^2\text{-}^o\text{R (W/m}^2\text{-}^o\text{K)}$$

where

* = Evaluated at Eckert's reference temperature, T^*

$\bar{h}_{pl}$ = Heat transfer coefficient of plate at the laminar region

L = Distance from leading edge of plate, ft (m)

k^* = Thermal conductivity of air at T^*

$$k^* = \frac{1.529075\ (10)^{-3}\sqrt{T^*(1.8)}}{1 + 441.72\,/\,T^*(10)^{21.6/T^*}} \quad \text{Btu/ft-hr-}^{o}\text{R (W/m-}^{o}\text{K)}$$

P_r^* = Prandtl number at T^*

$$P_r^* = \frac{\mu^* C_p^*}{k^*}$$

R_{el}^* = Reynolds number at laminar region at T^*

$$R_{el}^* = \frac{\rho^* V_\infty l}{\mu^*}$$

C_p^* = Specific heat of air at T^*

μ^* = Viscosity of air at T^* lb/ft-hr (kg/m-hr)

$$C_P^* = 0.24\{1 + \frac{2}{7}(\frac{5{,}550}{T^*})^2 \frac{(\exp(5{,}550/T^*)}{[\exp(5{,}550/T^*) - 1]^2}\} \quad \text{Btu/lb-}^{o}\text{R}$$

$$\mu^* = \frac{2.66(10)^{-3} \times T^{*(3/2)}}{T^* + 198.6} \quad \text{lb/ft-hr}$$

T_{pl} = Plate surface temperature, °R (°K)

T^* = Eckert's reference temperature, °R (°K)

$$T^* = 0.28T_\infty + 0.50T_{pl} + 0.22T_{Rl}$$

V_∞ = Free stream velocity, ft/hr (m/hr)

$$\rho^* = \frac{\rho_\infty T_\infty}{T^*}$$

where ρ_∞ = Free stream density of air, lb/ft^3 (kg/m^3)

(2) For turbulent regions on a flat plate, the recovery temperature and heat transfer coefficient are computed from the equations:

$$T_{RT} = T_\infty(1 + 0.178M_\infty^2)$$

where

T_{RT} = Recovery temperature of the plate at turbulent region

$S_t = \dfrac{C_f}{2S}$ Stanton number

C_f = Local skin friction coefficient

$$C_f = \frac{1}{F_c[2\log_{10}(F_{rx}R_{el}) - 0.65^{2.3}]}$$

where

F_c = Configuration factor of a body

and

$$F_c = \frac{(T_{RT} - T_\infty)}{T_\infty[Sin^{-1}(\alpha/\sqrt{\psi}) + Sin^{-1}(\beta/\sqrt{\Psi})]^2}$$

$$\alpha = T_{RT} - 2T_{\infty} + T_{PL}$$

$$\beta = T_{RT} - T_{PL}$$

$$\psi = T_{RT}^2 + 2T_{RT}T_{PL} - 4T_{\infty}T_{PL} + T_{PL}^2$$

$$F_{rx} = \frac{(T_{RT} / T_{PL})^{0.772}}{[F_C \cdot (T_{PL} / T_{\infty})^{0.702}]}$$

S = Reynolds analogy factor

$$S = \frac{0.89 + P_r[11.5\sqrt{C_f / 2}\sqrt{T_{PL} / T_{\infty}}]}{1 + 11.5\sqrt{C_f / 2}\sqrt{T_{PL} / T_{\infty}}}$$

A.4.2.1.1.3 Input conditions. Three hypothetical flight conditions are considered:

a. High altitude cruise (aero cooling).

b. Low altitude attack (aerodynamic-heating).

c. High altitude supersonic intercept (aerodynamic-heating).

The Mach number and altitude profiles associated with conditions (a) through (c) above are shown in figures A-13 through A-15, respectively. Atmospheric temperature profiles based on MIL-HDBK-310 should be used in the analysis of the high altitude cruise and low altitude attack flight conditions. The cold atmosphere model (figure A-16) should be used with the high altitude cruise, the hot atmosphere model (figure A-17) with the low altitude attack, and the U.S. Standard Atmosphere, 1976, with the high altitude intercept.

A.4.2.1.1.4 Energy balance and solution of equations. The procedure for setting up the nodal energy balances and solving the resulting network of equations is the same as that described in the dump storage sample problem of A.4.1.1.

A.4.2.1.1.5 Results. Computed warhead temperature response curves for the three flight conditions of interest are given in figures A-18 through A-20.

A.4.3 Humidity. The humidity environment to which a weapon will be exposed is independent of the weapon. The severity of the environment is a function of geography, temperature, altitude and time of day. The humidity environment is potentially degrading to most weapon components. Conditions that cause moisture penetration of weapon components should be considered during the design phase of the weapon. Some of these are (1) condensation in air-conditioned avionics equipment after aircraft flight; (2) exposure of seals to low pressure at altitude followed by exposure to high humidity at the completion of the combat mission, and (3) exposure of containers incorporating breather valves to daily temperature changes. Figure A-21 shows an accepted worldwide humidity environment.

A.4.4 Sand and dust. The severity of the sand and dust environment is a function of geography, humidity, temperature, and wind conditions (see references listed in Appendix F). The sand and dust particles are particularly destructive to jet engines, missile seeker domes, control surface of actuating devices, and moving or rotating devices that are not sealed. In certain types of carrying aircraft such as vertical takeoff and landing aircraft (VTOL) and helicopters, these effects are magnified. The sand and dust environment is defined by composition and particle size as follows:

Composition:

Fe_2O_3	=	5 to 10%
Al_2O_3	=	15 to 30%
SiO_2	=	remainder

Particle size:

0.0001 to 0.125 inch in diameter

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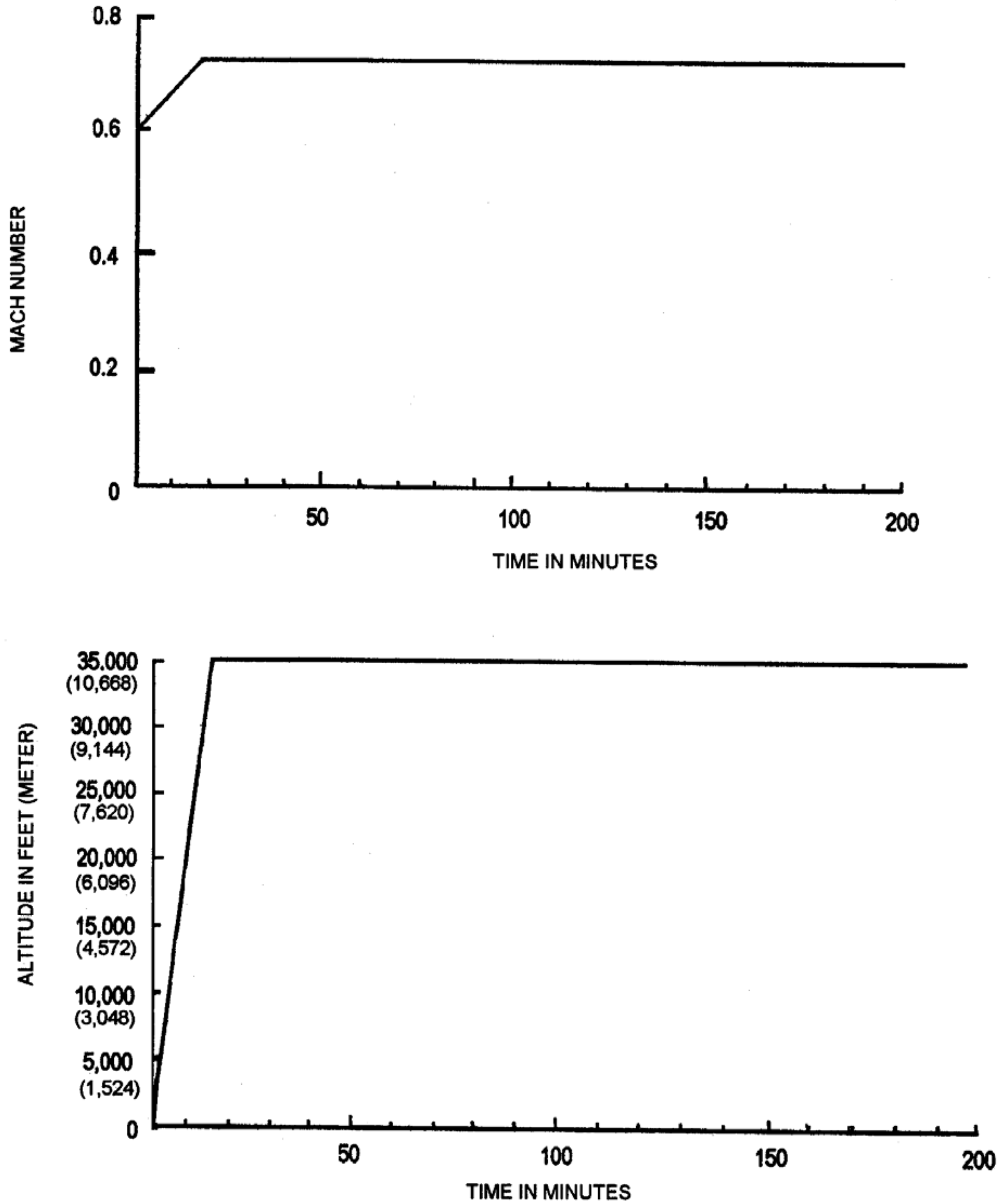

FIGURE A-13. High altitude cruise profile.

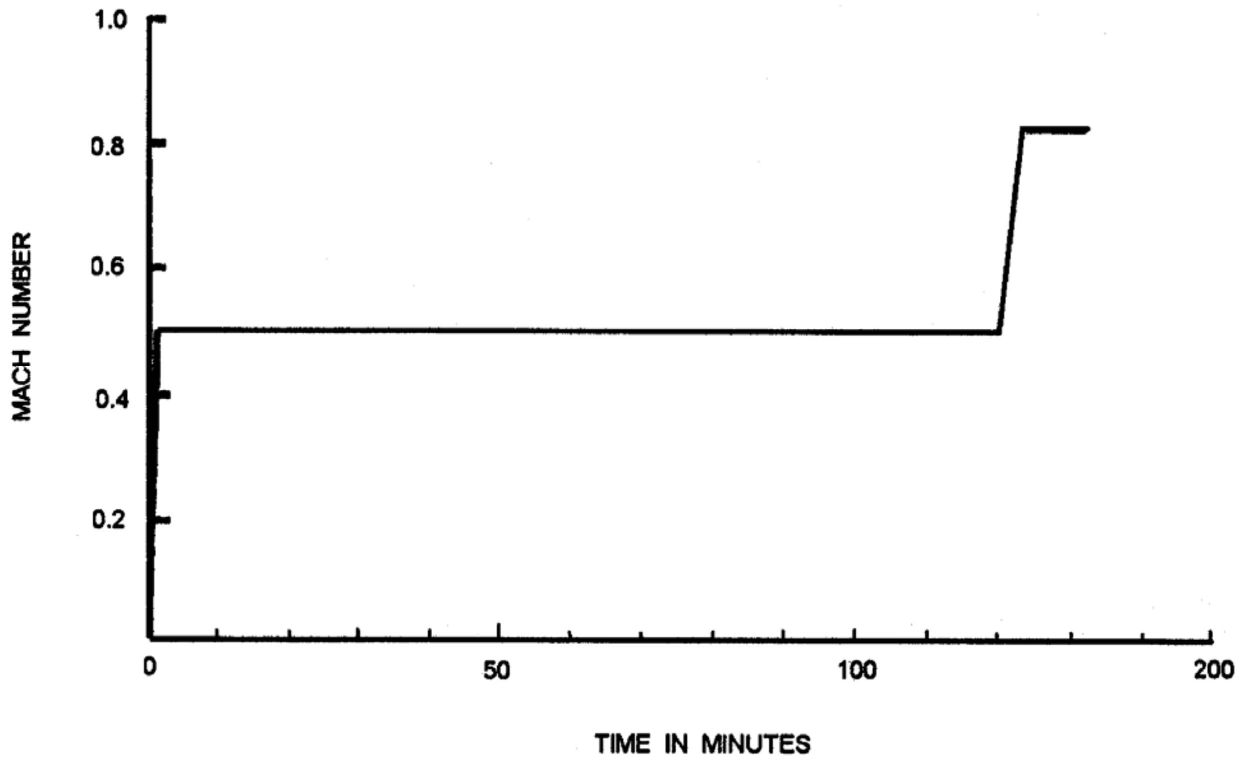

FIGURE A-14. Low altitude, sea level, attack profile.

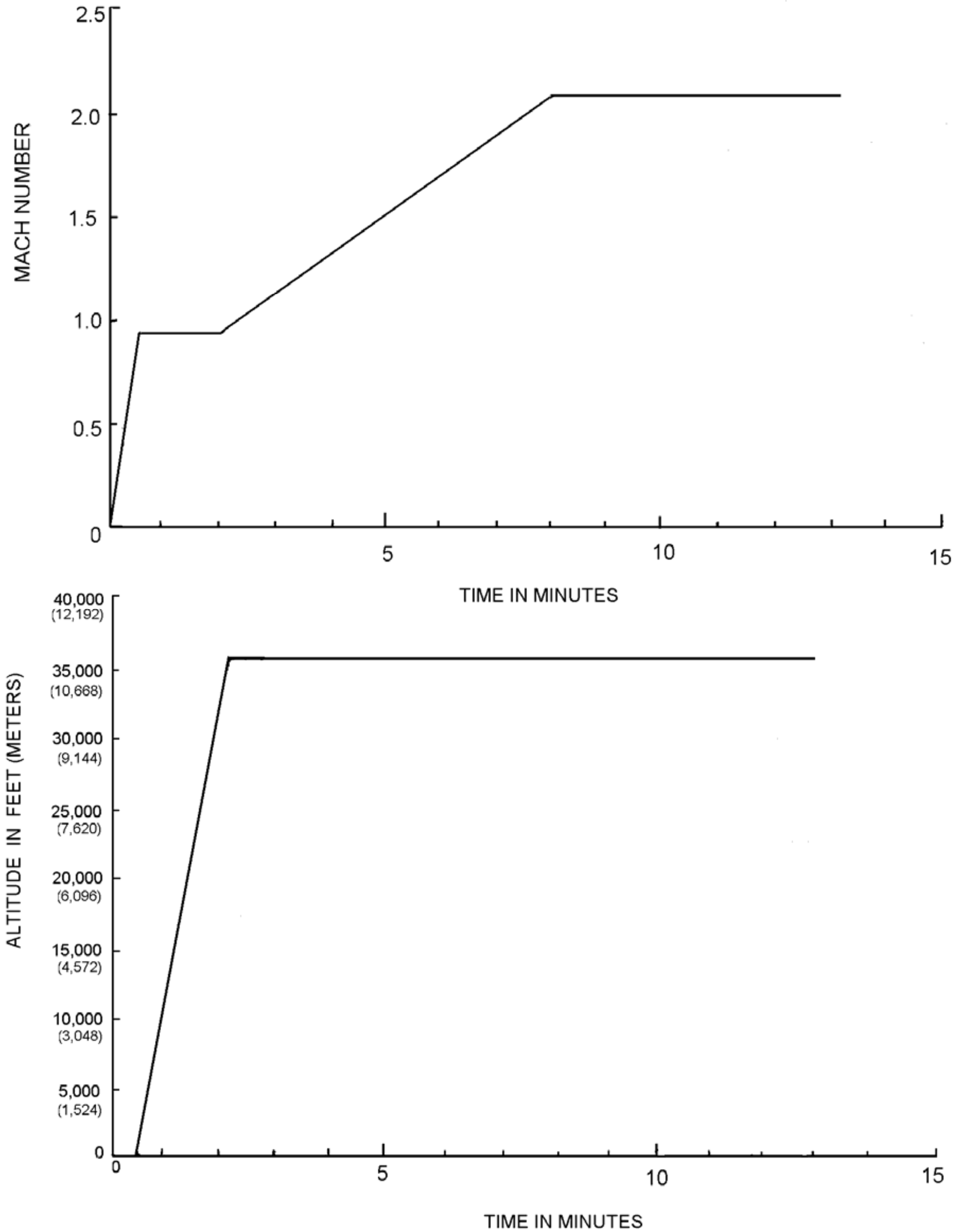

FIGURE A-15. High altitude supersonic intercept profile.

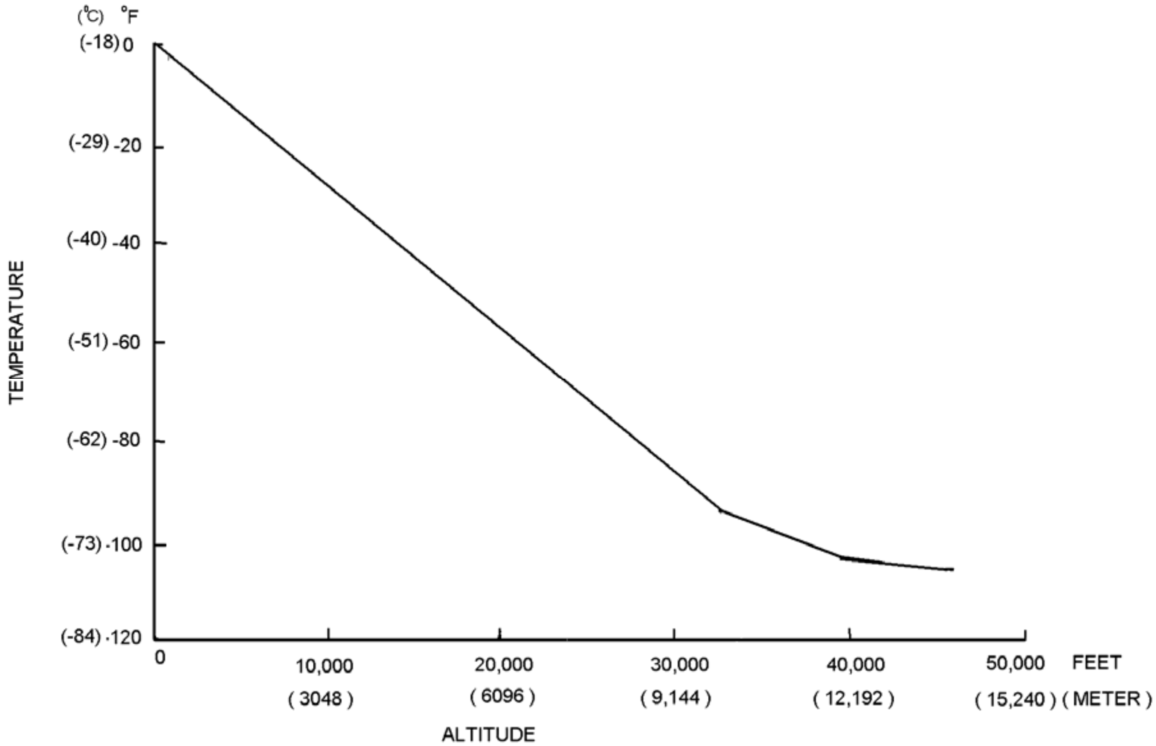

FIGURE A-16. Cold atmosphere model (sample).

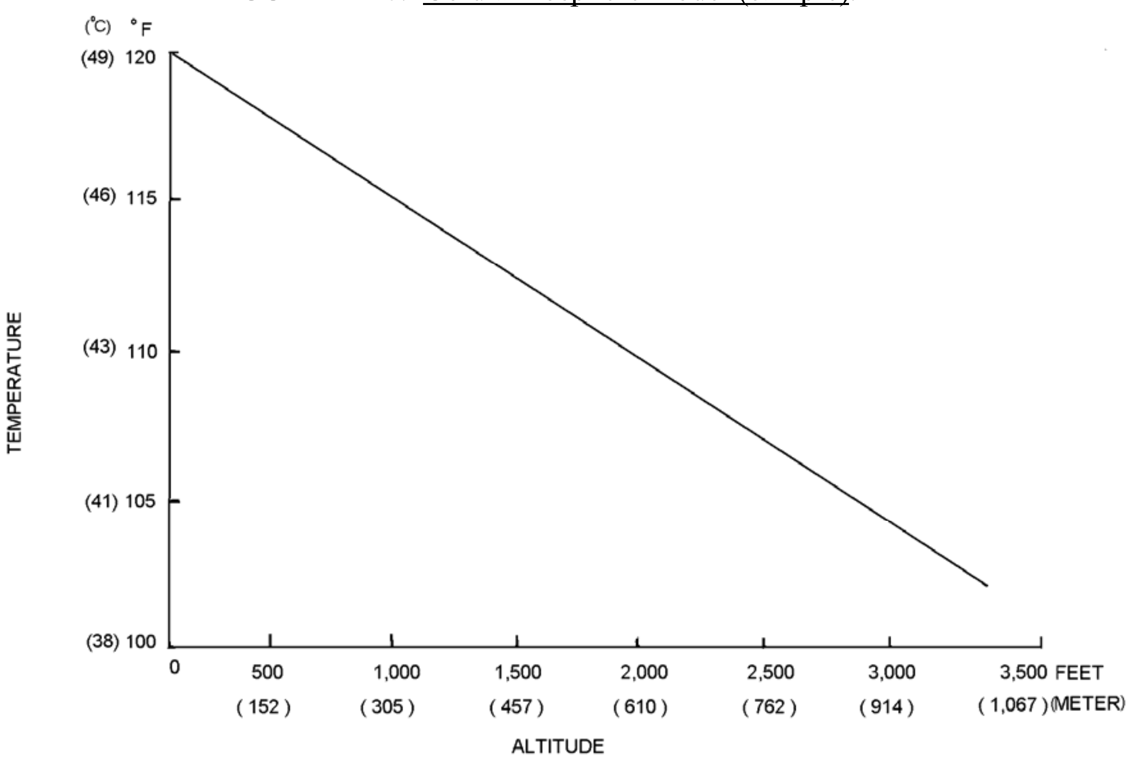

FIGURE A-17. Hot atmosphere model (sample).

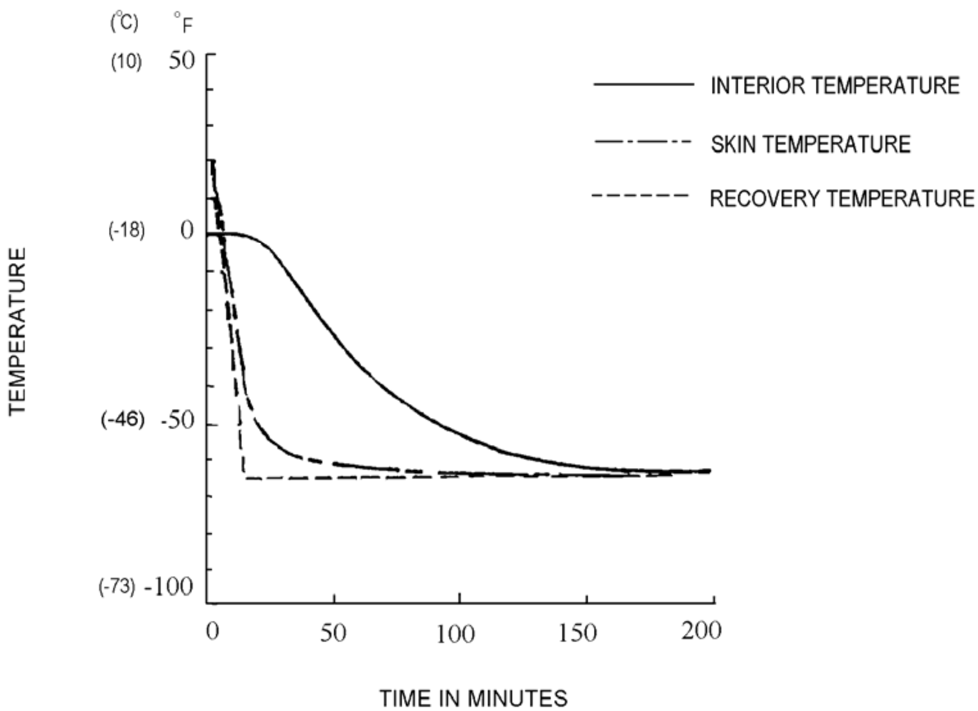

FIGURE A-18. Warhead temperature response for high altitude cruise.

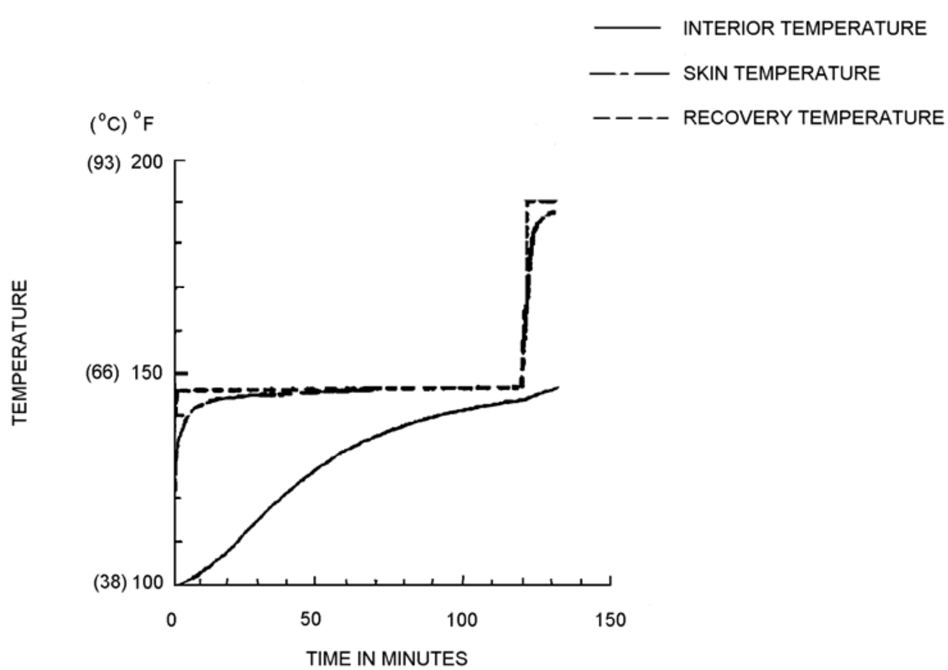

FIGURE A-19. Warhead temperature response for low altitude attack.

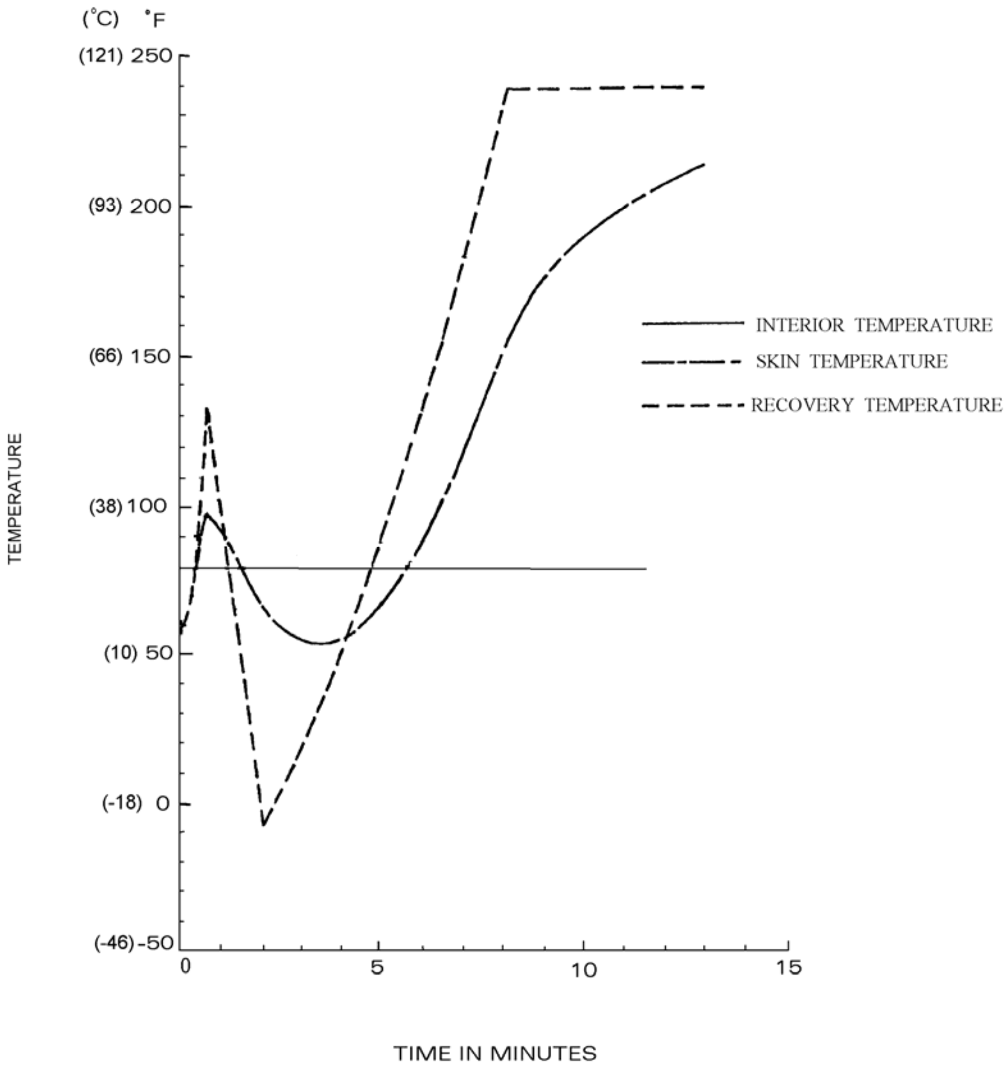

FIGURE A-20. Warhead temperature response for high altitude intercept.

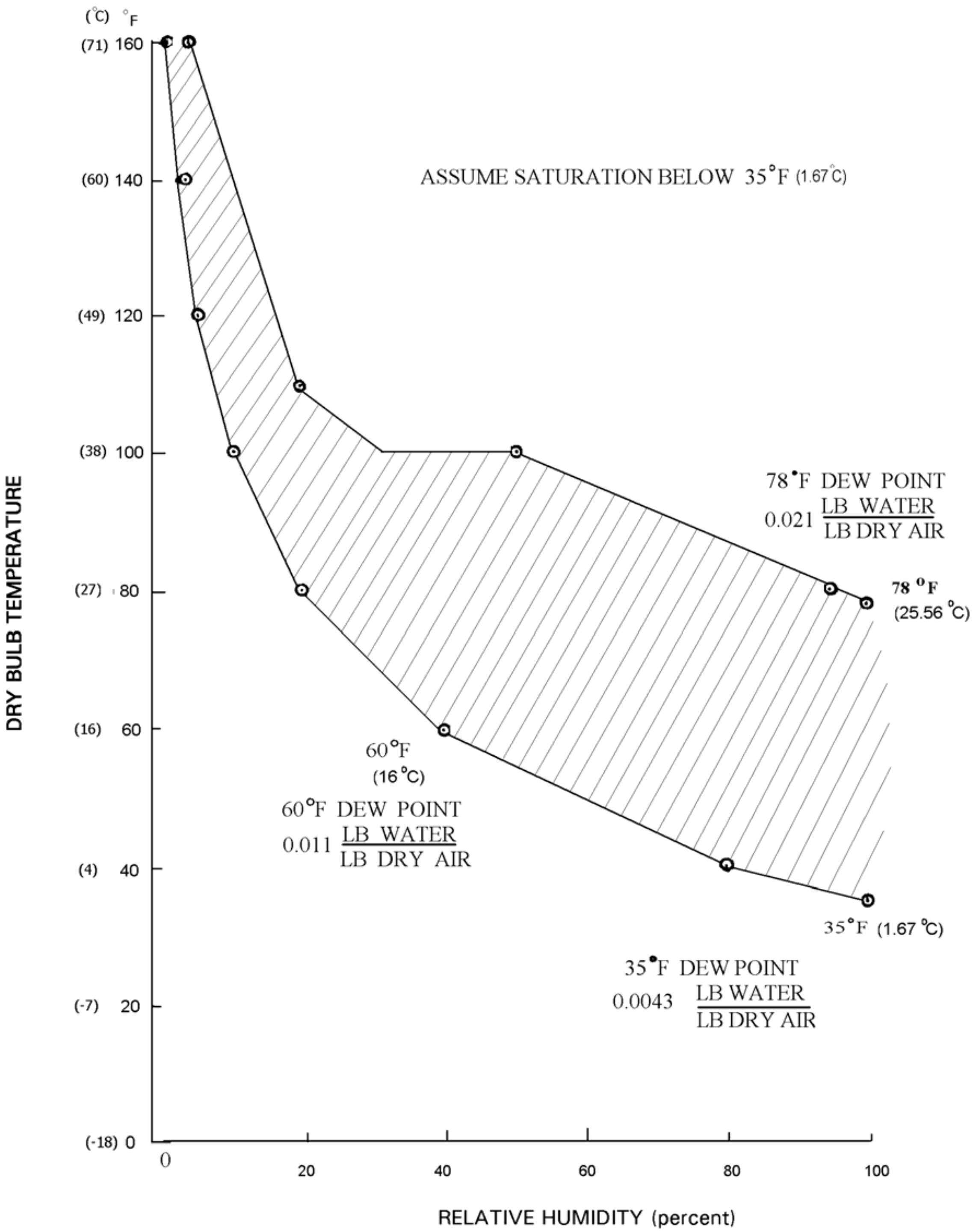

FIGURE A-21. Worldwide humidity environment.

A.4.5 Acceleration.

A.4.5.1 Captive flight. The loads experienced by the weapon during captive carry are determined by the carriage location and the flight limitation placed on the carrying aircraft. Prior to the availability of hardware and the establishment of combat use tactics, captive flight loads based on similar weapons, and the loads specified in MIL-STD-8591 should be used as appropriate to carrying aircraft flight conditions.

A.4.5.2 Launch-to-target. Accelerations experienced by weapons following launch are dependent on the propulsion unit thrust profile, missile weight, and limitations placed on the weapon's aerobatic maneuvers.

A.4.6 Shock.

A.4.6.1 Transportation shock, truck. The shock inputs to a weapon container during truck transport are initiated by transit across such road hazards as bumps, chuckholes, and railroad tracks.

A.4.6.2 Transportation shock, rail. The shock input to the weapon containers during rail transport are initiated during assembly and disassembly (humping) of the train and during rapid or emergency stop.

A.4.6.3 Transportation shock, ship. The shock environment on board ship arises from an adjacent underwater detonation. Before analysis of the weapon structure is started, appropriate criteria must be determined. Refer to MIL-S-901 for shipboard shock.

A.4.6.4 Transportation handling shock. The weapon container and contents are subjected to repeated shocks due to handling during loading and unloading prior to and following each transportation event. The following drop heights and disposal criteria apply to both environmental and safety criteria.

Drop Height, ft		Weapon condition
0 - 1.5	-	In container: safe and no degradation of performance
	-	Out of container: safe for damage inspection.
1.5 - 10	-	Safe in or out of container for return to work.
10 - 40	-	Safe in or out of container for immediate disposal.

A.4.6.5 Underway replenishment (see 3.13). The weapon is subjected to shocks during underway replenishment. Two methods of underway replenishment are: vertical replenishment from helicopter and direct high-line transfer from the ammunition ship (AE) or fast combat support ship (AOE). The maximum transfer line velocity is 10 ft/sec, hence impact at 10 ft/sec is possible. This impact is equivalent to a drop of about 19 inches.

A.4.6.6 Airfield and aircraft carrier handling. Airfield and aircraft carrier handling shocks are initiated by movement across bumps, obstacles, and irregularities on the hangar decks, flight decks, elevators, magazines and airfields. Obstacles include arresting cables, tie-down rings, ground power cables or cable shields and elevator and deck interface discontinuities. Weapons are normally carried on the MHU Munitions Transporter (afloat) and the MHU-202/M Munitions Trailer (ashore). These transporters are rigid frames with hard rubber tires or high inflation pneumatic tires that offer little shock mitigation to protect the weapon from shocks incurred in transit while in or out of their respective containers. Shock mitigation (if required) would need to be added to a specially created Transporter to Weapon Interface Adapter. For additional guidance, contact Naval Air Warfare Center Aircraft Division, Support Equipment Department, Airframe Supportability, Code 4.8.1.6.

A.4.6.7 Shock, captive carry. Captive carry shock is induced by catapult takeoff and arresting and landing shock and should be part of the captive flight environmental measurement program. The number of anticipated catapults and arrested landings for the weapon is obtained from analysis of projected combat use tactics (a bomb may undergo one flight; an air-to-air missile may undergo several hundred flights) and is also a function of attachment to the aircraft.

A.4.6.8 Shock, launch-to-target. The launch sequence shock environment is highly weapon dependent. Factors contributing to this environment are (1) aircraft separation mechanism, (2) propulsion unit ignition, (3) initial acceleration rate, and (4) pyrotechnic events used to initiate missile functions. Figures A-22 and A-23 present typical shock and shock spectrum (see A.3.9) data for store/aircraft separation. Contributions of propulsion unit ignition, pyrotechnic events, and fin opening cannot be estimated. When hardware is available, structural response to these phenomena is measured. Reasonable limits can be specified for a missile and its aircraft interface so that they may stay within these limits.

A.4.7 Vibration.

A.4.7.1 Transportation vibration, truck. The weapon is packaged or containerized during transportation by truck, hence the vibration is input to the package or container.

Vibration during truck transportation is caused by truck passage over rough roads or terrain and by unbalanced rotating portions of the truck power train. The magnitude of the induced vibration depends on the type of truck used, the load condition of the truck, and the skill of the operator. Figure A-24 shows typical vibration levels for this environment.

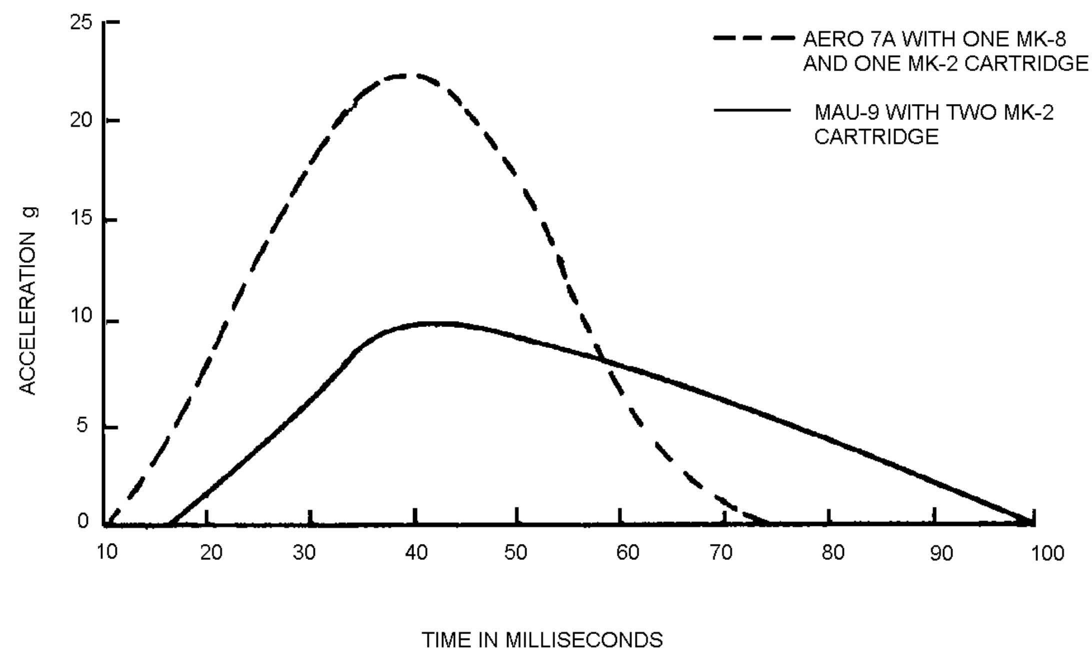

FIGURE A-22. Acceleration versus time for AERO-7A and MAU-9A racks separating a 1200-pound store.

Note: Zero time is cartridge fire time. The final ejection velocity required for safe separation determines which curve will apply to the weapon.

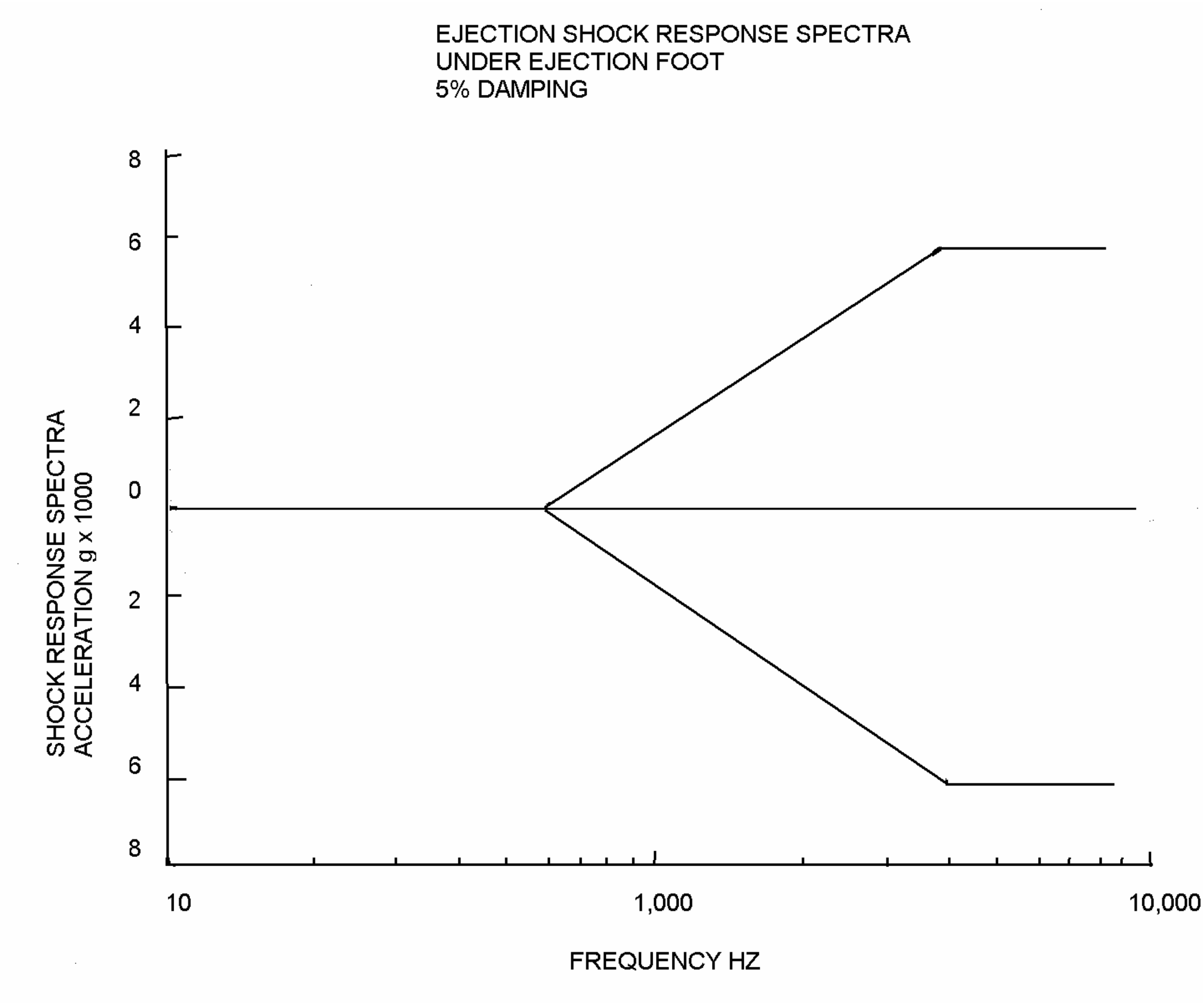

FIGURE A-23. High acceleration, short duration ejection, shock spectra AERO-7A and MAU-9 ejection racks using one Mk 8 and one Mk 2 cartridge.

A.4.7.2 Transportation vibration (rail). A weapon is packaged or containerized during transportation by rail; hence vibration is input to the container or package. Vibration experienced during rail transportation is caused by the passage of the rail car over rough rail bed. In addition, starting, stopping, and train makeup and disassembly (humping) induce high transient vibration levels. Figure A-25 shows typical vibration levels for this environment.

A.4.7.3 Transportation vibration (ship). A weapon is packaged or containerized during transportation by ship, hence vibration is input to the package or container. The vibration experienced is caused by the rotating equipment on the transporting vessel and by the response of the vessel to high sea states. The magnitude of the vibration depends on the type of ship constraints placed on slam or emergency maneuvers and maximum sea state in which the ship operates. All types of commercial and naval vessels, which transport weapons, must be considered. Figure A-26 shows typical values for this environment. Refer to MIL-STD-167-1 and MIL-STD-167-2 for applicable shipboard vibration.

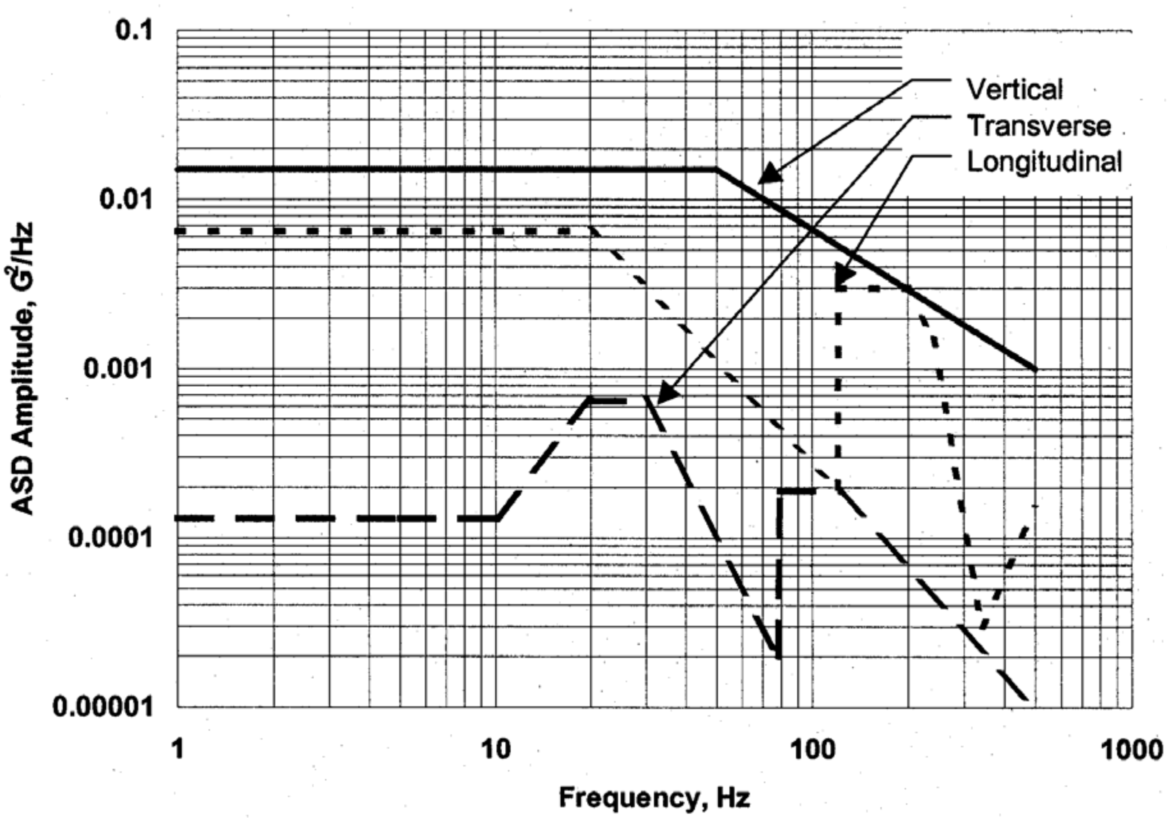

FIGURE A-24. Truck transportation vibration envelopes.

A.4.7.4 Transportation vibration (aircraft). A weapon is packaged or containerized during transportation by aircraft, hence vibration is input to the package or container. The vibration experienced by the aircraft caused by aerodynamic loads, rotating equipment, and runway roughness during takeoff and landing are transmitted structurally. Vibration caused by the jet engine exhaust is transmitted acoustically. Figure A-27 shows typical values for this environment.

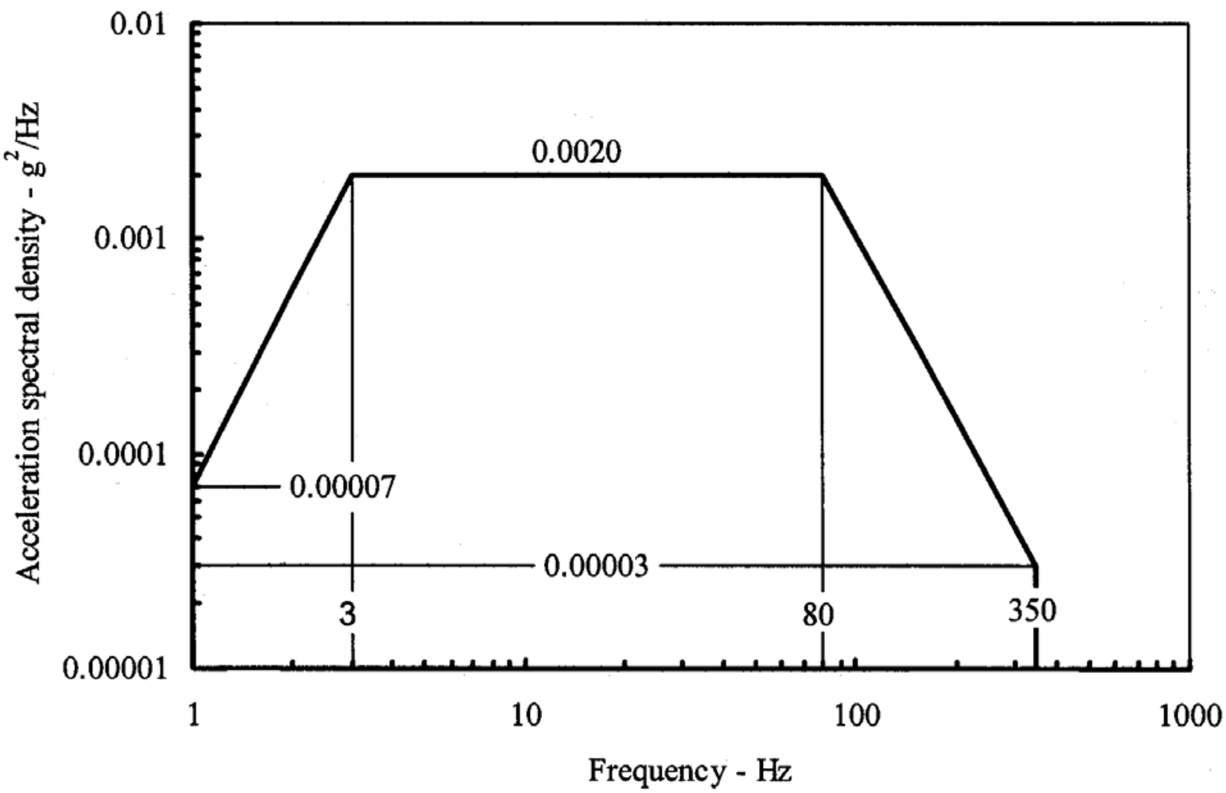

FIGURE A-25. Railroad cargo vibration envelopes.

A.4.7.5 Captive flight vibration (high-performance aircraft). The vibration environment experienced by the weapon during captive carry on high-performance aircraft is induced by fluctuating pressure fields about the weapon. The vibration is random in nature and is characterized by its statistical properties. Some of the forcing functions that induce random vibration are the turbulent boundary layer about the weapon, vortex shedding, separated flow and shock wave impingement. The vibration levels experienced during captive carry are a severe, long-term dynamic environment. When hardware becomes available, this environment is measured on each candidate use aircraft (see Appendix D). Prior to hardware availability, a first approximation of the anticipated random vibration levels may be calculated by the methods given in MIL-STD-810 and STANAG-4370.

A.4.7.6 Captive flight vibration, intermediate performance aircraft (turboprop). The vibration environment experienced by the weapon during captive carry on intermediate performance aircraft is the result of:

(1) Vibration resulting from propeller passage through the air at the blade passage frequency, and

(2) Random vibrations resulting from fluctuating pressures about the store during captive carry.

The pressure fluctuations arise from the turbulent boundary layer, vortex shedding (see A.3.14), and shock wave impingement. Random vibration is characterized by their statistical properties. Vibration effects from both sources are summed, producing a combination of complex sine-wave vibration superimposed on the random levels. The methods of MIL-STD-810 may be used to calculate the random vibration levels. In addition to the random vibration levels, the spectrum will contain narrow-band spectral peaks at the propeller passage frequencies and harmonics.

A.4.7.7 Captive flight vibration helicopter. The vibration induced is complex sine waves and are caused by:

(1) Rotating equipment on board the helicopter which transmits the vibrations through the structure to the store, and
(2) Pressure fluctuations about the store caused by the propeller passage and occurring at the blade passage frequency.

In the absence of measured data, the methods of MIL-STD-810 and STANAG-4370 may be used to calculate vibration levels. The total weight of the store and launcher must be used for calculating the amplitudes of vibration at rotor passage frequencies and multiples thereof.
The number of anticipated captive carries must be determined in order to develop the duration of exposure to these forcing functions.

A.4.7.8 Gunfire vibration on board aircraft. The vibration environment experienced by a weapon mounted in near proximity (8 feet or less) of the muzzle of rapid-fire multi barrel automatic guns is an extremely intense short-term environment. The vibration is induced by blast pressure from the muzzle impinging on the aircraft structure or store. These over-pressures occur at rates from 25 to 100 Hz and excite the structure in the muzzle vicinity. An additional effect is localized aerodynamic flow separation, which has the effect of causing intense random vibration in the higher frequency ranges. These phenomena result in vibration that is a mix of complex periodic vibration at harmonics of the firing rate of the gun with random vibration at the higher frequencies. Measurement of the effects of this environment is necessary. The calculation procedures of MIL-STD-810 Method 519 are used to calculate the power spectral density.

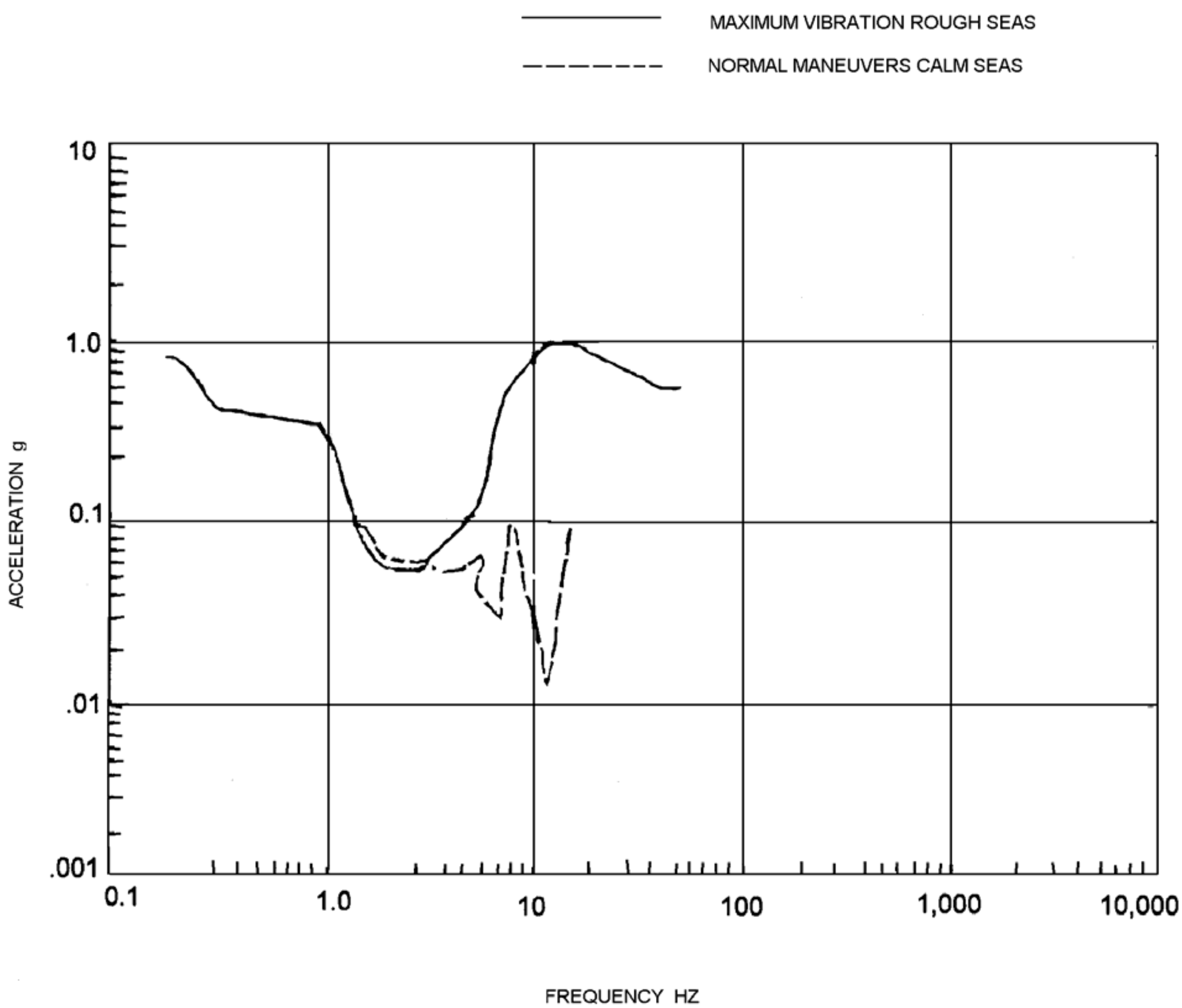

FIGURE A-26. Ship vibration envelopes.

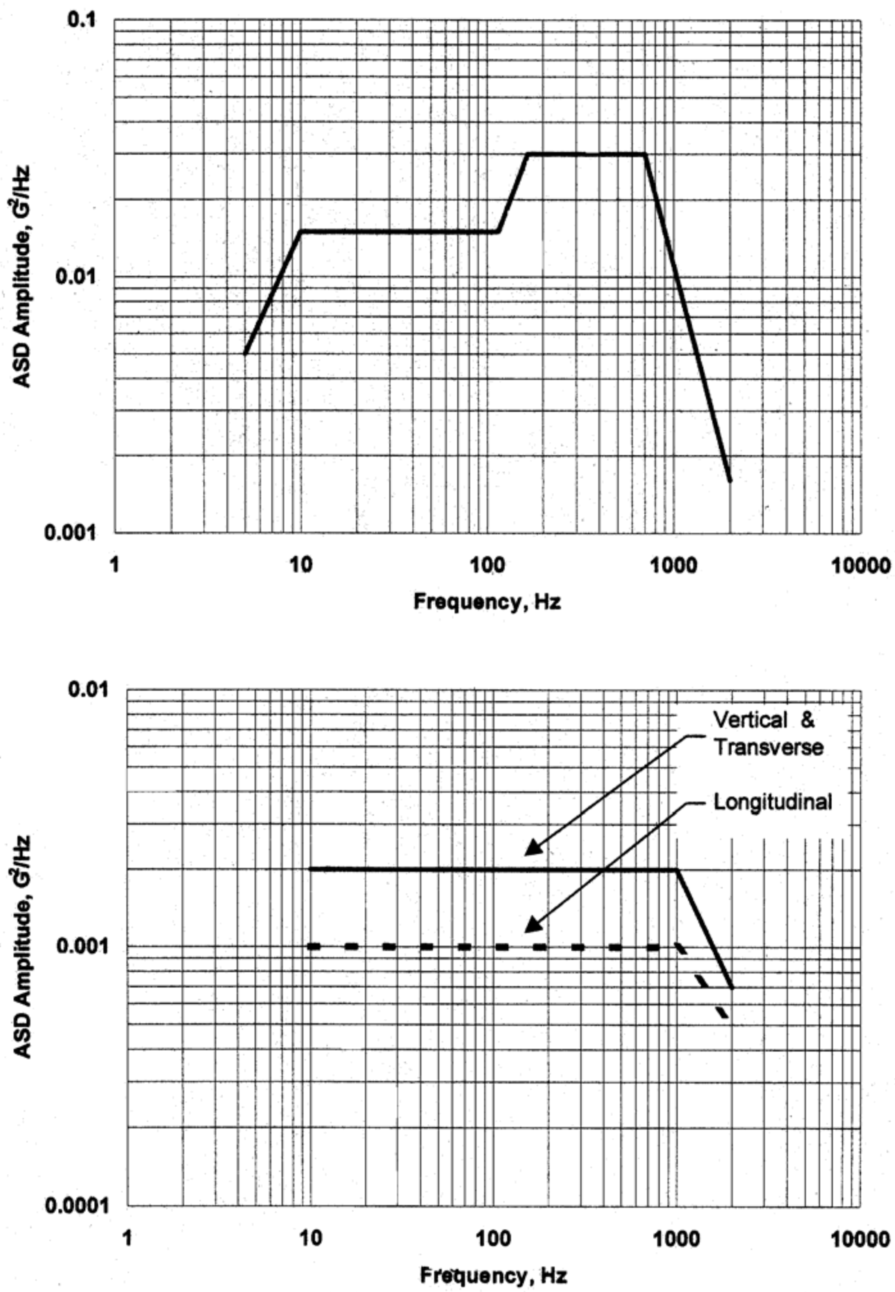

FIGURE A-27. Vibration envelope of jet aircraft cargo area.

A.4.7.9 Vibration launch-to-target. The vibration environment experienced by the missile during free or powered flight is induced by fluctuating pressures about the weapon and by the thrust of the propulsion unit. The vibration is random in nature and is characterized by its statistical properties. MIL-STD-810 can be used to calculate approximate vibration levels.

A.4.7.10 Acoustic environment. The weapon experiences fluctuating pressures resulting from unsteady aerodynamic flow during free flight and captive carry on high-performance aircraft. These fluctuations are generally random in nature and may or may not exhibit spatial correlation. The environment is highly dependent on hardware and air steam interaction in which air scoops, ram-air turbines (RAT) and nose geometry are typical design variables that can cause more intense pressure fluctuations. This environment is commonly called acoustics. The levels may be calculated using the methods specified in MIL-STD-810.

A.4.8 Sample data display matrix. A method of presenting environmental design criteria is shown in tables A-V through A-VIII. When displayed in this manner all major events, corresponding environments and weapon's status in the factory-to-target sequence are noted. The numbers given in the data display matrix are for illustration purposes only.

A.4.8.1 Transportation. The weapon should perform as required in the development specification subsequent to the missile and container being subjected to the environments listed in table A-V.

A.4.8.2 Storage, handling and underway replenishment. The weapon should perform as required in the development specification after the weapon in its container has been subjected to the environments defined in table A-VI.

A.4.8.3 Airfield and aircraft carrier storage and handling. The weapon should perform as required in the development specification after the weapon in its shipping container has been subjected to the storage environments specified in table A-VII. The weapon should perform as required in the development specification after being subjected to the handling environments with weapon out of the container as specified in table A-VII.

A.4.8.4 Captive and free flight. The weapon should perform as required in the development specification while being subjected to the environments specified in table A-VIII.

TABLE A-V. Transportation environmental criteria (example).

Environment event	Transportation of missile in shipping container			
	Truck	Rail	Ship	Air (flight)
Air temp/time High	Fig. A-6	Fig. A-6	Fig. A-8	Fig. A-10
Air temp/time low	Fig. A-7	Fig. A-7	40°F for 24 hrs	Fig. A-9
Relative humidity	Fig. A-21	Fig. A-21	Fig. A-21	Fig. A-21
Rain	50 mm/hr for 1 hr	50 mm/hr for 1 hr	50 mm/hr for 1 hr	NA
Ice and hail	25 mm/hr 50 mm buildup	25 mm/hr 50 mm buildup	25 mm/hr 50 mm buildup	NA
Snow	250 mm/hr for 0.5 hr	250 mm/hr for 0.5 hr	250 mm/hr for 0.5 hr	NA
Corrosion rates	Negligible time dependent	Negligible time dependent	Negligible time dependent	Negligible time dependent
Sand and dust	45 knot wind .015 to 3.2 mm dia particle size	45 knot wind .015 to 3.2 mm dia particle size	NA	NA
Shock	3.5 g for 25-50 ms half sine wave	25 g for 25-ms half sine wave	80 g, 4 ms vertical	Negligible
Vibration (peak values)	Fig. A-24	Fig. A-25	Fig. A-26	Fig. A-27
Electromagnetic environment	To be determined			
Acoustic	Negligible	Negligible	Negligible	Negligible
Altitude	Sea level to 10,000 ft	Sea level to 10,000 ft	Sea level	10,000 ft
Fungus	Use non-nutrient materials only			

Table for illustration only

TABLE A-VI. Storage handling environmental criteria (example).

Environment/event	Transportation of missile in shipping container			
	STORAGE			At Sea Transfer
	Igloo	Covered	Dump	
Air temp/time (high)	100°F for 24 hrs	Fig. A-5	Fig. A-3	Fig. A-4
Air temp/time (low)	0^{o}F for 72 hrs	-10^{o}F for 72 hrs	-40^{o}F for 72 hrs	30^{o}F for 24 hrs
Relative humidity	Fig. A-21	Fig. A-21	Fig. A-21	Fig. A-21
Rain	NA	Negligible	50 mm/hr for 1 hr	50 mm/hr for 1 hr
Ice and hail	NA	Negligible	25 mm/hr for 1 hr	Negligible
Snow	NA	Negligible	250 mm/hr for 0.5 hr	Negligible
Corrosive rates	Time dependent	0	Time dependent	Negligible (time dependent)
Sand and dust	Negligible	45 knot wind .015 to 3.2 mm dia particle size	45 knot wind .015 to 3.2 mm dia particle size	NA
Shock	NA	NA	NA	10 ft/sec impact velocity
Vibration	NA	NA	NA	Negligible
Electromagnetic environment	To be determined			
Acoustic	Negligible	Negligible	Negligible	Negligible
Fungus	Use non-nutrient materials only			
Immersion	NA	NA		

This table is for illustration only.

TABLE A-VII. Airfield and aircraft carrier storage and handling environmental criteria (example).

Environment /event	Airfield		Aircraft carrier	
	Missile in shipping container	Missile out of container	Missile in container	Missile out of container
	Storage	Handling	Storage	Handling
Air temp / time (high)	Fig. A-6	140°F for 2 hrs	Fig. A-4	110°F for 2 hrs
Air temp / Time (low)	-40 °F for 72 hrs	-40 °F for 72 hrs	40 °F for 24 hrs	30 °F for 24 hrs
Relative humidity	Fig. A-21	Fig. A-21	Fig. A-21	Fig. A-21
Rain	50 mm/hr for 1 hr	50 mm/hr for 1 hr	NA	50 mm/hr for 1 hr
Ice and hail	25 mm/hr for 1 hr	25 mm/hr for 1 hr	NA	None
Snow	250 mm/hr for 1/2 hr	250 mm/hr for 1/2 hr	NA	None
Corrosion rates	Time dependent	Negligible (time dependent)	Time dependent	Negligible (time dependent)
Sand and dust	45-knot wind .015 to 3.2 mm dia particle size	45-knot wind .015 to 3.2 mm dia particle size	NA	NA
Acceleration loads	NA	NA	NA	NA
Shock	NA	15 g, 11-18 ms	80 g, 4 ms vertical	15 g, 11-18 ms
Vibration	NA	Negligible	Refer to Fig. A-11	Negligible
Electromagnetic environment	To be determined			
Acoustic	Negligible	Negligible	Negligible	Negligible
Fungus	Use non-nutrient materials			

This table is for illustration only.

TABLE A-VIII. Captive and free flight environmental criteria (example).

Environment/event	Missile out of container	
	Aboard aircraft	Launch to target
Skin temp/time (high)	150°F for 10 min 120°F for 1 hr	Up to 187°F for 4 min
Skin temp/time (low)	-62°F for 4 hr	-3°F for 5 min
Relative humidity	Fig. A-21	Fig. A-21
Rain	Aircraft flight limitations	Aircraft flight limitations
Ice and hail	Aircraft flight limitations	Aircraft flight limitations
Snow	Aircraft flight limitation	Aircraft flight limitations
Corrosion	Negligible	NA
Sand and Dust	.015 to 3.2 mm dia particle size	NA
Acceleration	Figs. A-22 & 23	System dependent
Shock	15 g, for 20 ms ± long + vertical	TBD
Vibration	Figs. A-24 through A-27	Figs. A-24 through A-27
Electromagnetic environment	to be determined	
Acoustic	165 dB	160 dB
Gun blast	2 psi, plane wave 1 ms duration	NA
Ignition shock	NA	Complex Transient
Altitude	Figs. A-13 through A-15	Figs. A-18 through A-20

This table is for illustration only

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USE OF ENVIRONMENTAL DATA IN DEVELOPMENT TEST PLANS

B.1 SCOPE

B.1.1 Scope. This appendix provides guidelines for the use of environmental data in developing test plans.

B.1.2 Introduction. The intent of environmental testing is to demonstrate proper functioning of a weapon following and during its exposure to the environments encountered in the factory-to-target sequence. Each environmental test or sequence of tests conducted in support of feasibility evaluation, qualification, reliability and maintainability demonstration, and acceptance tests addresses a specific environment or combination of environments delineated in the EICL. The environmental test plan developed includes:

a. Tests reflecting the environments and parameters in the EICL and OED.

b. The combinations of environments whose synergistic effects can cause degradation of weapon performance.

c. Required functionality of the test item during and following the environmental test.

d. Detailed failure criteria and disposition instructions.

B.2. APPLICABLE DOCUMENTS

MIL-STD-810, STANAG-4370 and STANAG-4325 listed in 2.2.1 apply to this appendix.

B.3 DEFINITIONS

This section is not applicable to this appendix.

B.4 DETAILED GUIDANCE

B.4.1 Limitations of environmental simulation capabilities. The limitations of present environmental simulation methods, along with the wide diversity of environments and air-launched weapon encounters, require careful consideration. The following sections address some of the areas which should be considered in the development of the plans.

B.4.2 Captive flight dynamic environment high performance aircraft. The principal forcing function of the captive flight vibration is the fluctuating pressure about the weapon. The almost infinite number of carrying configurations and resulting complex environments prevent exact duplication of captive flight vibration. The alternative is to conduct a vibration test or an acoustic test or combinations of both. Each approach has its pitfalls. A vibration test attempts to duplicate, with a single degree-of-freedom exciter, the effects of the high-intensity fluctuating pressure field. The vibration test may be adequate if following an appropriate measurement program (see Appendix D) and detailed structural analysis, the motion of several points on the structure are specified along with the input(s) from the vibration exciter. Acoustic tests adequately simulate the flight dynamic environment if the environment can be totally defined and a similar acoustic field generated in the laboratory. The test forces the weapon to vibrate in a manner similar to the service use forcing function. Because of high-frequency limitations of vibration test equipment and low-frequency limitations of acoustic facilities, both acoustic and vibration tests should be conducted. The acoustic levels should be developed following a detailed measurement program. In specifying an acoustic test, the corresponding motions expected on the structure should be detailed.

B.4.3 Temperature simulation. The test equipment generally used for temperature or temperature profile simulation is the laboratory test ovens, most of which are forced convection heating sources. It may be a usable simulation tool, depending on the event being modeled.

B.4.3.1 Aerodynamic heating environment. The aerodynamic heating environment is specified in the environmental test plan as a specific test or as part of combined tests. Care must be taken in specifying the skin temperature and time profile. There is no standard way to simulate this environment in the testing laboratory. One method used to approximate the specified skin temperature profiles is forced convective heating in an oven.

B.4.3.2 Dump storage (hot). The primary forcing function in hot dump storage is solar radiation. Radiation is a directional heating mode, hence the area of maximum (or high) heat flow is less than half the area of the weapon. The heat flow into the weapon is maximum when the surface of impingement is normal to the rays of the sun and it typically produces directional heating on the weapon. All other surfaces receive less than the maximum heat. Conventional convection ovens do not produce directional heating within the weapon. Solar radiation chambers provide a more realist test. When specifying tests that attempt to duplicate natural radiation heating environments with a convection oven, the heating rate in the oven and the effective heated area should be taken into consideration.

B.4.4 Choice of environmental test parameters. Laboratory test levels are converted from the parameters and profiles in the environmental design criteria document. The number of occurrences and test duration is based on the factory-to-target sequence, the use requirement for the weapon and any operational information on similar weapons (see Appendix E).

The wide diversity of factory-to-target sequences is illustrated in the following:

a. A typical air-to-air missile may be subjected to hundreds of captive-flight hours, hundreds of catapult take-off and arrested landing shocks, and multiple excursions through the transportation and storage and repair cycle prior to being expended or removed from service.

b. A 1,000-pound bomb may experience only 1 hour of captive flight, one catapult take-off, no arrested landings, and one excursion through the transportation and storage portion of the factory-to-target sequence before being expended.

B.4.4.1 <u>Time compression.</u> Time compression techniques are used in lieu of extended tests where appropriate. Time compression failures or degradation should be representative of the failure modes experienced under actual use conditions. Care should be taken to clearly identify possible failures that may be accelerated as a result of using time compression techniques.

B.4.5 <u>Dynamic test fixturing, control, analysis and instrumentation</u>.

B.4.5.1 <u>Fixturing</u>. The environmental test plan specifies the test parameters such as vibration levels, axes test times, and the fixture that will hold the test item. The environmental criteria documentation should be examined to determine whether the test item is containerized and where and how the item is mounted in service use. Fixturing specified in the environmental test plan should simulate service or normal mounting means. The principal problem or pitfall in selecting an adequate vibration or dynamic test is in the selection of the fixture. Some simulations that require different approaches are the following:

a. During transportation, the weapon is containerized. The vibration and shock inputs are to the container.

b. Avionics equipment may be mounted on racks with vibration and shock isolators hence; the vibration and shock inputs are to the mounting rack.

c. A weapon in captive carry is mounted on a bomb rack or launcher. The vibration inputs are to the weapon, which is mounted on an appropriate rack.

B.4.5.2 <u>Control and measurement points</u>. The locations of the measurement and control transducers should be specified for vibration and shock tests. Some examples of specifying the measurement point and control are:

a. When the normal mounting of the item is in the container, the vibration input is controlled in the plane at the base of the container in the test axis.

b. For a captive flight vibration test, the measurement points on the weapon are the same as points used during the acquisition of the captive flight data. The control transducer(s) and input points are determined following specific analyses of the structure input fixture and vibration levels.

B.4.5.3 Instrumentation and analyses. The environmental test plan should detail the instrumentation accuracy limitations and analysis techniques. The plan may specify the techniques and limitations delineated in MIL-STD-810. Examples of the type of detail expected in the test plan are:

a. Instrumentation type, accuracy, calibration, redundancy. These should include accelerometer type, thermocouple type, tracking filter required, basic response time of meters and control equipment. Limitations on case strain sensitivity and mounting natural frequency of accelerometers used frequency response of microphones, and limits of measuring wet bulb and dry bulb temperatures.

b. The analysis techniques specified will include limitations on random vibration analysis and shock spectrum analysis and synthesis.

B.4.6 Other documents. The following documents contain environmental testing. The weapon developers are recommended to use them if additional tests are necessary.

(a) STANAG-4325

(b) STANAG-4370

(c) MIL-STD-810

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DESIGN USE OF ENVIRONMENTAL DATA

C.1 SCOPE

C.1.1 Scope. This appendix illustrates the use of environmental data in the design evolution of weapons.

C.1.2 Introduction. The use of environmental data in the design evolution of weapon hardware is necessary to assure proper function of the hardware in its use environment. Reliability estimates of the weapon are based, in part, on demonstrated ability to function during and after exposure to the environments detailed in the environmental profile report. The environmental design criteria document uses the results of analytical investigations and data, along with field measurement data, to establish the environmental extremes and describe the profiles affecting the weapon in service use. Those major areas of the environment considered in the design iteration are addressed in this appendix. Since design procedures vary from one facility to another, a detailed instruction on how to incorporate the environmental data into the design iteration is not presented.

C.2 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

C.3 DEFINITIONS

C.3.1 Abbreviations and acronyms used in Appendix C. The abbreviations and acronyms used in Appendix C are defined as follows:

a. ACS - Air Conditioning Scoop

C.4 DETAILED GUIDANCE

C.4.1 Design verification tests. During the preliminary phase of the design evolution, selected environmental tests are performed. These tests, as appropriate, are used to establish proper functioning of preliminary designs in given environments. The tests are performed early in the design evolution to minimize the costs of redesign in the event weaknesses or malfunctions of the initial design concept are detected.

C.4.2 Thermal environment. The thermal environments encountered in a weapon's factory-to-target sequence are presented in time vs. temperature profile format to amplify the fact that steady state temperature extremes rarely occur in the factory-to-target sequence. Temperature variations with time result in thermal gradients in the various items of the weapon. The effects of a thermal gradient can cause significant differences in performance when compared to the effects of steady state temperature conditions. As a minimum, the effects on the following areas should be addressed:

a. Function of propulsion units.

b. Limitations placed on warhead materials.

c. Seeker dome dimensions, material, and geometry.

d. Limitations on semiconductor types.

e. Temperature gradients in electronic circuits, which can degrade the function of circuits that were designed using constant temperature in stability analysis.

C.4.2.1 Thermal analysis. A minimum thermal design should cover the following analyses:

a. An aerodynamic heating analysis that uses the required flight regimes and weapon trajectories to determine skin temperature extremes.

b. An analysis of component and structural response to aerodynamic heating in conjunction with other active heat dissipaters within the weapon. It should be concurrent with the structure analysis effort.

c. An analysis of weapon response to long-term-storage thermal environments. This analysis uses storage temperature profiles measured on similar hardware.

C.4.3 Vibration acoustics, shock, and acceleration. The dynamic environment can degrade the performance of the weapon. The effects can range from fracture of a weapon structure to generation of noise in electronic circuitry, which can degrade sensitivity. Some examples of possible dynamic degradation of weapon function are:

a. Degradation of propulsion unit properties such as cracking of propellant grains and separation of the liner.

b. Degradation of warhead properties and electrical functions of fusing devices.

c. Degradation of electronic packaging such as broken printed circuit boards or broken leads on devices.

d. Momentary discontinuities in connectors, relay, and switches.

e. Catastrophic structural failure (fracture or breakage) from cumulative damage effects.

f. Weapon guidance and control problems caused by large vibratory displacements at resonant nodes of the weapon structure. These effects are highly degrading to the performance of strap down inertial guidance schemes.

C.4.4 Dynamic analysis. A minimum design should cover the following analyses:

a. A load analysis that considers loads and loading conditions, detailed in part in the environmental design criteria documentation to ensure structural integrity of the weapon.

b. A detailed structural analysis to determine the normal response modes of the weapon. This will include a mathematical model developed in junction with a laboratory model vibration study.

c. Other analyses that examine the effects of unusual aerodynamic configurations such as air conditioning scoops (ACS), ram-air-turbine (RAT), and other protrusions.

C.4.5 Handling and transportation (in container). The weapon is packaged or containerized during transportation and is subjected to a series of handling or carrier induced shocks and vibration. For design purposes, the container and hardware are considered as a unit and the transmissibility characteristics of the container and weapon are established at various temperatures. When these transfer characteristics are determined, the weapon response to shocks and vibration is calculated and included in the load analysis document.

C.4.6 Material deterioration, corrosion, fungus, and humidity. The materials used in fabricating weapons are subjected to chemical, electrochemical, and biological deterioration. The environmental profile report should detail the types of environments such as humidity, corrosion, and fungus that degrade the weapon materials.

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GUIDELINES FOR MEASUREMENT, ACQUISITION, AND PROCESSING OF AIRBORNE WEAPON ENVIRONMENTAL DATA

D.1 SCOPE

D.1.1 Scope. This appendix covers the basic aspects of acquiring environmental data and some typical processing techniques.

D.1.2 Introduction. A captive or free flight environmental measurement program should be conducted early in the weapon development cycle to verify the analysis performed in developing environmental engineering documents. The captive flight data should be included in revisions to OED.

D.2 APPLICABLE DOCUMENT

IRIG-106 Telemetry Standards listed in 2.2.1 applies to Appendix D.

D.3 DEFINITIONS

D.3.1 Impedance matching. To make impedance of load equals to internal impedance of power in an electrical circuit, transmission lines, or devices.

D.3.2 Abbreviations and acronyms used in Appendix D. The abbreviations and acronyms used in this appendix D are defined as follows:

IRIG - Inter-Range Instrumentation Group
OED - Operational Environmental Documentation

D.4 DETAILED GUIDANCE

D.4.1 Data recorded. Specific data requirements should be determined from the OED. The minimum data acquisition program should cover:

a. Vibration.

b. Temperature.

c. Acceleration.

d. Acoustics.

e. Shock.

D.4.2 Data acquisition devices. A typical instrumentation system for measuring, acquiring, and processing captive or free flight environmental data is shown on figure D-1.

D.4.3 Transducers. Typical airborne transducers are:

a. Piezoelectric accelerometers.
b. Piezoresistive accelerometers.
c. Strain gages.
d. Microphones (or high frequency pressure pickups).
e. Thermistors.
f. Thermocouples.

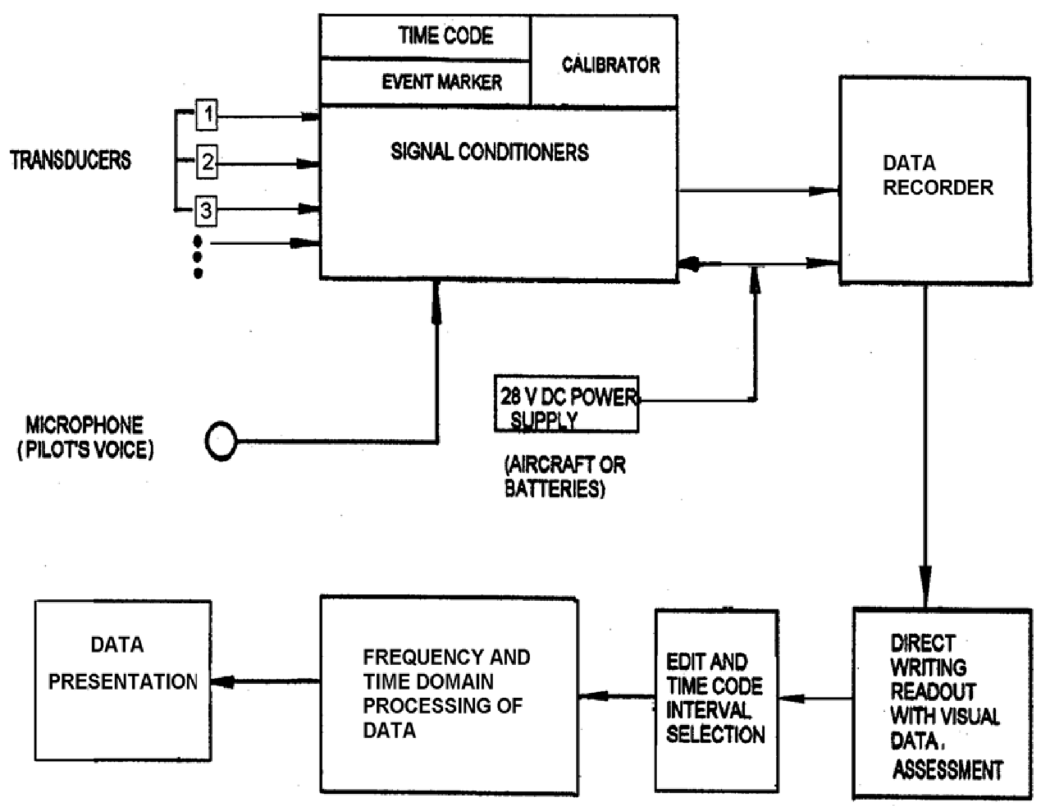

FIGURE D-1. Typical instrumentation system.

D.4.3.1 Accelerometers. Accelerometers are used to measure response vibration. The accelerometers can have errors associated with improper mounting methods, temperature and acoustic effects, cable mountings, and accelerometer mass loading effects. The useful frequency response and accuracy, depends on the specific type.

D.4.3.2 Strain gages. Strain gages are used to measure the static and dynamic strains. Acceptable gages are thin-foil types and are not reusable. Strain measurement inaccuracies are caused by transverse sensitivity, strain averaging over the gage area, hysteresis, and temperature effects. Frequency response can be as great as 50 kHz.

D.4.3.3 Microphones. Microphones are high frequency pressure transducers used to measure the acoustic environment in a weapon section or on the weapon surface. Temperature, vibration, and ambient pressure changes can cause errors.

D.4.3.4 Thermistors and thermocouples. Thermistors and thermocouples measure the thermal response of the weapon surface or component. Thermistors change resistance with temperatures; thermocouples generate an electromotive force dependent on wire material and reference temperature. Thermocouples require a reference junction unit and can be simply constructed. Care must be used to eliminate lead wire fatigue. Thermistors are expensive when used in large quantities since each one requires an operational amplifier. Thermistors may require high power levels and may be non-linear.

D.4.4 Signal conditioners. A detailed description of signal conditioners is not presented herein because each signal conditioner comprises components that have special functions. However when components are used to construct a signal conditioner, care must be taken to ensure proper impedance matching (see D.3.1), adequate frequency response and stability under real environmental operating conditions and packaging constraints. The signal conditioner conforms to IRIG-106.

D.4.5 Data recorder. Data recorders conform to IRIG-106. Prior to use, airborne recorders are carefully evaluated under realistic operating environmental conditions.

D.4.6 System calibration. Calibration of the total system should be completed prior to field measurement. The total system includes transducers, signal conditioners, data recorder and wiring. The system calibration determines the frequency response of each channel.

D.4.7 Weapon and aircraft configuration. When establishing a flight test program, the variations of weapon and aircraft configurations are analyzed for:

a. Effect of an adjacent weapon.

b. Effect of doors, inlets, cavities, scoops, and protrusions.

c. Different aircraft and flight profiles.

D.4.8 Analysis. Analysis of the measured environmental data includes:

a. Filtering or scaling.

b. Transformation to the frequency, time, or amplitude domain.

c. For conversion from analog to digital or digital to analog data, the technique ranges from visual examination of oscillograph records to implementing sophisticated Fourier transform techniques.

D.4.9 Interpretation of analysis results. Upon completion of the analysis, the data are interpreted in terms of variations due to:

a. Different measuring points on the weapon.

b. Different flight conditions.

c. Different aircraft.

d. Weapon carriage configuration.

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OPERATIONAL USE DATA

E.1 SCOPE

E.1.1 Scope. The appendix provides sample data on the factory-to-target sequence of a given missile and notes sources from which the data may be obtained. The data in this appendix applies to a specific missile and should not apply to other missiles without prior approval from the responsible agency.

E.1.2 Introduction. Data on existing missile systems are available from several sources and may be used by weapon system developers in preparing an environmental profile report for the weapon system being developed. An evaluation of the mission phases and time spent in each mission phase for a specific air-to-air missile is presented as an example.

E.2 APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

E.3 DEFINITIONS

E.3.1 Store mix configuration. The aircraft should be configured with a mix of pods, bombs and missiles depending on the combat objective.

E.3.2 Abbreviations and acronyms used in this appendix E. The abbreviations and acronyms used in this appendix E are defined as follows:

a. CVA - Combat Vehicle Attack
b. FAC - Fleet Analysis Center
c. FCG - Flight Control Group
d. NARF - Naval Air Rework Facility
e. NATOPS - Naval Air Training and Operating Procedures Standardization
f. NWS - Naval Weapons Station
g. OPEVAL - Operational Evaluation
h. TECHVAL - Technical Evaluation
i. TSG - Target Seeker Group

E.4 DETAILED GUIDANCE

E.4.1 Principal data source. The principal fleet feedback source for air-launched guided missiles is the Fleet Analysis Center (FAC), Naval Weapons Station, Seal Beach, Corona Annex, Corona, Calif. FAC maintains records of significant events in the factory-to-target sequence of air-launched guided missiles. Field activities report each of the following events of each serialized air-launched guidance and control section.

a. Transfer from one activity to another.

b. The results of maintenance or checkout performed on board attack aircraft carrier (CVA) at the Naval Weapons Station (NWS) or at the Naval Air Rework Facility (NARF).

c. The number of captive flights, number of captive f1ight hours and number of catapults and arrestments.

E.4.2 FAC sample data. An example of data provided by FAC shows the type of information that can be developed from this source.

a. FAC data on 174 missiles were analyzed to determine the probable number of days each missile spent at the NWS or overseas storage, in surface transportation (rail or truck), on an ammunition ship (AE), and on a CVA.

b. The data on the 174 missiles included; (a) the NWS factory acceptance test data of each TSG and FCG (target seeker group and flight control group) unit, (b) the firing data and locations and dates of each test and (c) captive flights at successive locations between the NWS factory acceptance and firing of the missile. The gaps resulting from a lack of shipping records which would show the exact date a missile was transferred from one activity to another were filled in the following manner.

(1) For each pair of successive missile locations, the number of days elapsed between the last record at the first location and the first record of the second location was determined.

(2) If the first and second of a pair of locations were West Coast NWS and West Coast CVA, or East Coast NWS and East Coast CVA, no time was allotted for truck and rail transportation between the CVA and the NWS; the number of days elapsed between the last record at the first activity and the first record at the second activity was divided by two. This number was added to the number of days elapsed between the first and last record at each of the two activities.

(3) If the first and second of a pair of locations were other than as in item (2) above, the number of days of surface transportation (rai1 or truck) and AE transportation or both needed to transport the missile from the first to the second location was subtracted from the number of days

elapsed between the last record at the first activity and the first record of the second activity; the result was divided by two and added to the time at each of the two activities as in item (2).

(4) For each missile, the resulting number of days spent at each activity was combined for similar activities (NWS, overseas storage, CVA, surface transportation, or AE) to derive an estimate for the total time each missile spent at each type of location.

c. The frequency distribution of total missile time at each type of location was determined for the total sample of 174 AIM-7E/7E-2 missiles and is shown on figures E-1 through E-6. These statistics are summarized in table E-I.

TABLE E-I. Factory-to-target sequence summary (sample size-174).

Time segment	Probability	Mean time days	Standard deviation days	95 percentile days	Percent of total Time
NWS Storage	1.0	492	420	1,244	48
Overseas Storage	0.49	163	320	878	16
CVA	0.83	366	338	1,020	34
AE	0.36	7	11	24	1
*Rail/truck	0.26	4	8	14	1

* Does not include time required to transport missiles between NWS, CVA, and AE.

E.4.3 Other information sources. There are several avenues of approach in developing information on possible use modes of a particular weapon. This information includes carry configurations of similar weapons, use experience on weapons with similar combat roles, and aircraft in different store mix configurations. Some of the possible sources for this information are:

a. Naval Air Training and Operating Procedures Standardization (NATOPS) manuals for each of the candidate carrying aircraft. The NATOPS manual can be used to predict maximum performance capabilities of the carrying aircraft with all possible store mixes.

b. Operational evaluation and technical evaluation (OPEVAL and TECHEVAL) reports on similar weapons in use. These reports can be used to predict combat tactics for the weapon system being developed.

c. Consultations with air and ground crews about use experience with similar weapons. These consultations supplement the information developed above.

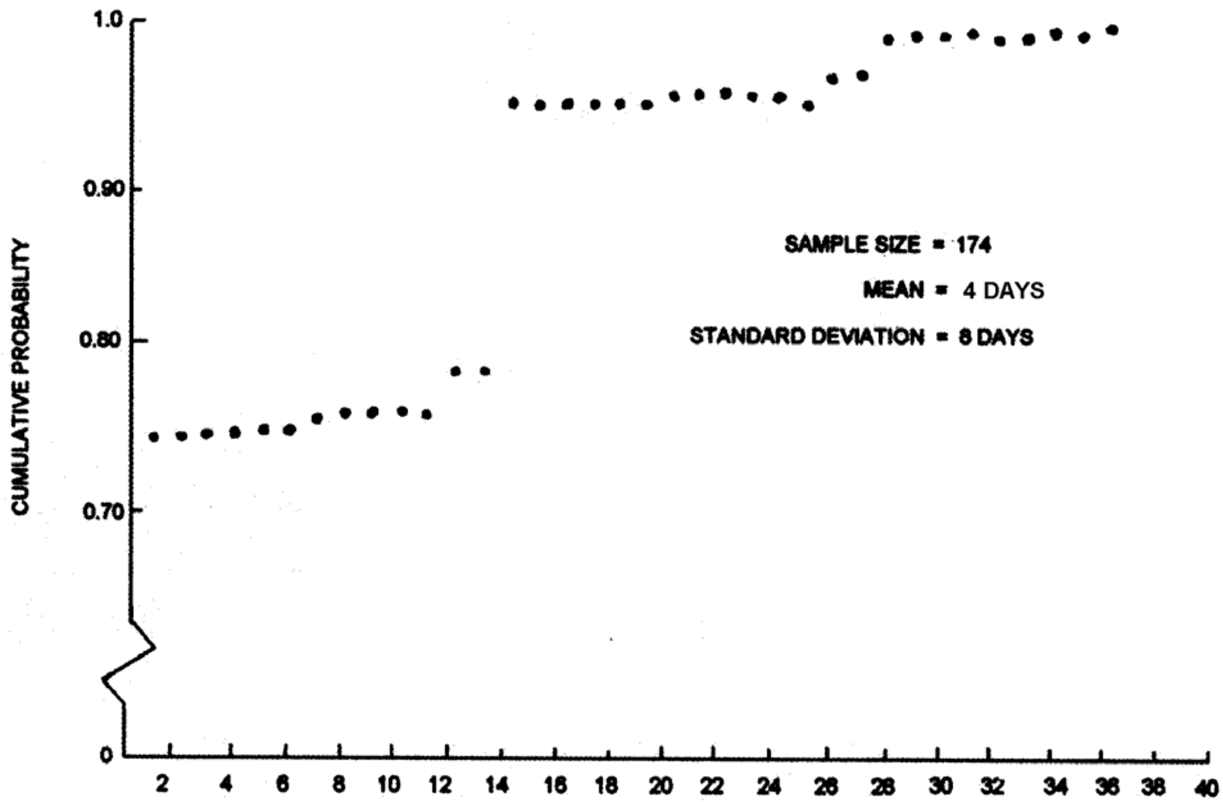

FIGURE E-1. SPARROW III AIM 7E/7E-2 time in rail and truck transportation.

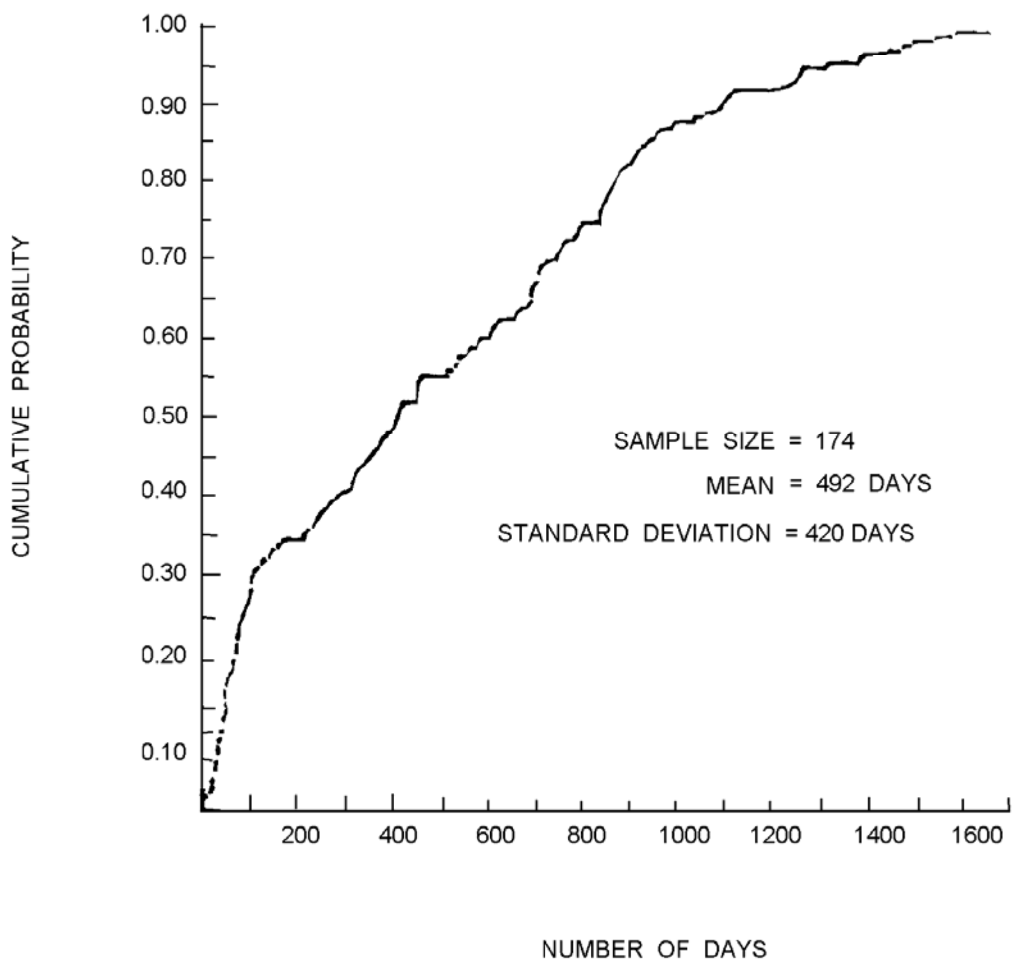

FIGURE E-2. SPARROW III AIM 7/7E-2 time at Naval Weapons Station.

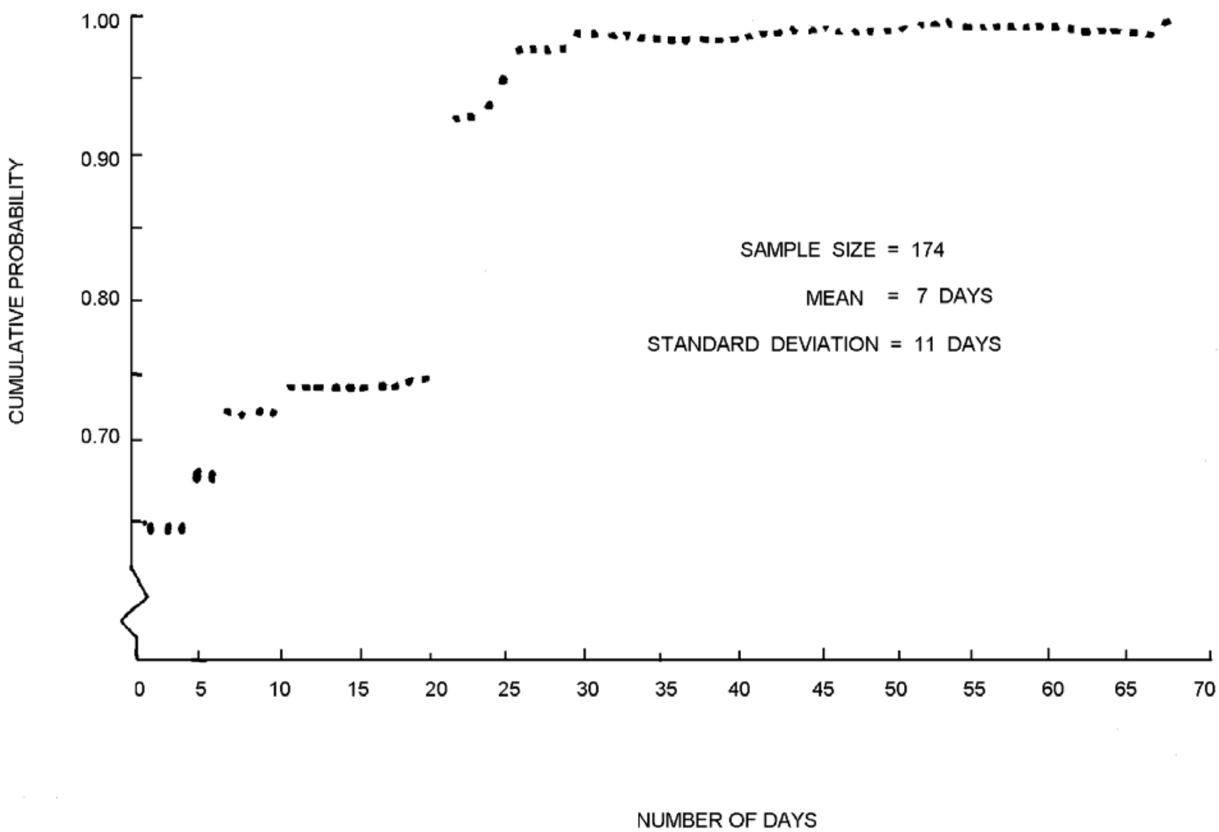

FIGURE E-3. SPARROW III AIM 7E/7E-2 time on ammunition ship.

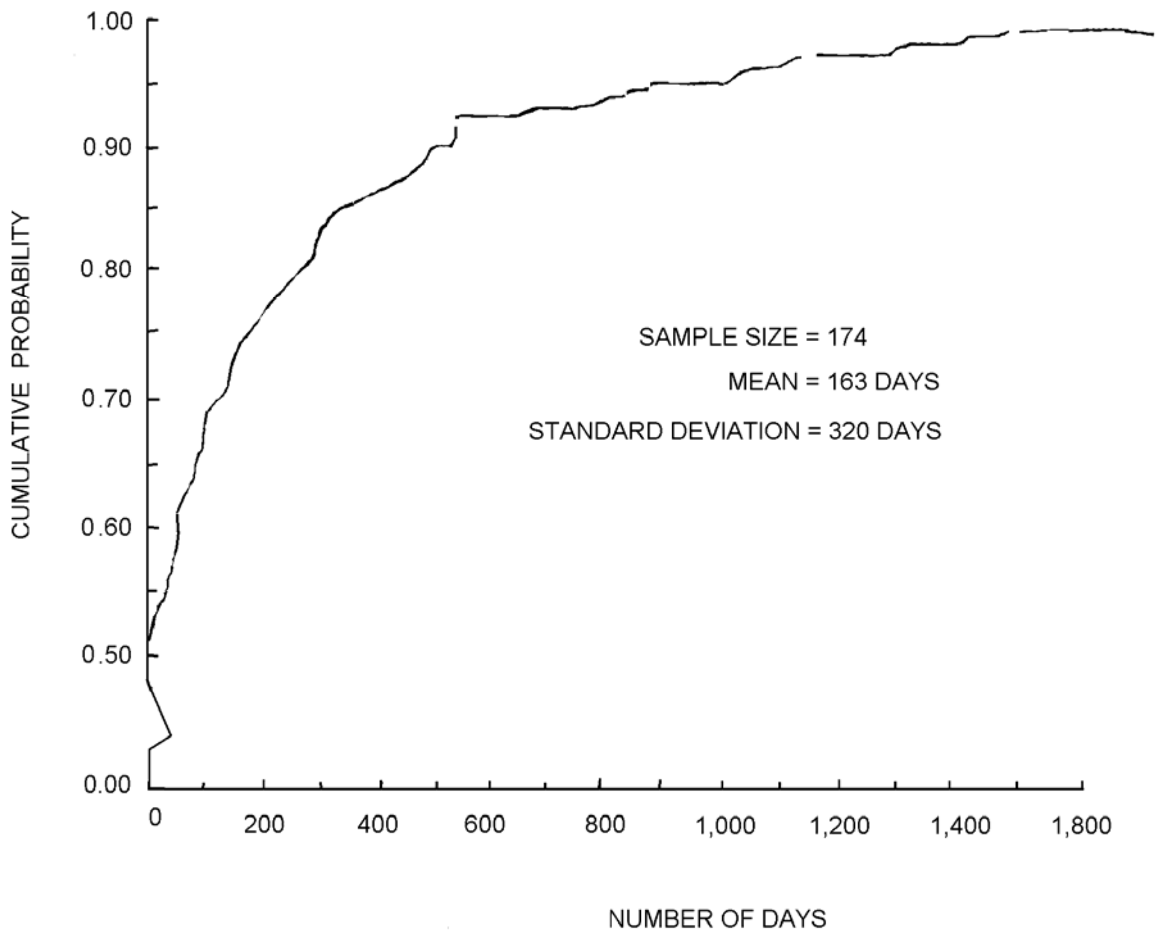

FIGURE E-4. SPARROW III AIM 7/7E-2 time in overseas storage.

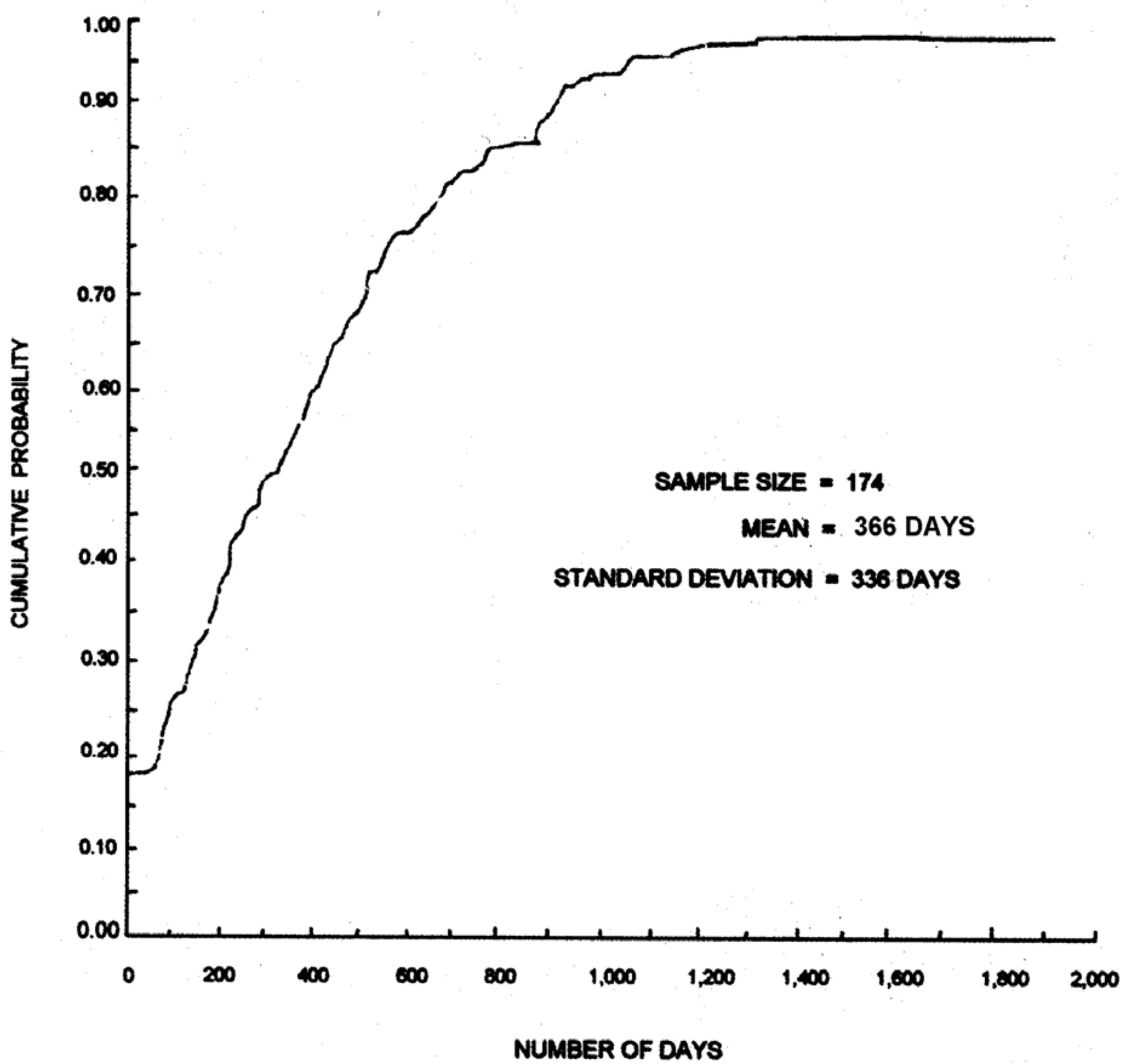

FIGURE E-5. SPARROW III AIM 7/7E-2 time on attack aircraft carrier.

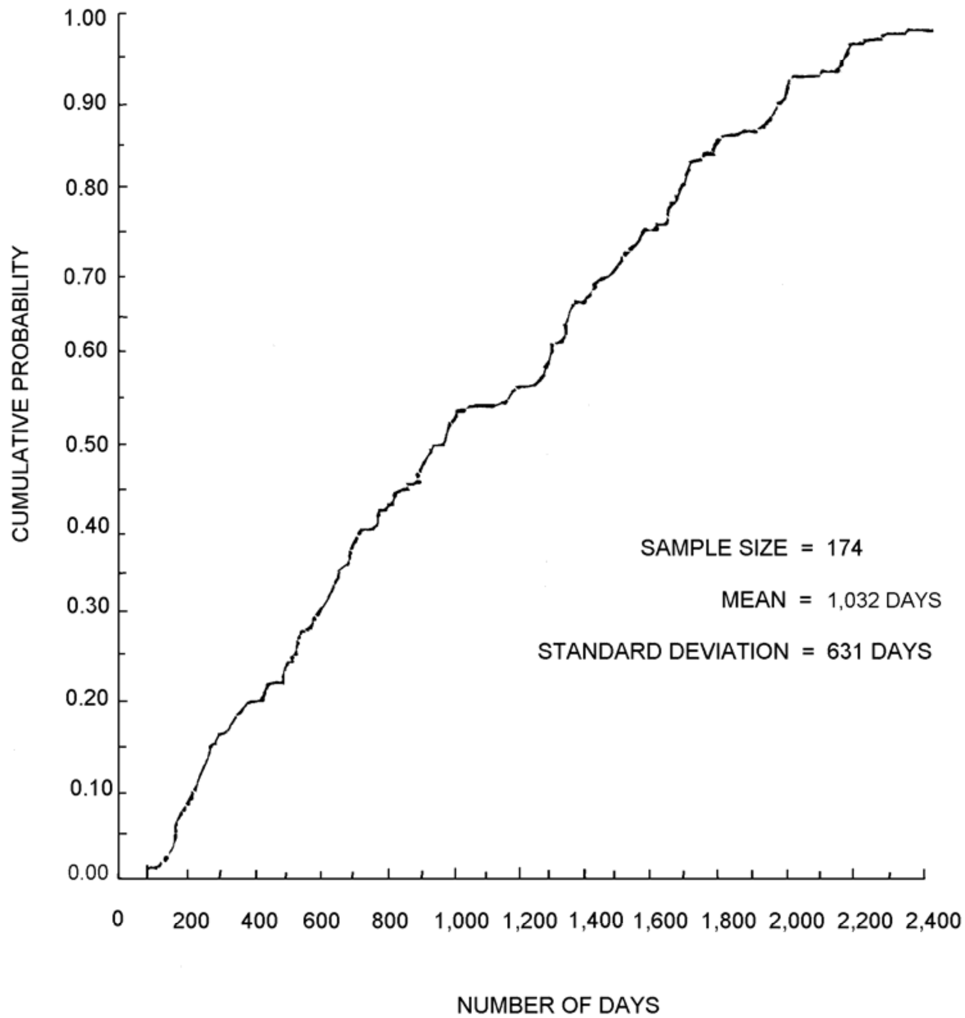

FIGURE E-6. SPARROW III AIM 7/7E-2 time in factory-to-target sequence.

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BIBLIOGRAPHY OF ENVIRONMENTAL DOCUMENTS

F.1 SCOPE

F.1.1 Scope. This appendix contains a partial list of reports, papers, and publications recommended to be used with this handbook.

F.1.2 Availability. The following bibliographical documents listed herein may be obtained from the publishers or the following originating agencies.

(1) The United States Department of Commerce, National Technical Information Service (NTIS), Attention Library Technician, Research Services, Room 1021, 5285 Port Royal Road, Springfield, Virginia 22161. Telephone (703) 487-4670 or (703) 321-9038 and Facsimile (703) 321-8547, web site: http://www.ntis.org.

(2) The Defense Technical Information Center (DTIC) 8725 John J. Kingman Road Suite 0944, Fort Belvoir, VA 22060-6218, Telephone: (703) 767-8222, web site: http://www.dtic.mil.

(3) Commanding Officer, Navy Research Laboratory, Research Report Section 4555 Overlook Avenue, S. W., Washington, DC 20375-5335, Telephone: (202) 767-7384, Facsimile: (202) 404-8176, web site: http://infoweb2.nil.navy.mil.

(4) Journal Articles, Linda Hall Library, 5109 Cherry Street, Kansas City, MO 64110 Telephone: (816) 363-4600, Facsimile: (816) 926-8785, web site: http://www.lindahall.org.

(5) Library of Congress, Photo Duplicating Services, Washington, D.C. 24540 Telephone: (202) 707-5640, Facsimile: (202) 707-0253, web site: http://www.loc.gov.

F.1.3 Abbreviations and acronyms used in Appendix F. The abbreviations and acronyms used in this appendix F are defined as follows:

a. AE - Ammunition Ship (underway replenishment)
b. AERO - Aeronautical
c. AFFDL - Air Force Flight Dynamic Laboratory
d. AFRPL - Air Force Rocket Propulsion Laboratory
e. AFSC - Air Force System Command
f. AFWAL - Air Force Wright Aeronautical Laboratory
g. AIM - Air Intercept Missile
h. ARM - Anti Radiation Missiles

i.	CV	-	Combat Vehicle
j.	EP	-	Engineering Papers
k.	HRS	-	Hours
l.	IRIG	-	Inter Range Instrumentation Group
m.	MAU	-	Munition Attack Utilities
n.	MNS	-	Mission Need Statement
o.	NASA	-	National Aeronautics and Space Administration
p.	NATO	-	North Atlantic Treaty Organization
q.	NOL	-	Naval Ordnance Laboratory
r.	NOLTR	-	Naval Ordnance Laboratory Test Report
s.	NOTS	-	Naval Ordnance Test Station
t.	NOTSTN	-	Naval Ordnance Test Station Technical News
u.	NRL	-	National Research Laboratory
v.	NTIS	-	National Technical Information Service
w.	NWC	-	Naval Weapons Center
x.	NWCTP	-	Naval Weapons Center Technical Papers
y.	ORD	-	Operational Requirement Document
z.	RAAF	-	Royal Australian Air Force
aa.	RER	-	Research Engineering Report
ab.	RH	-	Relative Humidity
ac.	SMNA	-	Systems Monitor Numerical Analyzer
ad.	STANAG	-	NATO Standardization Agreement
ae.	SVM	-	Shock and Vibration Monograph
af.	TF	-	Test Flight
ag.	TN	-	Technical News
ah.	TP	-	Technical Paper
ai.	TR	-	Technical Report
aj.	USANL	-	United States Army Natick Laboratory
ak.	WADC	-	Wright Air Development Center

F.2 ENVIRONMENTAL DOCUMENTS

F.2.1 Government publications.

F.2.1.1 Temperature.

a. Naval Ordnance Station. A “Fortran IV Program for the Solution of One Dimensional Heat Conduction Problems in Multilayer Plates, Cylinders, and Spheres Subject to Arbitrary Aerodynamic Heat Transfer”, by W. R. Compton and L. D. Shultz, China Lake, Calif., NOTS 17 July 1965. (NOTS TN 4061-124.)

b. “Measurement of Missile Thermal Response During Captive Flight at High Altitudes”, Part 2, Detailed Description of Equipment and Results, by Howard C. Schafer and Squadron Leader Batty J. Murphy, RAAF, China Lake, Calif, NWC. March 1973. 206 pp. (NWC TP 5365. Part 2. or RAAF No. TN-ARM-18.)

c. “Summary of Selected Worldwide Temperatures in Explosive Hazard Magazines”, by I.S. Kurotori and H.C. Schafer, China Lake, Calif, NWC, February 1972. 30 pp. (NWC TP 5174.)

d. “Temperature Profiles of Air Transported Materiel” by H.C. Schafer and R.A. Dickus, China Lake, Calif., NWC, October 1970. 48 pp. (NWC TP 4828.)

e. “Temperature Profiles of Truck Transported Ordnance”, by Billy D. Martin and Howard C. Schafer, China Lake, Calif, NWC. June 1970. 70 pp. (NWC TP 4822.)

f. U.S. Army Natick Laboratories, Environmental Protection Division, Quartermaster Research and Development Center, “Atlas of Arctic Environment” By Andrew D. Hastings, Natick, Mass., USANL, March 1961. (Research Study Report RER-32.)

g. “Occurrence of High Temperatures in Standing Boxcars”, by W. L. Porter, Natick, Mass., USANL, February 1956. (Report EP-27.)

F.2.1.2 Sand and dust.

a. Naval Weapons Center, “Survey and Study on Sand and Dirt” by Edward Kuletz and Howard C. Schafer, China Lake, Calif., NWC. August 1971. 50 pp. (NWC TP 5170.)

F.2.1.3 Corrosion.

No reports, papers, or publications available under corrosion.

F.2.1.4 Miscellaneous natural environments.

a. U.S. Air Force, Geophysics Lab, MA “Handbook of Geophysics and The Space Environment”, By Adolph S Jursa, 5 December 1985.

b. U.S. Army Materiel Command. “Engineering Design Handbook, Part 1. Basic Environmental Concepts”, Alexandria, VA, 31 July 1974.

c. U.S. Army Natick Laboratories, Environmental Protection Division, Quartermaster Research and Development Center, “Climatic Extremes for Military Equipment”, by Norman Sissenwine, Natick, Mass., USANL, November 1951. (Report No. 146.)

F.2.1.5 Shock.

a. Naval Ordnance Laboratory, “Comparison of Methods Used for Shock and Fourier Spectra Computations”, by R.S. Reed, Jr. White Oak, Silver Spring, MD, NOL, 24 November 1970. (NOLTR-70-243.)

b. Naval Research Laboratory, “Principles and Techniques of Shock Data Analysis”, by R.D. Kelly and G. Richmond. The Shock and Vibration Information Center, Washington D.C., NRL, 11969 (SVM-5).

F.2.1.6 Shock and vibration.

a. Air Force Systems Command, “Research Study on Ground Environment Loads Criteria for Guided Missiles”, by M.B. Thompson, J.B. Loser, and R.S. Brown, Wright-Patterson Air Force Base, Ohio, AFSC, August 1962 (WADC-TR-59-627).

b. Department of the Army, “Transportability Criteria Shock and Vibration”, April 1964, Washington, D.C., Headquarters, Department of the Army. (TP 55-100.)

c. Naval Research Laboratory, “Optimum Shock and Vibration Isolation”, by E. Sevin and W.D. Pilkey. The Shock and Vibration Information Center, Washington D.C., NRL, 1971. (SVM-6).

d. “Programming and Analysis for Digital Time Series Data”, by L. D. Enochson and R. K. Otnes. The Shock and Vibration Information Center, Washington, D.C., NRL, 1968. (SVM-3)

F.2.1.7 Vibration.

a. Air Force Systems Command, “Aircraft Gunfire Vibration” by R. W. Sevy and J. Clark, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, AFSC, November 1970. (Technical Report AFFDL, TR-70-131.)

b. “Solid Load Definition Study, The Vibration Environment”, by F. R. Wagner, Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, Calif., AFSC, January, 1969. (AFRPL-TF-68-140.)

c. “Vibration and Acoustic Test Criteria for Captive Flight of Externally Carried Aircraft Stores”, by A.G. Piersol, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, AFSC, December 1971. (Technical Report AFFDL-TF-71-158.)

d. Curtis, A. J., H.T. Abstein. Jr., N.G. Tinling, “Simulation of Complex Wave Periodic Vibration”. The Shock and Vibration Bulletin, Office of the Director of Defense, Research and Engineering, Bulletin 41, Part 4, December 1970.

e. National Aeronautics and Space Administration, “Vibration Manual”, ed. by Claude Greene. George C. Marshall Space Flight Center, Ala., NASA, 1 December 1971. (TMX 65669.)

f. Naval Research Laboratory, “Influence of Damping in Vibration Isolation”, by J.E.Ruzicka and T. F. Derby. The Shock and Vibration Information Center, Washington D C., NRL, 1971. (SVM-7.)

g. “Selection and Performance of Vibration Tests”, by A.J. Curtis, N.G. Tinling, H.T. Abstein, Jr. The Shock and Vibration Information Center, Washington, D.C., NRL, 1971. (SVM-8.)

h. “Equivalence Techniques for Vibration Testing”, by W. C. Fackler. The Shock and Vibration Information Center, Washington D.C., NRL, 1972. (SVM-9.)

i. Naval Weapons Center. “A Technique for Determining the Modes of Response of a Beam Using Quasi-Stationary Random Forcing Function Inputs”, by Robert G. Christiansen and Wallace W. Parmenter, China Lake, Calif., NWC, December 1971. 54 pp. (NWC TP 5244.)

j. Schock, R.W., and W.E. Paulson, “A Survey of Shock and Vibration Environments in the Four Major Modes of Transportation”. The Shock and Vibration Bulletin, Office of the Director of Defense, Research and Engineering, Bulletin No. 35, Part 5, February 1966.

F.2.1.8 Miscellaneous.

a. Air Force Systems Command, “Analysis of Aeronautical Equipment Environmental Failures”, by Allan Dantowitz, G. Hirschberger, and David Pravidlow, Wright-Patterson, Air Force Base, Ohio, AFSC, May 1971. (AFFDL-TR-71-32.)

b. Department of the Navy, “Replenishment at Sea”, Washington, D.C., Office of the Chief of Naval Operations. (NWP-38A.)

c. Naval Weapons Center, “Environmental Criteria Determination for Air-Launched Tactical Propulsion Systems”, Part 1, Stockpile-to-Target Sequence, by Howard C. Schafer, China Lake, Calif., NWC, July 1968. 28 pp. (NWC TP 4464, Part 1.)

F.2.2 Non-Government publications.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM-STP 462 - Effects of Environmental and Complex Load History on Fatigue Life

(Copies of this document are available online at www.astm.org or American Society for Testing and Materials (ASTM) International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI-S2.10 - Methods for Analysis and Presentation of Shock and Vibration Data, New York, ANSI, 1971. (S2 10.)

(Copies of this document are available online at www.ansi.org or American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036.) or the Defense Technical Information Center (DTIC), 8725 John J. Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218, Telephone: (703) 767-8222, web site: http://www.dtic.mil.

F.2.3 Miscellaneous guidebooks.

The following books are useful for review and may be available at local publication houses.

a. “General guidelines for Corrosion Testing of Members for Marine Applications”, Ashgate Publishing Co., October-1989.

b. “Aerospace Telemetry”, Volume 1 by H. L. Stiltz, Englewood Cliffs, NJ.

c. “Instruction for Engineering Measurement”, by J. W. Dally and W. F. Riley-published by John and Riley & Sons Inc.

d. “Random Data Analysis and Measurement Procedures”, New York John Wiley & Son Inc.

CONCLUDING MATERIAL

Custodians:
Army-MI
Navy-AS
Air Force-11

Preparing activity:
Navy-AS

(Project ENVR-2007-002)

Review activities:
Army-CE, EA, TE
Navy-MC, OS, SH
Air Force-22

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