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MILITARY STANDARD

ENVIRONMENTAL CRITERIA AND GUIDELINES FOR AIR-LAUNCHED WEAPONS

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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DEPARTMENT OF DEFENSE
Washington, D.C. 20301

ENVIRONMENTAL CRITERIA AND GUIDELINES FOR AIR-LAUNCHED WEAPONS

MIL-STD-1670A

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

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, New Jersey 08733 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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FOREWARD

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 weapons 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 weapons expected total service environment early in the design phase and translating this environment into design criteria that is to be demonstrated prior to the weapons operational use.

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1. SCOPE

1.1 Air-launched weapons environmental criteria and guidelines. This standard establishes guidelines for the environmental engineering required in support of air-launched weapon developments. Air-launched weapons include the following:

(a) Air-to-air weapons

(b) Air-to-surface weapons including free-fall weapons

(c) Aircraft gun pods

The following environments are not considered in this standard:

(a) Nuclear environment

(b) Electromagnetic environment

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

1.2 Purpose. The purpose of this standard is to:

(a) Provide acquisition managers with guidelines for the implementation of the required "most realistic test environment possible," per DoD Directive 5000.1.

(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 data on which to base weapon environmental design and test requirements.

2. REFERENCED DOCUMENTS

2.1 Issues of Documents. The following documents of the issue in effect on date of invitation for bids or requests for proposals form a part of this standard to the extend specified herein.

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STANDARDS

Military

MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-810	Environmental Test Methods
MIL-STD-961	Outline of Forms and Instructions for the Preparation of Specifications and Associated Documents

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. DEFINITIONS

3.1 Environmental Profile Report (EPR). A report that quantitatively describes the various environments that a given weapon may encounter in its factory-to-target sequence. Each environment is categorized as damaging or non-damaging; the corresponding rationale for such categorization is given.

3.2 Environmental Design Criteria Document (EDCD). This document contains a parametric delineation of environments to which a specific weapon design must be responsive, environmental design requirements, and an environmental qualification test plan.

3.3 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 or failed to accomplish the required mission.

4. GENERAL REQUIREMENTS

4.1 General. A major task in the development of a weapon is to ensure that its design is compatible with the environment to which it will be subjected. This standard provides the guidelines for use by the developing activity in conducting the required environmental engineering tasks. The technical approach, completeness and adequacy of the developer's plan for implementation of this standard is subject to approval by the cognizant acquisition manager.

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4.2 Environmental Development Plan (EDP). In order to assure that the weapon will be designed and tested for all pertinent environmental conditions to which it will be subjected throughout its life cycle, the developing activity shall submit an environmental development plan (EDP) for approval by the cognizant acquisition manager. The EDP shall include plans for conducting environmental engineering tasks during engineering design and development, and submitting necessary documentation in accordance with the guidelines of this standard.

4.3 Documents. The environmental engineering effort shall be reported in two documents: the Environmental Profile Report (EPR) and the Environmental Design Criteria Document (EDCD). Both shall be listed on the Form DD 1423.

4.3.1 Environmental documents development sequence. Figure 1 identifies the development sequence of the required environmental engineering documentation for the design and development of weapons.

4.3.2 Environmental Profile Report (EPR). The EPR shall include a delineation and examination of all probable environments or combination of environments that could affect the functioning, reliability, or operational capability of the weapon in accordance with 4.3.2.1.

4.3.2.1 Submission of EPR. The EPR shall be developed during the program initiation phase of weapon development and shall be submitted to the cognizant acquisition manager and approved before developing the EDCD. Early submission of the report and approval is necessary so that information on environmentally induced stresses can be included in the tradeoff studies of candidate weapon designs.

4.3.2.2 Support information for the EPR. The following information, necessary for the development of the EPR, will be provided by the acquisition manager:

(a) Candidate carrying aircraft, with aircraft flight limitations (altitude, Mach number, etc.), launcher locations on the candidate aircraft, and store mix, if possible.

(b) Mission profile of carrying aircraft.

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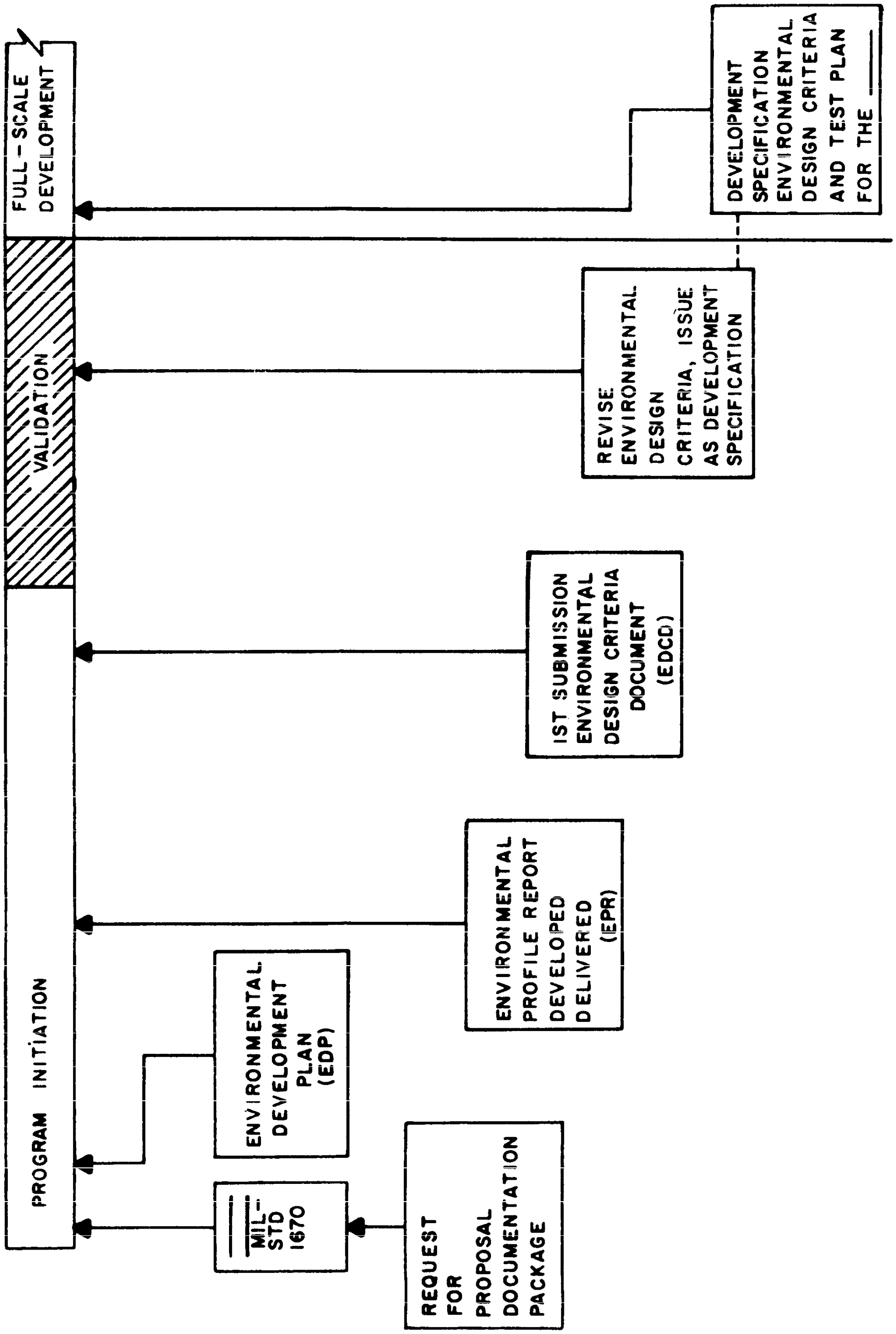

Figure 1. Documentation Development Sequence.

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(c) Required life of the candidate weapon components, (storage life, service life, number of flights, etc.).

(d) Anticipated combat use tactics.

(e) Proposed logistics cycle.

(f) Anticipated operational deployment (desert, worldwide, etc.).

(g) Operational experience on existing similar weapons.

(h) Other as required by the developing activity.

4.3.3 Environmental Design Criteria Document (EDCD). The EDCD shall contain specific quantitative design parameters for the weapon, environmental design requirements, and an environmental test plan in accordance with 4.3.3.3.

4.3.3.1 Submission of EDCD. The initial EDCD submitted will usually require revisions because some environments, such as captive flight, are highly hardware-dependent and must be determined by a detailed data acquisition program.

4.3.3.1.1 EDCD initial submission. The environmental design criteria, developed during the program initiation phase from a detailed analysis, extrapolation, and synthesis of the environments delineated in the EPR, shall include quantitative design parameters for those environments for which data exist, and estimates for those environments that are hardware-dependent. A plan for the acquisition of data to replace the estimates shall be included in the initial submission.

4.3.3.2 EDCD revisions. Revisions to the initial submission shall incorporate the hardware-dependent data acquired by the series of environmental measurement programs delineated in the initial submission. These data shall be developed when the basic configuration of the weapon is established. The final revision to the EDCD, complete with appropriate data, shall be formulated in accordance with MIL-STD-961, so that it may be issued as the weapon environmental specification, "Environmental Design Criteria and Test Plan for (specific weapon)" and shall be a requirement for full-scale development release.

4.3.3.3 Environmental Test Plan (ETP). An environmental test plan (ETP) shall be included as part of the weapons specification and shall be consistent with the parameters contained therein. The specification will be invoked at the beginning of the full-scale development of the candidate weapon system (Figure 1).

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5. DETAILED REQUIREMENTS

5.1 Documents. An Environmental Profile Report (EPR) and an Environmental Design Criteria Document (EDCD) shall be prepared for the development of the weapon. The EPR shall contain analyses of all probable environments and events in the factory-to-target sequence (Section 5.2). This report shall specify those applicable environmental conditions to which a given weapon can be expected to be exposed. The EDCD shall include parameters for use in the design and test of the weapon for those environments specified in the EPR. Appendices A through F contain data, recommended approaches, and guidelines that can be used in the preparation of these documents.

5.1.1 EPR. The EPR shall contain, for each environment or event, the following:

(a) Assumptions (applicability of the environments, events, or situations listed in section 5.2).

(b) References and source data.

(c) Techniques or methods of calculation.

(d) Calculations and results.

(e) Conclusions (when sufficient data are available) or plans for a further data-acquisition program.

(f) Suggested parameters for initial design and test purposes.

(g) Other considerations:

  (1) MIL-STD-210 is the current document describing climatic extremes. This document must be analysed for applicability for use on a specific weapon.

  (2) Synergistic effects and sequences shall be applied to environmental and safety tests (see section 5.3).

  (3) The operational status of the weapon (nonoperating, periodic check-out, training, repair cycle, and fully operational) shall be considered.

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(4) The packaging and transportation container shall be considered as an integral part of the weapon for purposes of environmental analysis, design, and environmental tests, as applicable.

(5) Safety constraints (covering such events as fragment impact, accidental release, fuel fire) shall be considered.

(6) Operational experience on existing similar weapons shall be used.

5.1.2 EDCD. The EDCD shall contain the following:

(a) A data display matrix (Tables I-IV in Appendix A are typical examples) of the environments specified in the EPR. The data display matrix shall include:

(1) The environmental parameters to be used in initial design and test.

(2) Combinations of simultaneously occurring environments.

(3) Identification of those design parameters that require further investigation (such as by an environmental measurement program).

(b) In the initial submission, a plan shall be included for acquisition of data identified in (3) above.

5.1.2.1 Final EDCD revision. The final revision of the environmental design criteria document shall include the following:

(a) The revised data display matrix, including data acquired by the environmental measurement program (paragraph 5.1.2b).

(b) An environmental test plan with procedures written based on the test methods of MIL-STD-810. These procedures shall be modified to reflect the selected parameters and profiles of the final revision of the environmental design criteria document and test-time durations based on analysis of the weapon's factory-to-target sequence. The environmental test plan shall include environmental qualification tests,

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required safety tests, suggested production acceptance tests, and where applicable, tests to be conducted to extreme limits for safety information; each test shall be identified with respect to these four categories.

5.2 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 shall be addressed by the developing agency are listed in the following paragraphs. Situation-dependent environments are listed in paragraphs 5.2.1.1 through 5.2.1.13, and the situations in which such environments will be encountered are given in paragraph 5.2.1.14. A discussion of the dynamically induced environments and the events that produce them are presented in paragraphs 5.2.2.1 through 5.2.2.4. Unusual system-oriented environments (such as cosmic radiation and insects) are not treated herein, but shall be included in the environmental profile report if applicable.

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

5.2.1.1 Temperature. Temperature shall be presented in degrees Fahrenheit and Celsius (^{O}F and ^{O}C) as a function of time. Steady-state or soak conditions shall be supported with written evidence of applicability.

5.2.1.2 Humidity. The humidity environment is presented in one of the following forms:

(a) Percent relative humidity at a corresponding dry bulb temperature.

(b) Pounds of water (H_2O) per pound of dry air.

(c) Clearly labeled combinations of (a) and (b).

Each steady-state relative humidity value shall be supported by written evidence of applicability.

5.2.1.3 Precipitation. The precipitation environment shall 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.

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

5.2.1.5 Sand and dirt. The sand and dirt environment shall be presented in the following form:

(a) Chemical composition of the sand and dirt (includes Fe_2O_3, $A\ell_2O_3$, and SiO_2).

(b) Particle size distribution.

(c) Relative particle velocity.

5.2.1.6 Wind. Wind shall be presented in terms of displacement per unit time. Wind shear (spatial variation of velocity with respect to a vertical axis) shall be presented where applicable.

5.2.1.7 Pressure. Pressure shall be presented in terms of force per unit area. Pressure or pressure differences are associated with changes in altitude, meteorological characteristics, water submersion, and thermal expansion. (Blast pressure should be considered as applicable.)

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

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

5.2.1.10 Fungus. The fungus environment shall be presented with reference to temperature, humidity, nutrient supply, time, and exposure. Consideration shall be given to any situation in which water or hydrocarbon liquids stand in metal structures. The EDCD shall call attention to the hazards of adding fingerprints, labels, inspection stamps, or organic substances to materials that are non-nutrient to fungus where applicable.

5.2.1.11 Solar radiation. Solar radiation shall be presented as British thermal units per hour square foot (Btu/hr-ft^2) in conjunction with

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the temperature, wind speed, and relative humidity at a given instant of time. Note: Direct solar radiation is but one part of a many-part heating matrix; some other radiation sources are:

(a) Earth's albedo

(b) Hardstand albedo

(c) Reflection from other ordnance

(d) Sky brightness

(e) Reradiation from clouds

(f) Reradiation from liquid droplets or airborne solids

5.2.1.12 Electrostatic and Residual Magnetism. Electric charge buildup shall be presented in standard electrical terms.

5.2.1.13 Water immersion. Immersion shall be presented in terms of depth of immersion, temperature, and duration.

5.2.1.14 Situations. The following situations shall be considered in specifying the environments of 5.2.1.1 through 5.2.1.13:

(a) Transportation and handling

  (1) Flatbed truck, exposed

  (2) Van truck

  (3) Boxcar

  (4) Flatcar

  (5) Handling equipment

  (6) Exposure on deck of cargo ship

  (7) Hold of cargo ship

  (8) Hardstand

  (9) Cargo aircraft

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    (10) Underway replenishment

(b) Storage and handling

    (1) Igloo magazine
    (2) Uninsulated sheet metal building
    (3) Roofed structure with no sidewalls
    (4) Dump storage, exposed
    (5) Dump storage, revetment
    (6) Railroad siding

(c) Operational handling and storage

    (1) Maintenance test
    (2) Maintenance shop
    (3) Aircraft carrier main deck
    (4) Weapons handling equipment
    (5) Unsheltered ordnance assembly table

(d) Aboard aircraft

    (1) Aircraft, carrier main deck
    (2) Aircraft, carrier hangar deck
    (3) Catapult lineup
    (4) Aircraft, in a revetment
    (5) Aircraft, on the runway
    (6) Vertical takeoff and landing (VTOL) jet blast
    (7) Jet blast (from other aircraft)

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(8) Bomb bay

(9) Store station of aircraft

(10) Rocket exhaust impingement

(11) Aircraft in flight

(12) Aircraft, hangered

(e) Launch-to-target

5.2.2 Dynamically induced environments.

5.2.2.1 Acceleration. The acceleration environment shall be presented as gravity units (g) for linear acceleration, or radians per second squared (rad/sec 2) for angular acceleration. Both shall be referenced to a given axis. The acceleration may be a given number presented in a load factor envelope plot.

The following acceleration-producing events are examined:

(a) Handling and hoisting operations

(b) Aerobatic maneuvers of the carrying aircraft

(c) Aerodynamic loading during aircraft flight

(d) Inertial accelerations during powered flight

(e) Weapon maneuvers during flight to the target

(f) Catapult launch

5.2.2.2 Shock. The shock environment shall be presented in one or more of the following forms with direction noted:

(a) Shock amplitude versus time, with acceleration amplitude in g specified on the vertical axis and duration in milliseconds on the horizontal axis. Only deterministic wave forms, such as half-sine, sawtooth, triangular, or square, shall be presented in this manner.

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(b) Shock spectrum shall be presented as response amplitude in g (vertical axis) versus frequency in hertz (Hz) (horizontal axis). The type of shock spectrum, the damping factor, and the shock pulse duration used in the calculation of the shock spectrum shall be provided.

(c) Fourier spectrum shall be presented as acceleration amplitude in g (positive and negative vertical axis) versus frequency in Hz (horizontal axis). The time interval of the shock, the effective filter bandwidth of the transformation, and smoothing techniques used in the transformation shall be presented.

The following shock-producing events are examined:

(a) Truck transportation

(b) Rail transportation

(c) Ship transportation

(d) Handling during transit, including drop

(e) Underway replenishment

(f) Airfield and aircraft carrier handling

(g) Catapult takeoff

(h) Arrested landing

(i) Ejection shock during aircraft/store separation (including adjacent store separation)

(j) Propulsion unit ignition, boost/sustain transition, and shutdown (including adjacent store ignition).

(k) Fin opening or abrupt control-surface movement

(l) Operation of electro-explosive devices

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(m) Operation of mechanical explosive devices

(n) Operation of mechanically initiated explosive devices

(o) Operation of mechanical retraction devices

(p) Rail launch tip-off

5.2.2.3 Vibration. The results of analytical investigation or vibration data analysis shall be presented in either or both of the following graphical forms:

(a) Amplitude shall be presented in g (vertical axis) versus frequency in Hz (horizontal axis).

(b) Power spectral density shall be presented as g^2/Hz (vertical axis) versus frequency in Hz (horizontal axis). Additionally, the following information used in data analysis shall be provided: (1) bandwidth, (2) averaging time, and (3) overall vibration level.

The following vibration producing events and conditions shall be examined:

(a) Transportation by truck, rail, ship, and aircraft

(b) Handling or transfer operations

(c) Captive-flight carriage

    (1) Turbulent boundary layer (especially on high performance aircraft)

    (2) Shock wave impingement

    (3) Flow changes caused by adjacent stores, pylons, and aircraft surfaces, and cavity effects with weapon bays

    (4) Rotating devices within or on the weapon

    (5) Rotating devices within or on the aircraft

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(6) Responses of the aircraft structure

(7) Flight line movement

(8) Catapult launch

(9) Takeoff and landing operations

(10) Adjacent gun firing

(11) Weapon control surface and wing responses

(12) Any unusual protrusion into the airflow

(d) Launch-to-target

(1) Turbulent boundary layer

(2) Propulsion unit

(3) Rotating devices

(4) Any unusual protrusion into the airflow

5.2.2.4 Acoustic. The high-intensity acoustic environment shall be presented as follows:

(a) The overall sound pressure level shall be given in decibels (dB) referred to 0.0002 dyne/cm^2 (20 micro pascals).

(b) The sound pressure level in each 1/3 octave band between 37.5 and 9,600 Hz shall be given and referred to the overall sound pressure level or 0.0002 dyne/cm^2. This may be presented graphically or in a table as decibels versus frequency. The location of the microphones shall be noted.

The following high-intensity acoustic producing events shall be examined:

(a) Captive carry on high- performance aircraft.

(b) Free or powered flight.

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(c) Mounting region with respect to jet engine intake or exhaust location.

(d) Firing of adjacent weapons.

(e) Stores with open cavities on carrying aircraft.

5.2.3 Chance of encounter. When the factory-to-target sequence of the weapon is examined, the chance of encountering each situation and the associated environments shall be evaluated on the basis of the specific mission. (Appendix E provides an example for this type of information for a specific weapon.)

5.3 Synergistic effects. Synergistic effects result from exposure of the weapon to a combination of concurrent environments whose effects on the weapon 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 operations.

(b) Temperature, humidity, shock, and vibration during transportation.

(c) Aerodynamic heating, altitude variations, humidity, shock, vibration, and acoustics during aircraft carriage.

The weapon factory-to-target sequence shall be examined for these effects.

5.4 Environmental engineering points of contact.

(a) ARMY - USAETL, ETL-GS-AC
Ft. Belvoir, VA 22060

(b) AIR FORCE - AFFDL/FEE
Wright-Patterson A.F.B, OH 45433

(c) NAVY - NWC, Code 453
China Lake, CA 93555

Custodians:

Army - AV
Navy - AS
Air Force - 11

Preparing activity:

Navy - AS

Project No. MISC-0B22

Review activities:

Army - EA, PA, CE

User activities:

Army - WV
Navy - EC, OS

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APPENDIX A

ENVIRONMENTAL DATA AND CALCULATION TECHNIQUES

10. 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, i.e., during the program initiation phase of development.

10.1 Introduction. The data presented herein are the current 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 container.

(b) The weapon is exposed to the environments during airfield/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 or 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 fungus, corrosion, and rainfall at altitude. These environments are not detailed herein, but their effects on the hardware are to be noted in the EDCD.

20. Temperature. The thermal environment of air-delivered ordnance during the factory-to-target sequence is divided into two basic categories: (1) transportation, storage, and handling, and (2) captive 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 weapons response to temperatures in both of these categories must be considered in the weapon design.

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20.1 Storage and transportation temperature computations. Computation of weapon temperature profiles during storage and transportation requires determination of (1) the appropriate thermal forcing functions, and (2) weapon response to these forcing functions. During dump storage, the primary forcing functions are (1) direct and reflected solar and atmospheric radiation and (2) convection from ambient air. During covered storage and transportation, the dominant forcing functions are (1) convection from the surrounding air, and (2) radiation exchange with compartment walls. Once the thermal forcing functions have been determined, weapon 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 the motor, liner, and propellant grain.

20.1.1 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-STD-210.

Basic Assumptions

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

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

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

(d) System initially soaked at 100°F.

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

Method of Solution

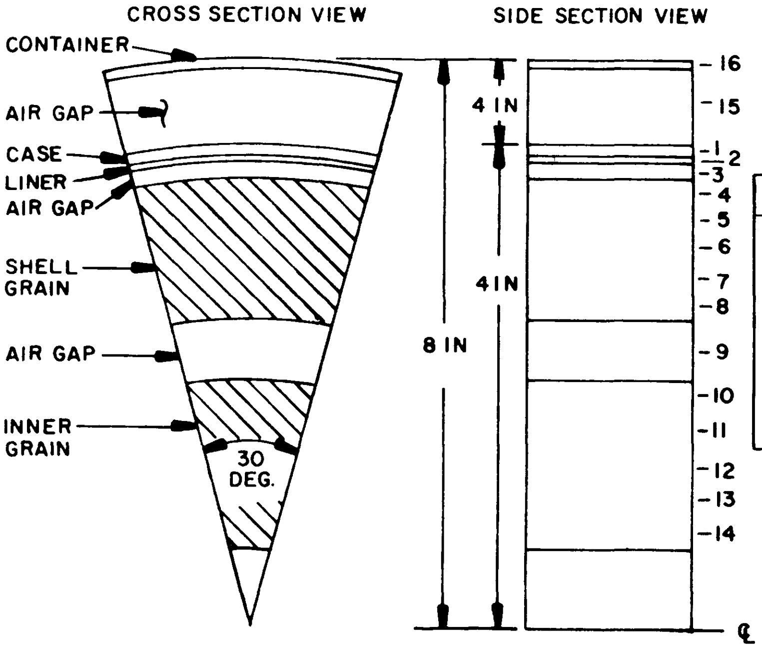
(a) Develop thermal model of system.

(b) Define input conditions.

(c) Write energy balance for each thermal node.

(d) Solve resulting system of energy balance to obtain temperature response of each node.

Thermal Model



NODE	PART	THICKNESS, IN
1	CASE	0.0625
2	LINER	0.025
3	AIR GAP	0.150
4-8	SHELL GRAIN	0.825
9	AIR GAP	0.5
10-14	INNER GRAIN	1.7
15	AIR GAP	4.0
16	CONTAINER	0.1

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Thermal Properties

	Density, lb/ft^3	Thermal conductivity, Btu/hr-ft-^{o}R	Specific heat, Btu/lb-^{o}R
Container	483.8	25.0	0.12
Motor case	483.8	25.0	0.12
Liner	108.9	0.19	0.28
Grain	105.2	0.22	0.29

NOTE: Thermal mass of air gaps neglected.

Input Conditions

Daily Cycle of Temperature and Other Elements Associated With the High Temperature Extreme for Ground Operations

Local standard time, hours	Temperature,		Relative humidity	Wind		Solar radiation	
	°F	°C	%	ft/sec	meters/sec	BPH[a]	LPH[b]
01	95	35	6	9	3	0	0
02	94	34	7	9	3	0	0
03	93	34	7	9	3	0	0
04	92	33	8	9	3	0	0
05	91	33	8	9	3	0	0
06	90	32	8	[illegible]	3	18	5
07	91	33	8	[illegible]	3	85	23
08	95	35	6	[illegible]	3	160	43
09	101	38	6	[illegible]	3	231	63
10	106	41	5	14	4	291	79
11	110	43	[illegible]	14	4	330	90
12	112	44	[illegible]	14	4	355	96
13	116	47	[illegible]	14	4	355	96
14	118	48	[illegible]	14	4	330	90
15	119	48	[illegible]	14	4	291	79
16	120	49	3	14	4	231	63
17	119	48	3	14	4	160	43
18	118	48	3	14	4	85	23
19	114	46	3	14	4	18	5
20	108	42	4	14	4	0	0
21	105	41	5	14	4	0	0
22	102	39	6	14	4	0	0
23	100	38	6	14	4	0	0
24	98	37	6	9	3	0	0

SAMPLE

[a] BPH - British thermal units per square foot per hour.
[b] LPH - Langleys per hour.

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Atmospheric Radiation (q_{atm})

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

where

σ = 0.1714×10^{-8} Btu/hr-ft^2-$^{o}R^4$

T_{air} = ambient air temperature, ^{o}R

a = 0.5

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

e = R.H. x saturation vapor pressure, mb

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

$$\bar{h}_c = 0.036 \; k/L \; Pr^{1/3} \; Re_L^{0.8} \quad \text{Btu/hr-ft}^2\text{-}^{o}R$$

where

k = thermal conductivity, Btu/hr-ft -^{o}R

L = length of container, ft

Pr = Prandtl number, $c_p \mu / k$

Re_L = Reynolds number, $VL\rho/\mu$

V = wind velocity, ft/hr

c_p = specific heat of air, Btu/lb-^{o}R

μ = viscosity of air, lb/ft-hr

ρ = density of air, lb/ft^3

Air properties are evaluated at film temperature

where

$$T_{film} = \frac{T_{air} + T_{container}}{2}$$

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.

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The energy balance per unit area of the top of the container is as follows:

$$\begin{aligned}\text{Heat stored} &= \text{solar radiation} + \text{atmospheric radiation} + \text{convention with ambient air}\\ &\quad - \text{radiation emitted} - \text{convention with air gap} - \text{radiation exchange with motor skin}\end{aligned}$$

Thus,

$$\begin{aligned}\rho c_p b \, dT/dt &= \alpha_s q_{solar} + \alpha_L q_{atm} + \bar{h}_c \,(T_{air} - T)\\ &\quad - \sigma\epsilon T^4 - h_{int}(T - T_{air\ gap}) - \sigma\epsilon(T^4 - T^4_{motor})\end{aligned}$$

where

ρ = density of container wall, lb/ft^3

c_p = specific heat of container wall, Btu/lb-^oR

b = thickness of container wall, ft

T = container temperature, ^oR

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

q_{solar} = solar radiation heat flux, Btu/ft^2-hr

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

q_{atm} = atmospheric radiation heat flux, Btu/ft^2-hr

T_{air} = ambient air temperature, ^oR

σ = Stefan-Boltzmann constant, Btu/ft^2-hr-$^oR^4$

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

h_{int} = convective heat transfer coefficient on internal surface of container ($\simeq 0.6$ Btu/hr-ft^2-^oR)

$T_{air\ gap}$ = temperature of air gap between motor and container, ^oR

T_{motor} = temperature of motor case, ^oR

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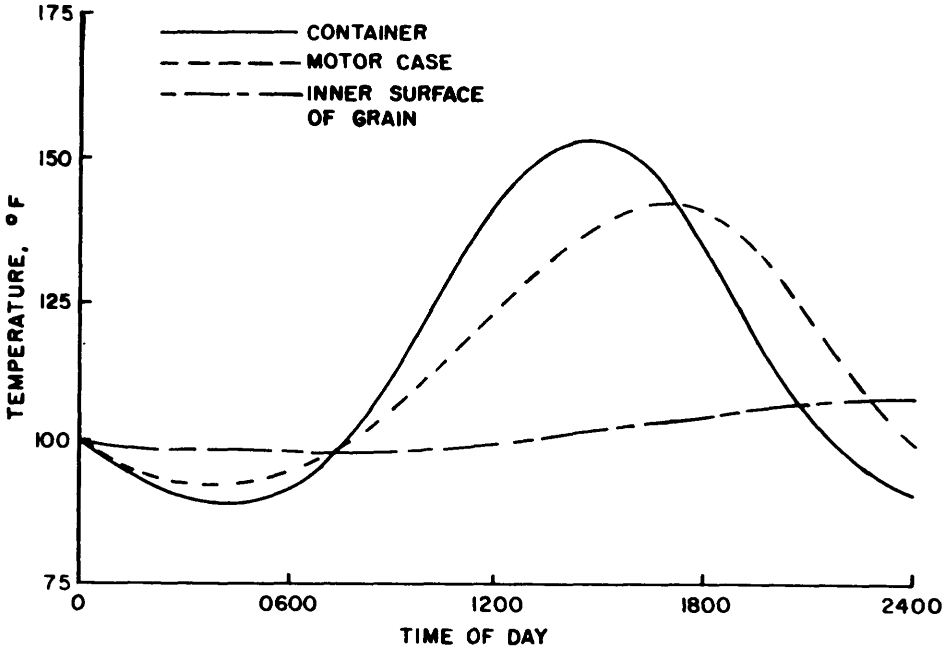
Similar expressions are developed for each thermal node, equating to heat transfer to and from adjoining nodes by conduction, convection, and radiation.

Solution of Equations

The resulting system of equations may be solved numerically by computer. With a typical thermal analyzer computer 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.

For this particular problem, the SINDA thermal computer program is used, and the system of equations is solved by implicit "forward-backward" finite differencing (Crank-Nicholson method).

Results (Typical Solution)



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20.1.2 Cumulative probability for dump-storage (limited data). Where the data from MIL-STD-210 are not appropriate for calculating container-wall temperatures, usable values for container-wall maximum and minimum temperatures can be obtained from Figures 2-4. Cumulative probability is plotted as a continuous function from 0 to 1. A management decision on "design maximum" temperatures may be made utilizing cumulative probability, keeping in mind that three sigma is 0.997. Figures 2-4 are each based on 8,760 hourly samples per year from a given thermocouple.

20.2 Air-temperature profiles for transportation and storage. Air-temperature profiles for selected transportation and storage situations are shown in Figures 5-10. For information on transportation and storage, see the references listed in Appendix F.

20.2.1 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, and (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-STD-210. These MIL-STD 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, 1962, 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, such as that for a case-bonded rocket motor where only heat conduction through a symmetrical shape is involved, to a very complex process, as in that for a guidance section where the effects of natural convection, radiation between components, contact resistance, and internal heat sources must be considered.

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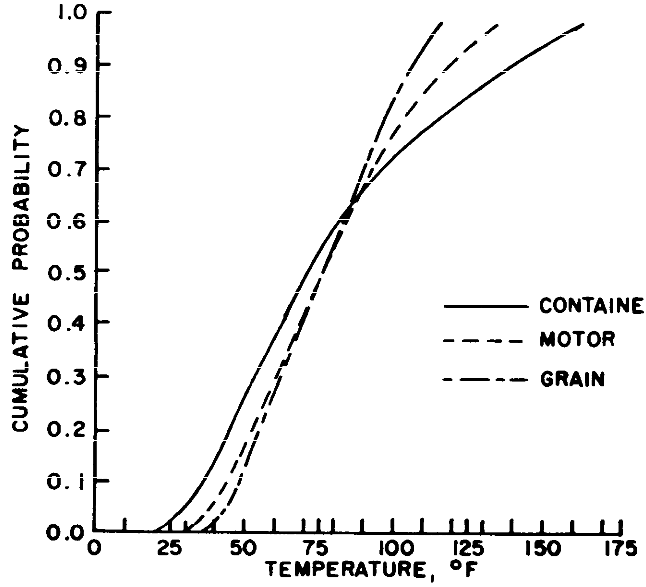

Figure 2. Cumulative Distribution of Desert Dump Stored 12-Inch-Diameter Motor Temperatures for the Period June 1970 through May 1971.

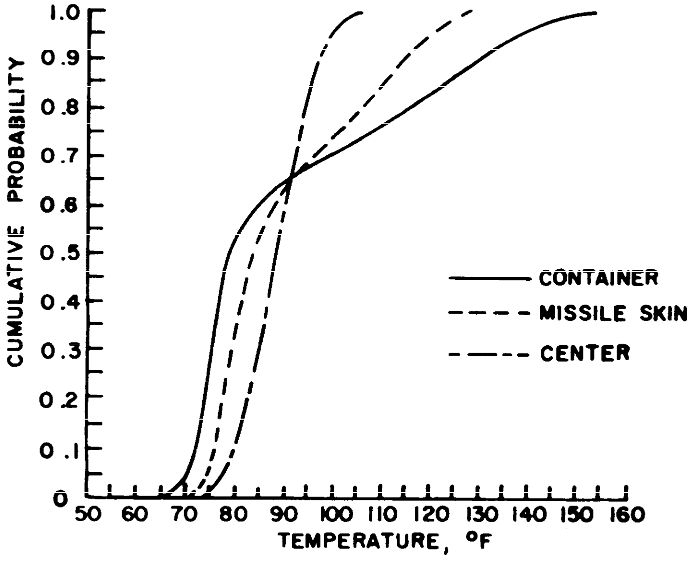

Figure 3. Cumulative Distribution Summary of Dump Stored 12-Inch-Diameter Motor Temperatures at Subic Bay for 1970.

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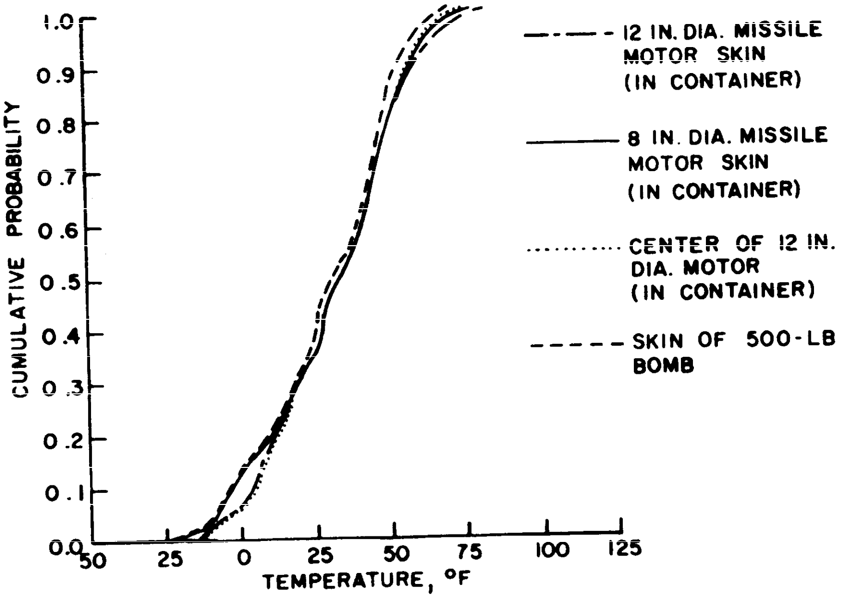

Figure 4. Cumulative Distribution Summary of Dump Stored Ordnance Temperatures at Fort Richardson for 1970.

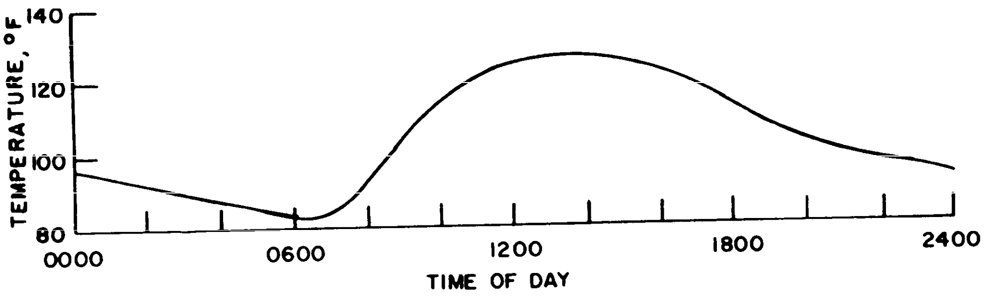

Figure 5. Truck, Van, Rail, and Covered Storage High Temperature Profile.

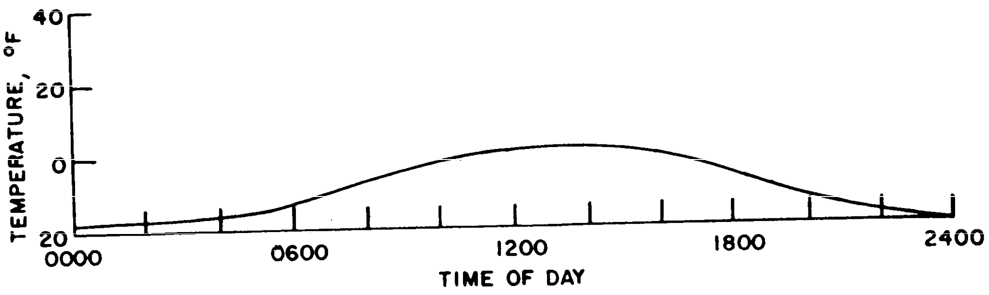

Figure 6. Truck, Van, and Rail Low Temperature Profile.

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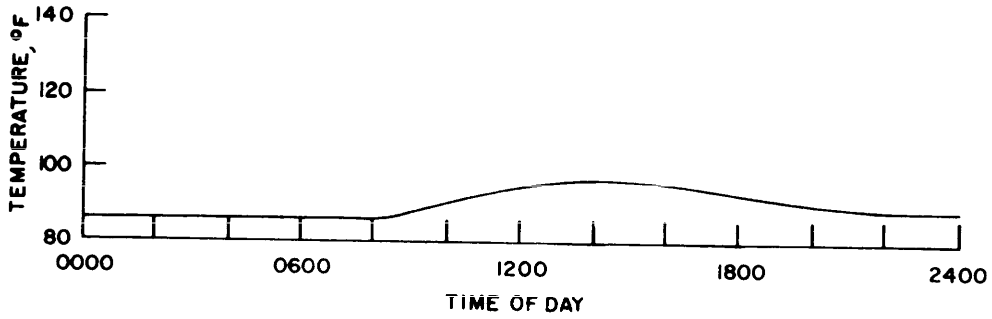

Figure 7. Ship and Aircraft Carrier Storage High Temperature Profile.

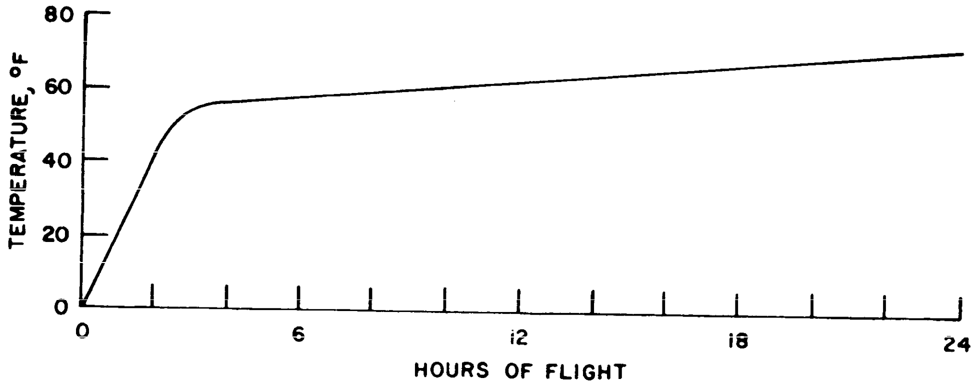

Figure 8. Air Cargo Compartment Low Temperature Profile.
NOTE: At end of flight, compartment temperature will again approach ambient.

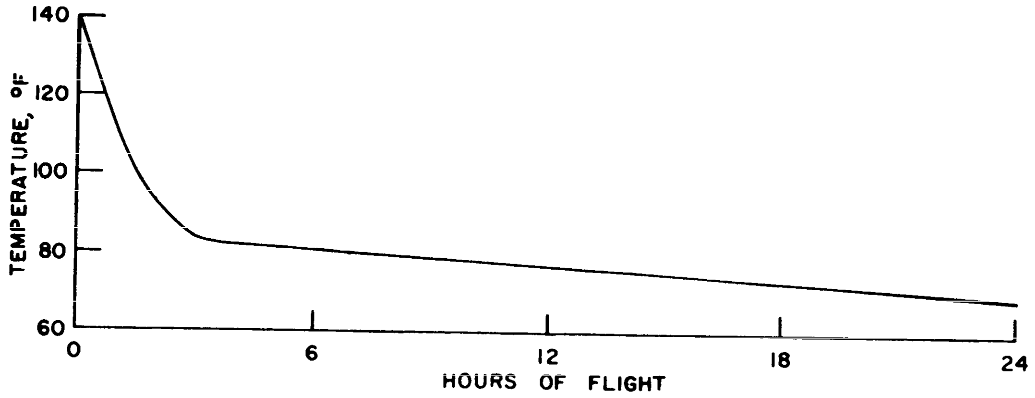

Figure 9. Air Cargo Compartment High Temperature Profile
NOTE: At end of flight, compartment temperature will again approach ambient.

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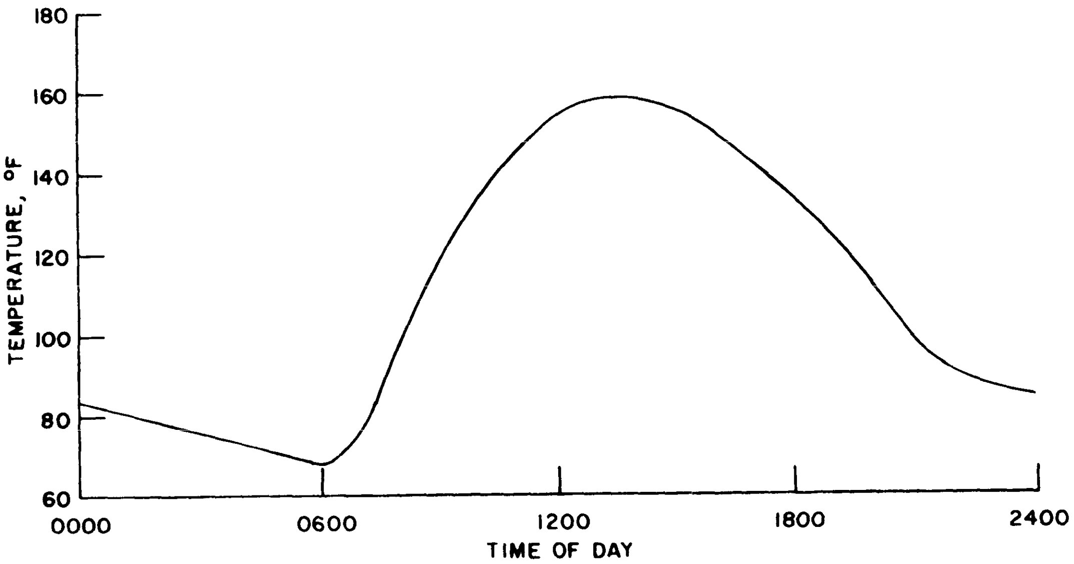


Figure 10. Airfield and Dump Storage Container Inner Wall High Temperature Profile.

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

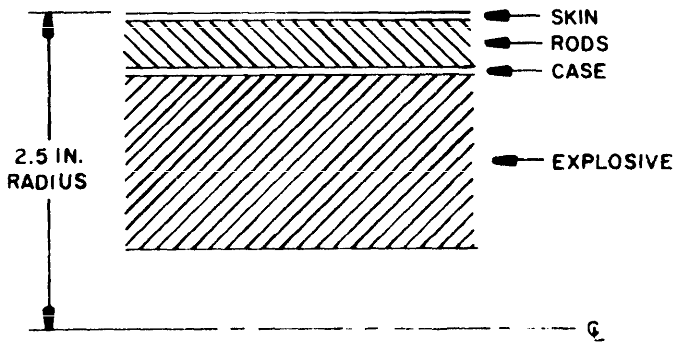
Basic Assumptions

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

(b) Aircraft/missile interference effects neglected

(c) Radiation neglected.

Thermal Model



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Thermal Properties

	Thermal conductivity, Btu/hr-ft-$^{\circ}$R	Density x specific heat, Btu/ft^3-$^{\circ}$R
Skin	30	55
Rods	12	35
Case	80	35
Explosive	0.19	29

Aerodynamic Heating Rate

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

$$q = h\,(T_R - T)$$

where

q = heat flow per unit area, Btu/hr-ft^2

h = aerodynamic heat transfer coefficient, Btu/hr-ft^2-$^{\circ}$R

T_R = recovery temperature, $^{\circ}$R

T = temperature of body, $^{\circ}$R

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

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

$$T_R = T_\infty(1 + 0.17M_\infty^2)$$

and

$$h = 0.332\ k^*/s\ Re_s^{*1/2}\ Pr^{*1/3}$$

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where

$*$ = evaluated at Eckert's reference temperature, T^*

∞ = evaluated at free stream temperature, T_∞

c_p^* = specific heat of air

$$= 0.24\left\{1 + \frac{2}{7}\left(\frac{5{,}550}{T^*}\right)^2 \frac{\exp\,(5{,}500/T^*)}{[\exp\,(5{,}500/T^*)\ -1]^{2}}\right\}\text{Btu/lb-}^{\circ}\text{R}$$

h = local heat transfer coefficient, Btu/ft^2-hr-$^\circ$R

k^* = thermal conductivity of air

$$= \frac{1.529075(10)^{-3}\sqrt{T^*\ 1.8}}{1 + 441.72/\ T^*(10)^{21.6/T^*}} \quad \text{Btu-ft/ft}^2\text{-hr-}^{\circ}\text{R}$$

M = free-stream Mach number

Pr^* = Prandtl number $= \mu^* c_p^* / k^*$

Re_s^* = Reynolds number $= \rho^* V_\infty s / \mu^*$

T_∞ = free-stream temperature, $^\circ$R

T_R = recovery temperature, $^\circ$R

T_w = plate surface temperature, $^\circ$R

T^* = Eckert's reference temperature, $^\circ$R

$$= 0.28T_\infty + 0.50T_w + 0.22T_R$$

V_∞ = free-stream velocity, ft/hr

s = distance from leading edge of plate, ft

μ^* = viscosity of air

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

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P_{∞} = free stream density, lb/ft^3

and

$$P^* = \rho_{\infty} T_{\infty} / T^*$$

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

$$T_R = T \quad (1 + 0.178 M_{\infty}^2)$$

and

$$h = \rho_{\infty} c_{p\infty} V_{\infty} S_t$$

where

S_t = Stanton number $c_f/(2S)$

c_f = local skin friction coefficient

$$= 1/\left\{ F_c \left[2\log_{10}(F_{rx} Re_s) \quad -0.65^{2.3} \right] \right\}$$

$$F_c = \frac{(T_R - T_{\infty})}{T_{\infty} \left[\sin^{-1} (\alpha/\sqrt{\psi}) + \sin^{-1} (\beta/\sqrt{\psi}) \right]^2}$$

$$\alpha = T_R - 2T_{\infty} + T_W$$

$$\beta = T_R - T_W$$

$$\psi = T_R^2 + 2T_R T_W - 4T_{\infty} T_W + T_W^2$$

$$F_{rx} = \frac{(T_R/T_W)^{0.772}}{\left[F_c (T_W/T_{\infty})^{0.702} \right]}$$

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S = Reynolds analogy factor

$$= \frac{0.89 + Pr\,[11.5\ \sqrt{c_f/2}\ \sqrt{T_w/T_\infty}\,]}{1 + 11.5\ \sqrt{c_f/2}\ \sqrt{T_w/T_\infty}}$$

Input Conditions

Three hypothetical flight conditions are considered.

(a) High-altitude cruise (Aerocooling).

(b) Low-altitude attack (aeroheating).

(c) High-altitude supersonic intercept (aeroheating).

The Mach number and altitude profiles associated with conditions (a) through (c) above are shown in Figures 11-13, respectively.

Atmospheric temperature profiles based on MIL-STD-210 should be used in the analysis of the high-altitude-cruise and low-altitude-attack flight conditions. The cold-atmosphere model (Figure 14) should be used with the high-altitude cruise, the hot-atmosphere model (Figure 15) with the low-altitude attack, and the U.S. Standard Atmosphere, 1962, with the high-altitude intercept.

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 paragraph 20.1.1.

Results

Computed warhead temperature response curves for the three flight conditions of interest are given in Figures 16-18.

30. 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,

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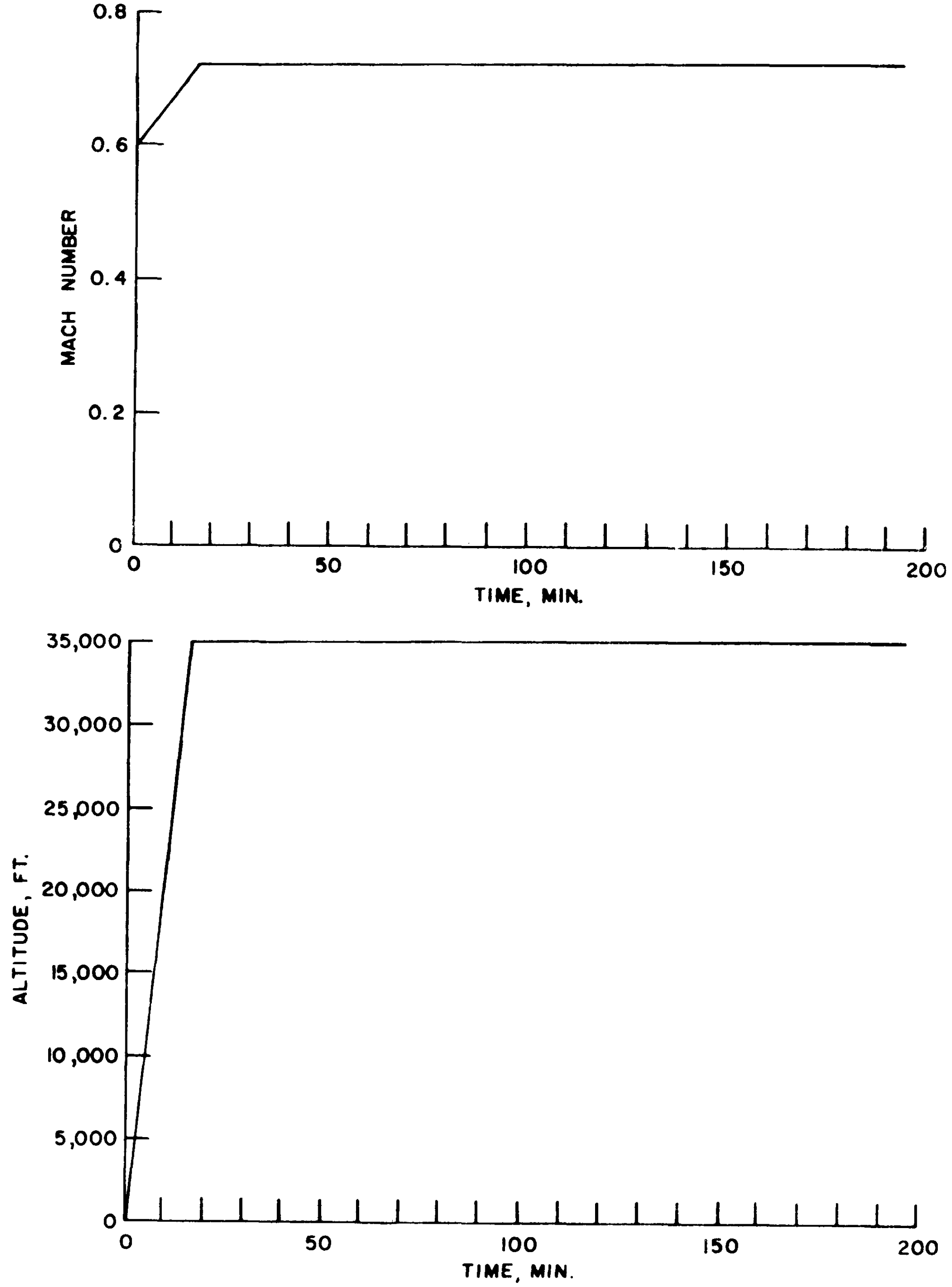

Figure 11. High-Altitude Cruise Profile.

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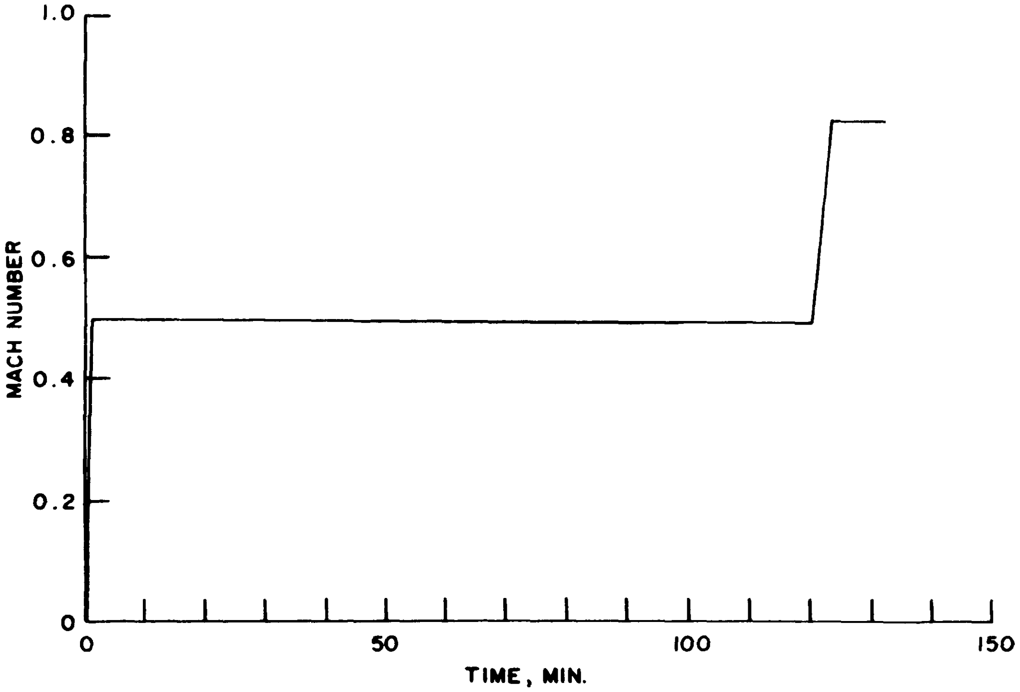

Figure 12. Low-Altitude (Sea Level) Attack Profile.

(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 19 shows an accepted world wide humidity environment.

40. Sand and dirt. The severity of the sand and dirt environment is a function of geography, humidity, temperature, and wind conditions. (See references listed in Appendix F.) The sand and dirt particles are particularly destructive to jet engines, missile seeker domes, control surface 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 dirt 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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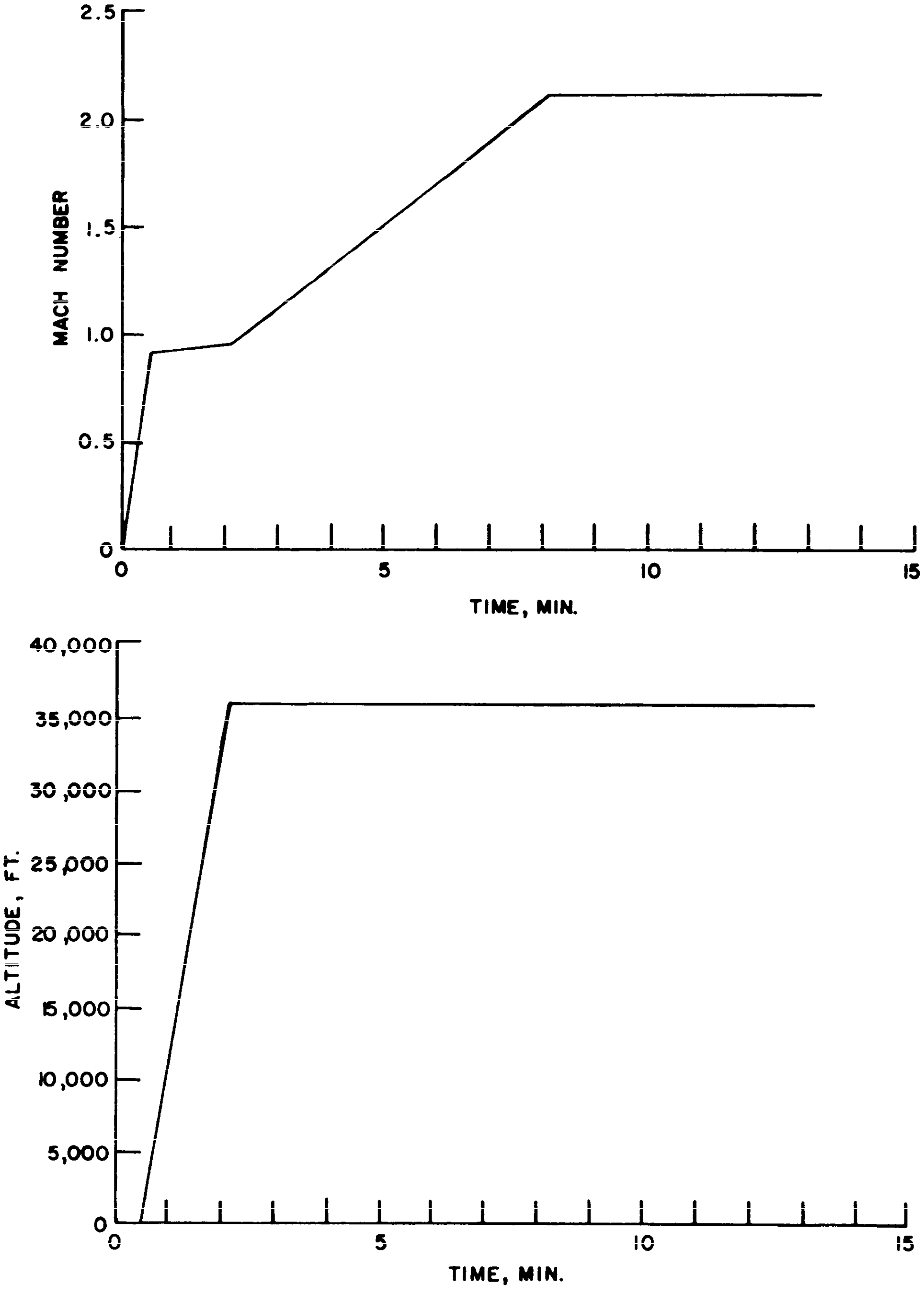

Figure 13. High-Altitude Supersonic Intercept Profile.

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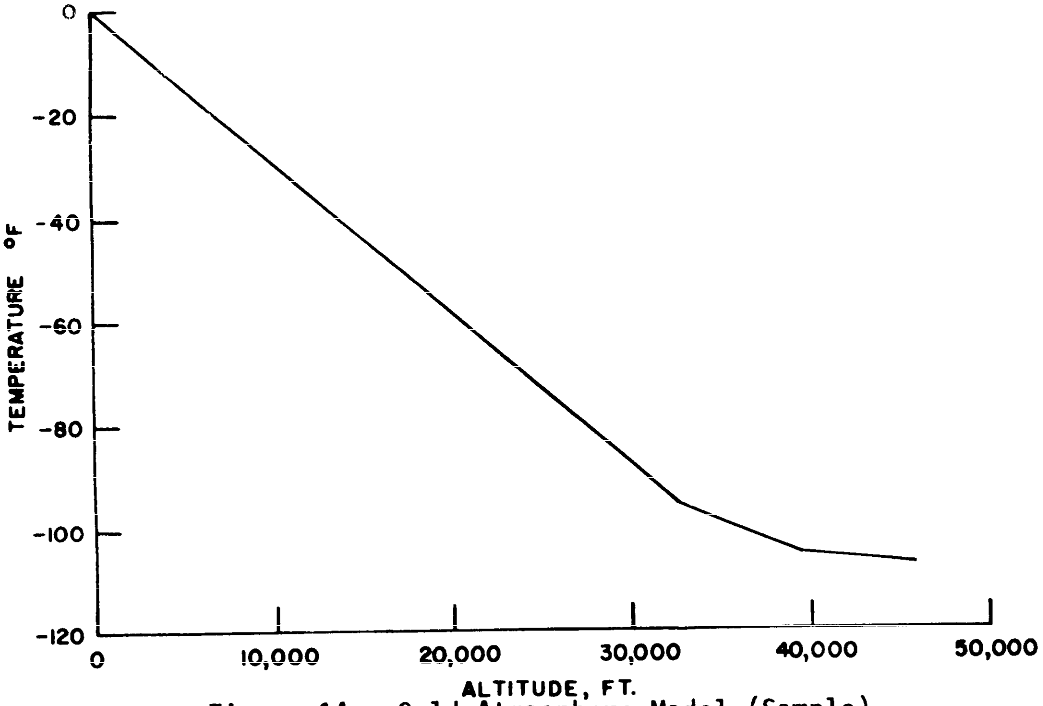

Figure 14. Cold-Atmosphere Model (Sample).

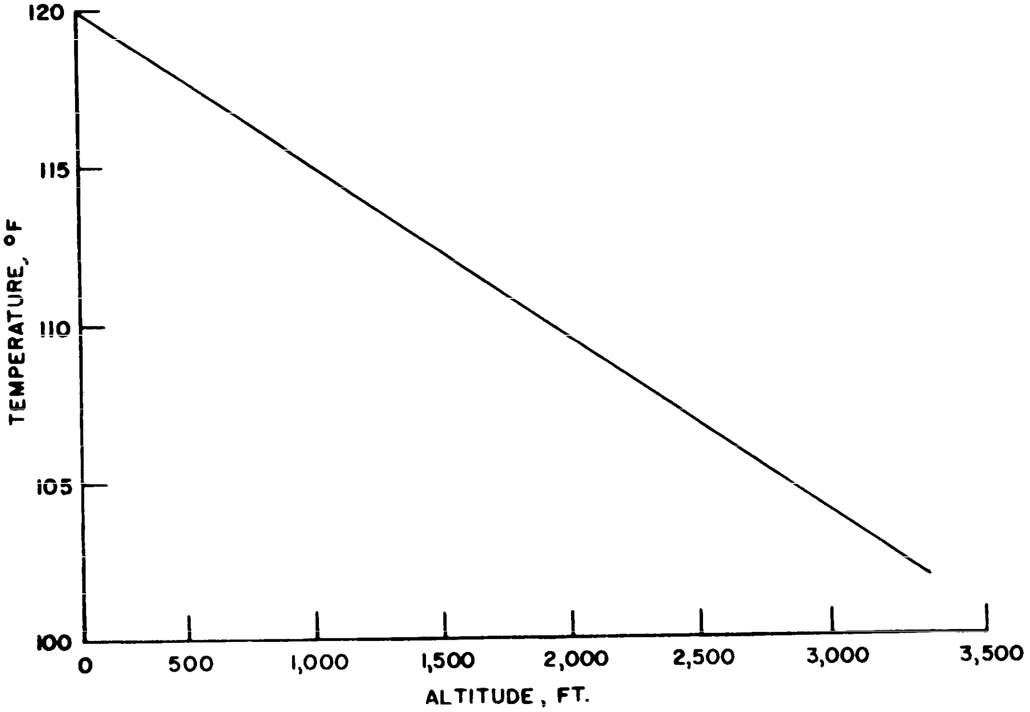

Figure 15. Hot-Atmosphere Model (Sample).

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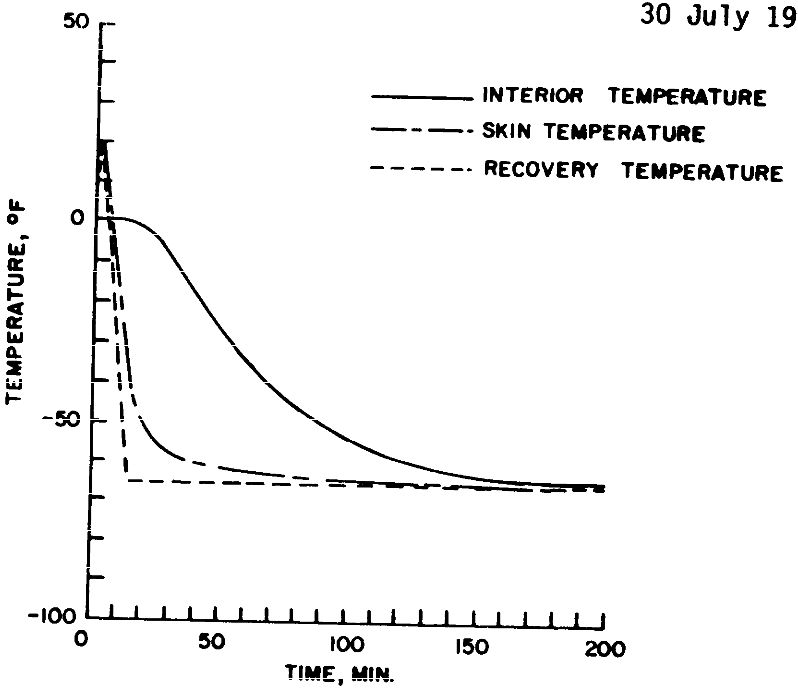

Figure 16. Warhead Temperature Response for High-Altitude Cruise.

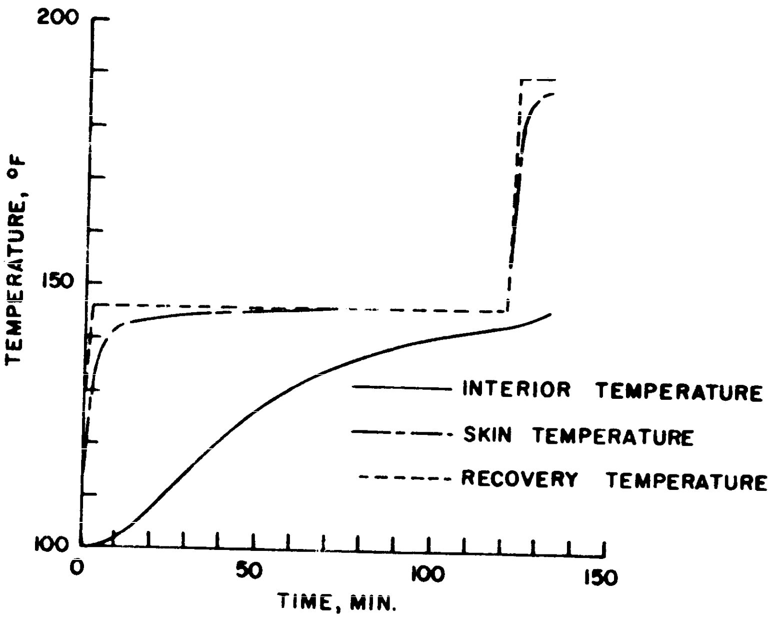

Figure 17. Warhead Temperature Response for Low-Altitude Attack.

ng events of each serialized air launched guidance and control section

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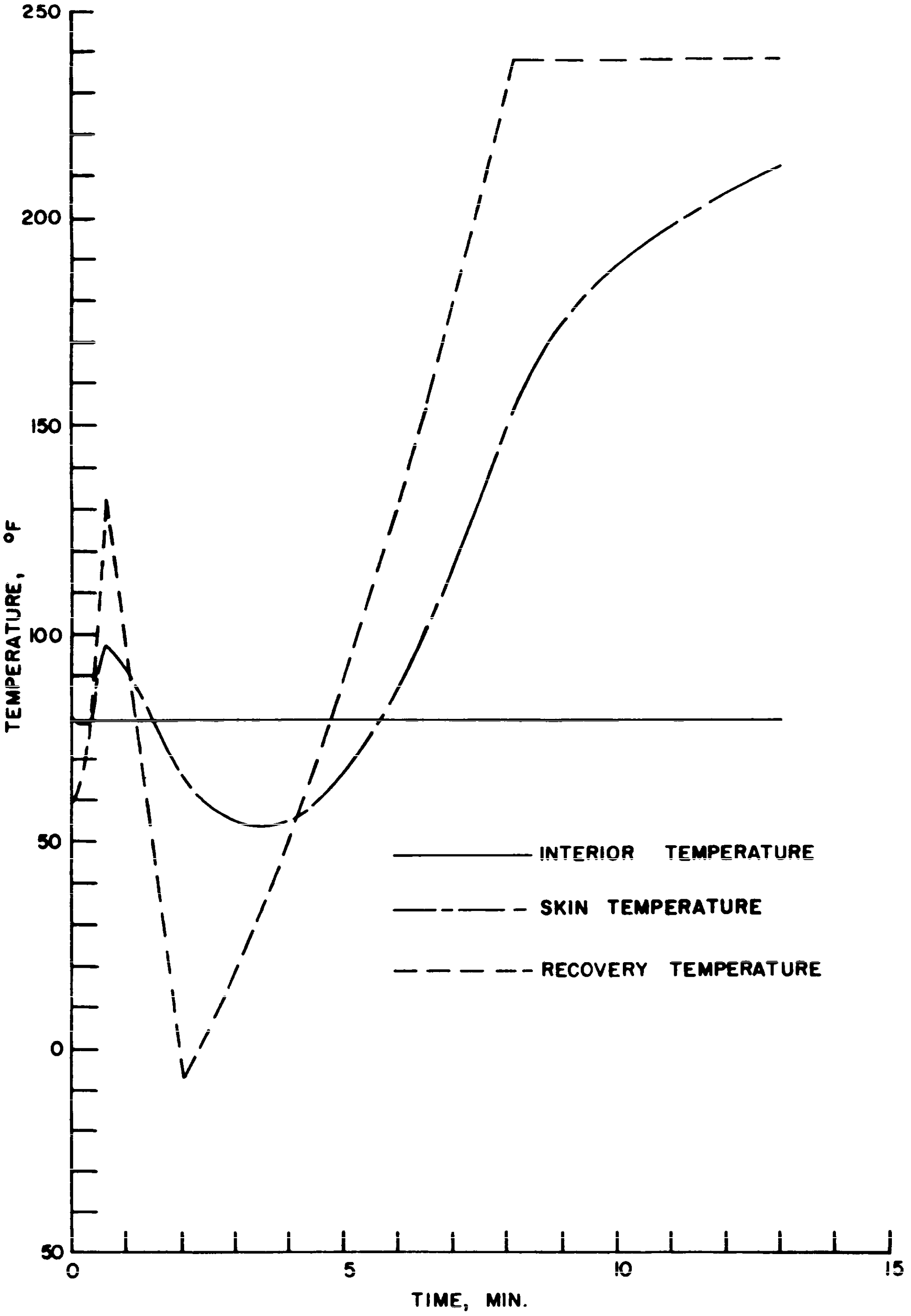

Figure 18. Warhead Temperature Response for High-Altitude Intercept.

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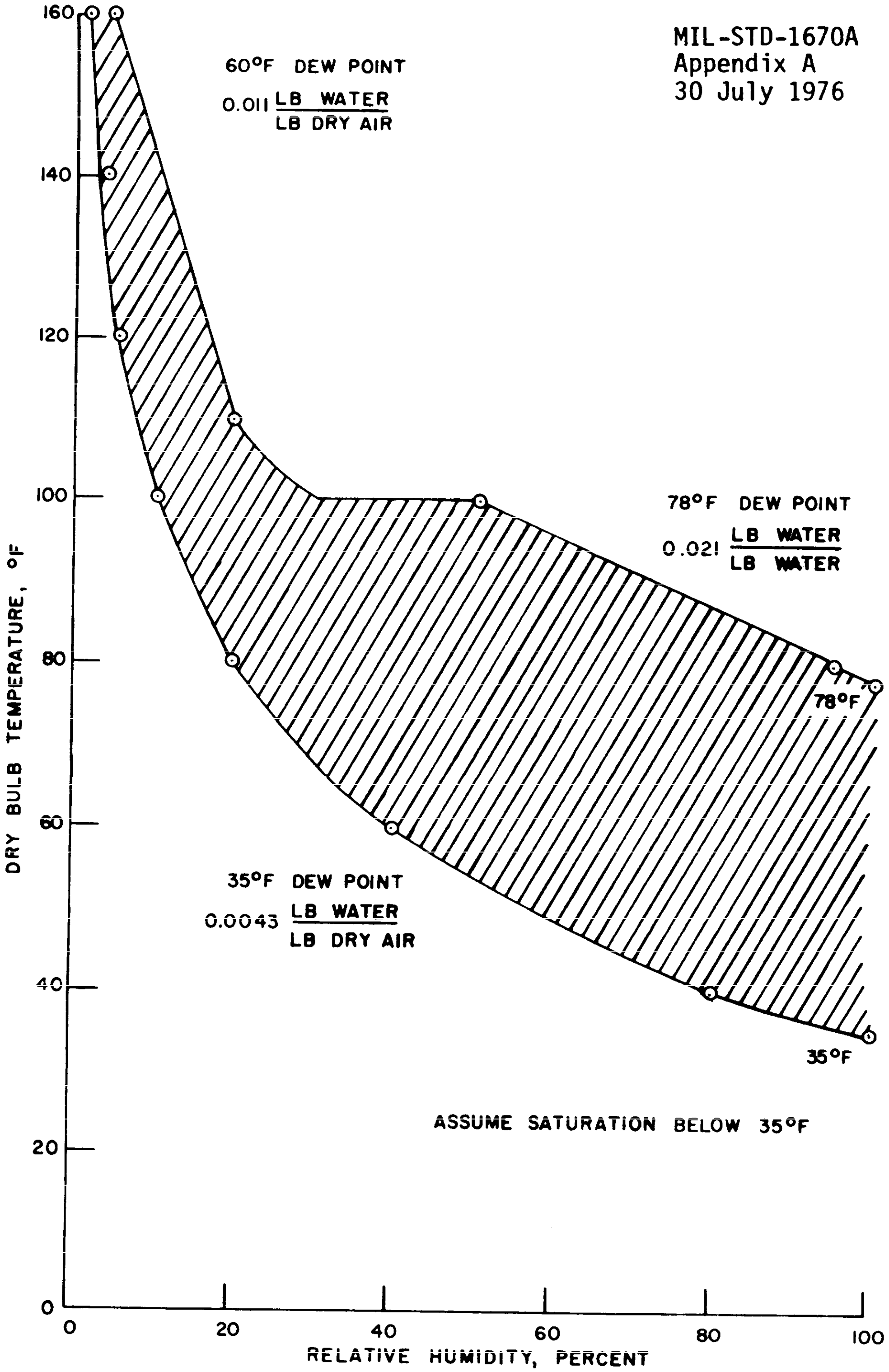

Figure 19. Worldwide Humidity Environment.

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50. Acceleration.

50.1 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-A-8591 should be used as appropriate to carrying aircraft flight conditions.

50.2 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.

60. Shock.

60.1 Transportation shock, truck. The shock inputs to the weapon container during truck transport are initiated by transit across such road hazards as bumps, chuckholes, and railroad tracks. Values of 3.5 g, 25 to 50 milliseconds, half-sine pulse are typical for this environment.

60.2 Transportation shock, rail. The shock inputs to the weapon containers during rail transport are initiated during assembly and disassembly (humping) of the train and during rapid or emergency stop. Typical values for this environment are 25 g, 25 ms, half-sine.

60.3 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.

60.4 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 1/2	In container: safe and no degradation of performance Out of container: safe for damage inspection
1 1/2 - 10	Safe in or out of container for return to work
10 - 40	Safe in or out of container for immediate disposal

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60.5 Underway replenishment. The weapon is subjected to shocks during underway replenishment. Two methods of underway replenishment are vertical replenishment by helicopter and direct high-line transfer from the AE/AOE. The maximum transfer line velocity is 10 ft/sec; hence impact against steel plates at velocities up to 10 ft/sec are possible. This impact is equivalent to a drop of about 19 inches.

60.6 Airfield/aircraft carrier handling. Airfield/aircraft carrier handling shocks are initiated by excursions across bumps, obstacles, and irregularities on the hangar deck, flight deck, elevators, magazines, and airfield. Obstacles include arrestment cables, tie-down rings, ground power cables or cable shields, and elevator/deck interface discontinuities. Normally, weapons are transported on the AERO-21 handling skid, a rigid-frame trailer with hard rubber wheels and no shock mitigation devices to protect the weapon from shocks incurred in transit. Typical values for this environment are 15 g, 75 ms, half-sine.

60.7 Shock, captive carry. Captive carry shock is induced by catapult takeoff and arrested landing. The shock caused by catapult and arrestment should be part of the captive flight environmental measurement program. Typical values are 25 g, 20 ms, half-sine, positive and negative in the lateral axis, and 6 g, 25 ms, half-sine, positive in the vertical axis. 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.

60.8 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 20 and 21 present typical shock and shock spectrum 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 to stay within these limits.

70. Vibration.

70.1 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 vibrations depends on the type of truck used, the load condition of the truck, and the skill of the operator. Figure 22 shows typical vibration levels for this environment.

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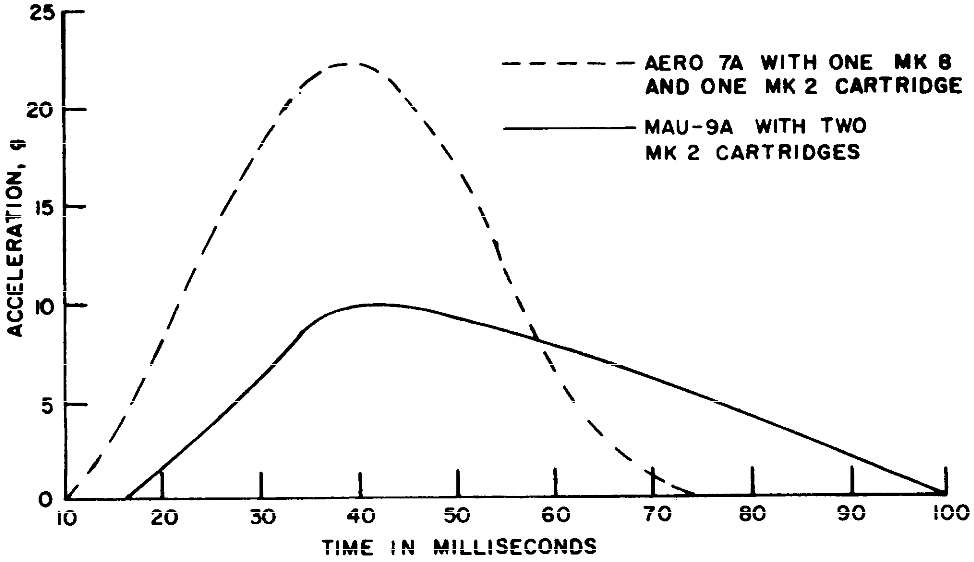

Figure 20. Acceleration Versus Time for AERO-7A and MAU-9A Racks Separating a 1,200-Pound Store. (Zero time is cartridge fire time. The final ejection velocity required for safe separation determines which curve will apply to the weapon.)

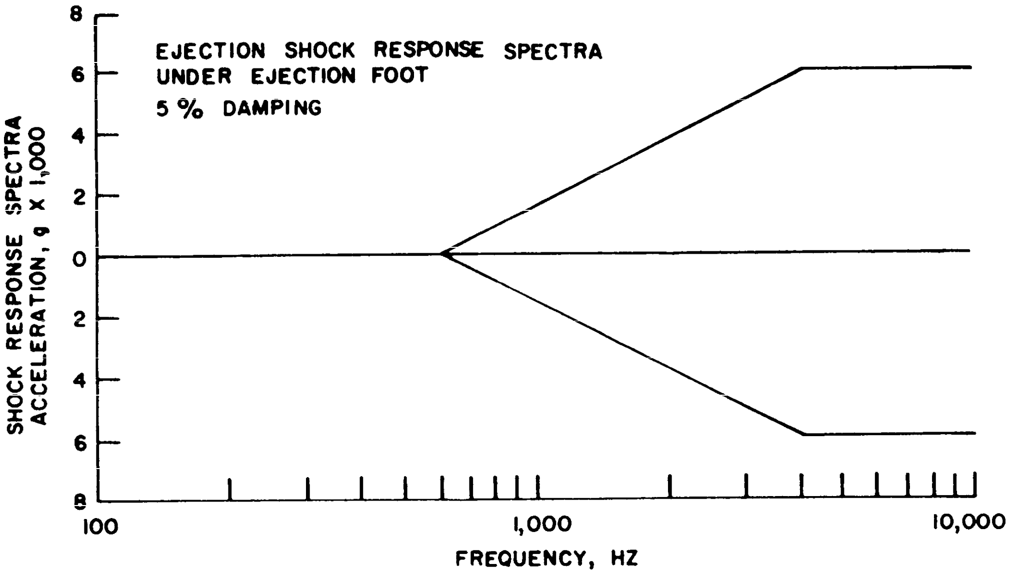

Figure 21. High Acceleration, Short Duration Ejection Shock Spectra AERO-7A and MAU-9 Ejection Racks Using One Mk 8 and One Mk 2 Cartridge

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70.2 Transportation vibration, rail. The weapon is packaged or containerized during transportation by rail; hence the vibration is input to the container or package. Vibration during rail transportation is caused by the passage of the railcar over rough rail bed. In addition, starting, stopping, and train makeup and disassembly (humping) induce high transient vibration levels. Figure 23 shows typical vibration levels for this environment.

70.3 Transportation vibration, ship. The weapon is packaged or containerized during transportation by ship; hence the vibration is input to the container or package. The vibration experienced by the weapon 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 vibrations 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 must be considered. Figure 24 shows typical values for this environment.

70.4 Transportation vibration, aircraft. The weapon is packaged or containerized during transportation by aircraft; hence the vibration is input to the container or package. The vibrations in the aircraft caused by aerodynamic loads, rotating equipment, and runway roughness during takeoff and landing are transmitted structurally; vibrations caused by the jet engine exhaust are transmitted acoustically. Figure 25 shows typical values for this environment.

70.5 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 vibrations are random in nature and are characterized by their statistical properties. Some of the forcing functions that induce random vibrations 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.

70.6 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) vibrations 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, and shock wave impingement.

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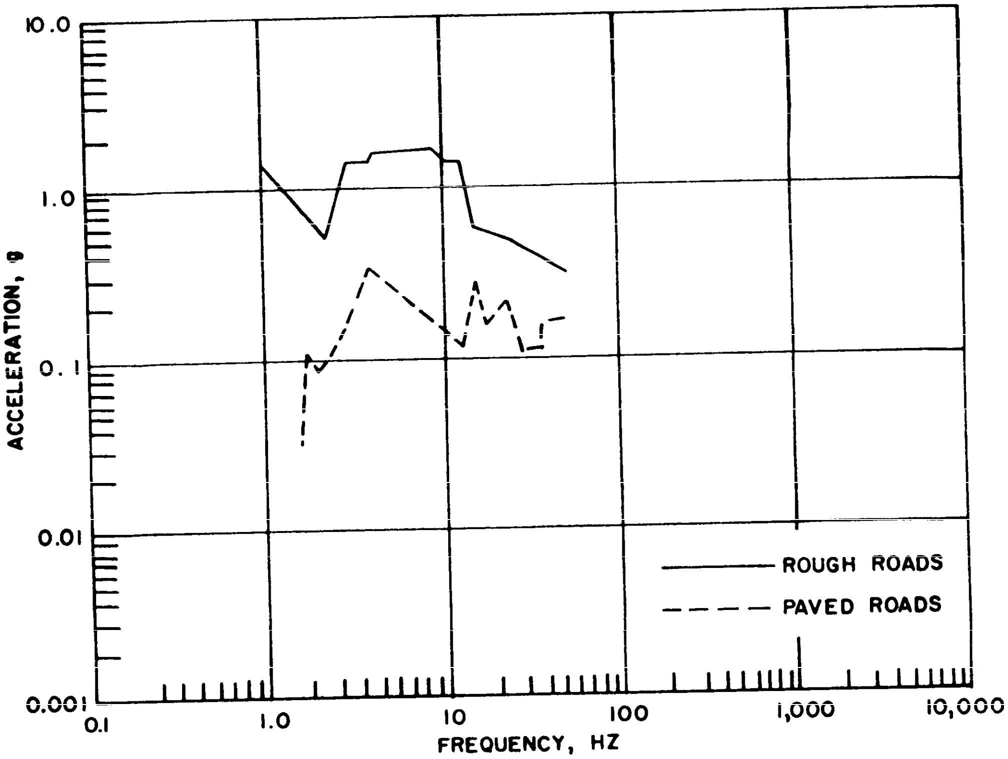

Figure 22. Truck Transportation Vibration Envelopes.

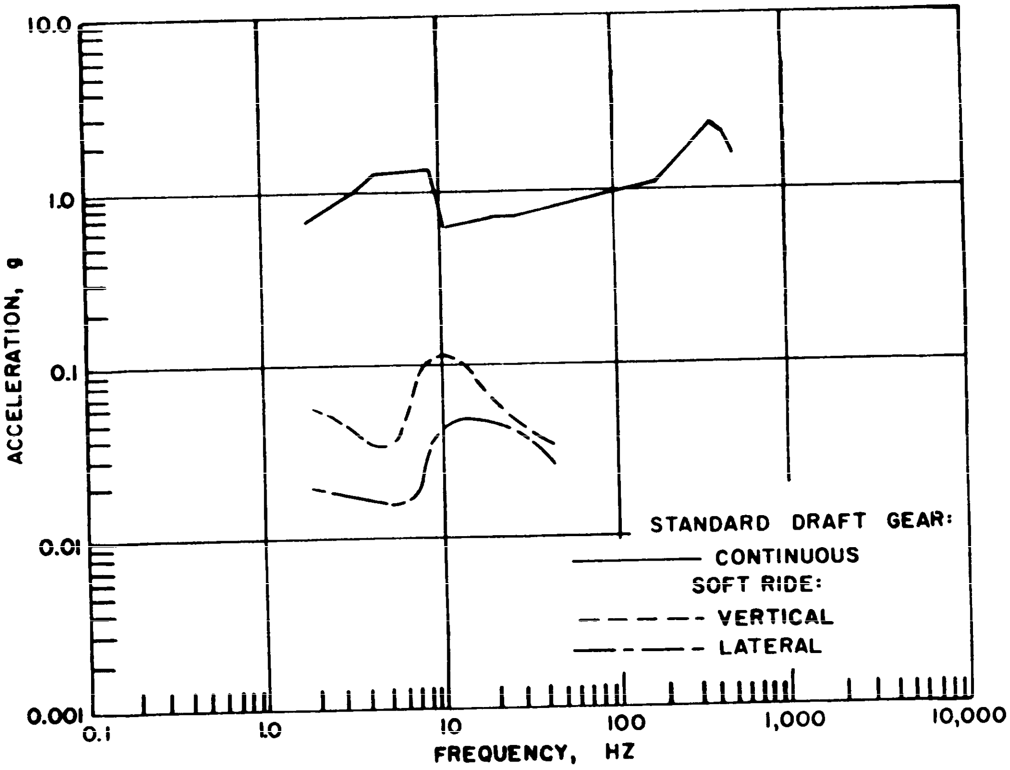

Figure 23. Railroad Vibration Envelopes.

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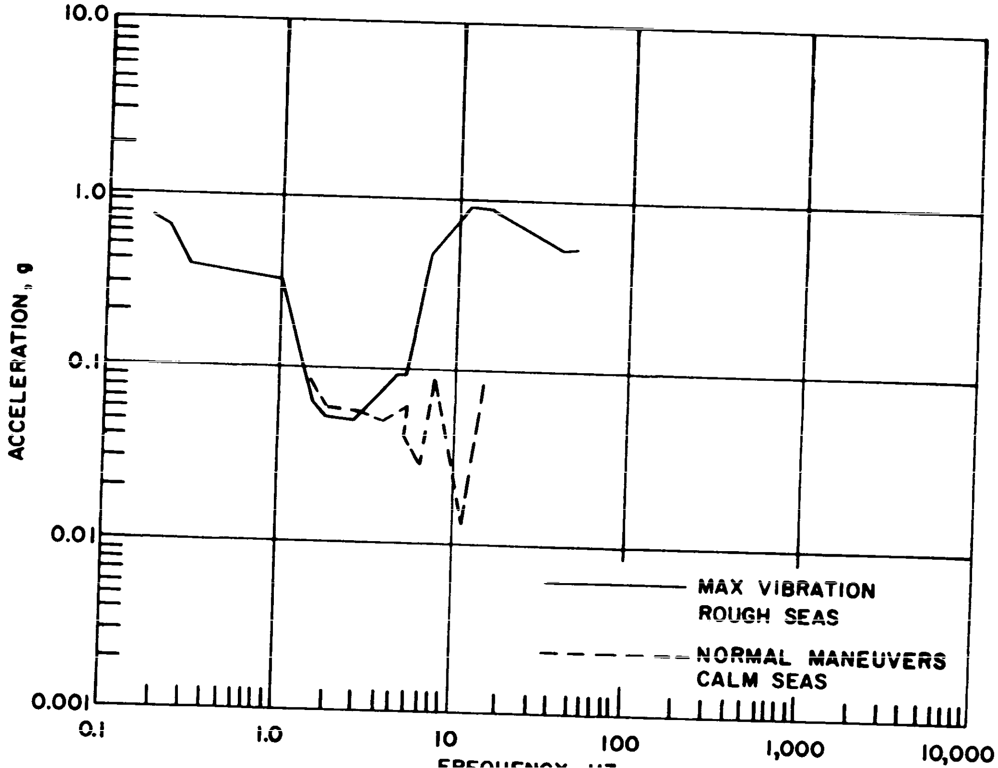

Figure 24. Ship Vibration Envelopes.

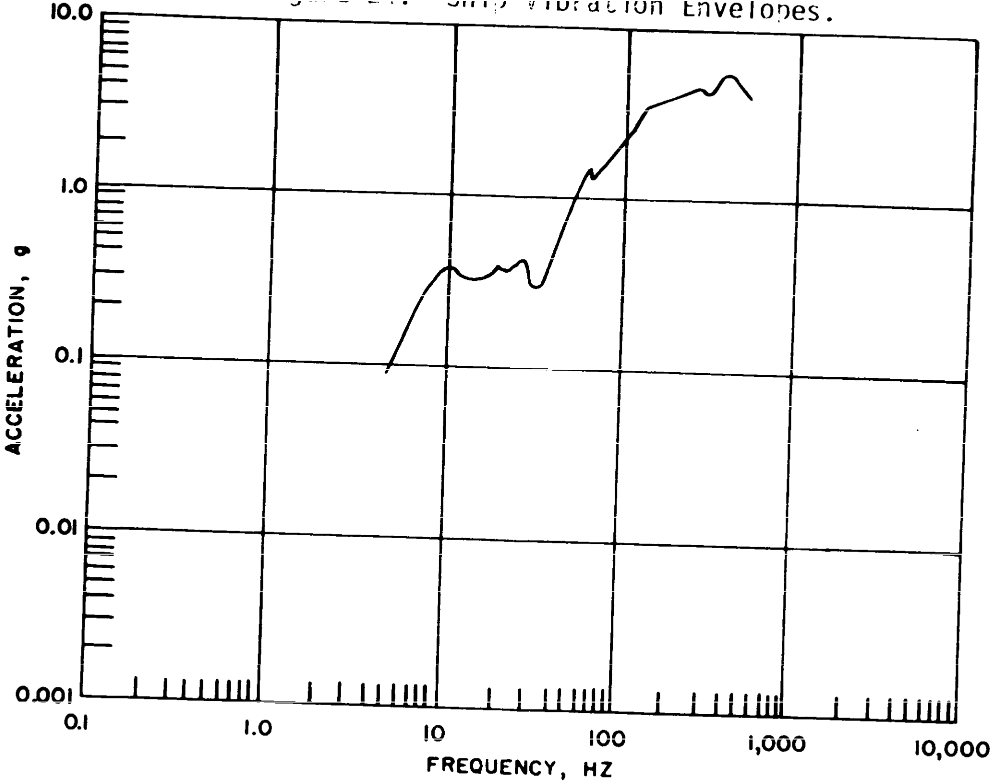

Figure 25. Vibration Envelope of Jet, Turboprop and Propeller Aircraft Cargo Area.

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The random vibrations are 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.

70.7 Captive flight vibration, helicopter. The vibrations induced are 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 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 of multiples thereof. The number of anticipated captive carries must be determined in order to develop the duration of exposure to these forcing functions.

70.8 Vibration, on board aircraft. The vibration environment experienced by the weapon mounted on board aircraft is dependent on the class of aircraft, mounting location on the aircraft, and the flight dynamic limitations of the carrying aircraft. In the absence of flight data and as a first approximation to the appropriate vibration levels, the methods of MIL-STD-810 may be used.

70.9 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 multibarrel automatic guns is an extremely intense short term environment. The vibrations are 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 vibrations in the higher frequency ranges. These phenomena result in vibrations that are a mix of complex periodic vibrations 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 are used to calculate the power spectral density plot, and the high-frequency random vibration portion.

70.10 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 thrusting of the propulsion unit. The vibrations are random in nature and are characterized by their statistical properties. MIL-STD-810 can be used to calculate approximate vibration levels.

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70.11 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 of MIL-STD-810.

80. Sample data display matrix. A method of presenting environmental design criteria is shown in Tables I - IV. When displayed in this manner, all major events, corresponding environments, and weapon status in the factory-to-target sequence are noted. The numbers given in the data display matrix are for illustration purposes only.

80.1 Transportation. The weapon shall perform as required in the development specification subsequent to the missile and container being subjected to the environments listed in Table I.

80.2 Storage, handling, and underway replenishment. The weapon shall perform as required in the development specification after the weapon (in its container) has been subjected to the environments defined in Table II.

80.3 Airfield and aircraft carrier storage, and handling. The weapon shall perform as required in the development specification after the weapon (in its shipping container) has been subjected to the storage environments specified in Table III. The weapon shall perform as required in the development specification after being subjected to the handling environments (with weapon out of the container) as specified in Table III.

80.4 Captive and free flight. The weapon shall perform as required in the development specification, while being subjected to the environments specified in Table IV.

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TABLE I. Transportation Environmental Criteria.*

ENVIRONMENT/EVENT	TRANSPORTATION			
	Truck	Rail	Ship	Air (Flight)
Air Temp/Time (high)	Fig. 1	Fig. 1	Fig. 3	Fig. 5
Air Temp (low)	Fig. 2	Fig. 2	40°F for 24 hrs	Fig. 4
Relative humidity	Fig. 12	Fig. 12	Fig. 12	Fig. 12
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 1/2 hr	250 mm/hr for 1/2 hr	250 mm/hr for 1/2 hr	NA
Corrosion rates	Negligible (time dependent)	Neg[illegible] ([illegible] [illegible]c)	Negligible (time dependent)	Negligible (time dependent)
Sand dust (Para 6.3.3)	45 knot wind .015 to 3.2 mm dia particle size	[illegible]low wind [illegible]5 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 vert	Negligible
Vibration (peak values)	Fig. 8	Fig. 9	Fig. 10	Fig. 11
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. (Para 6.2)
Fungus	Use non-nutrient materials only			

← MISSILE IS IN SHIPPING CONTAINER →

SAMPLE

*Table for illustration only.

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TABLE II. Storage, Handling Environmental Criteria.*

SAMPLE

ENVIRONMENT/EVENT	STORAGE			At Sea Transfer
	Igloo	Covered	Dump	
Air Temp/Time (high)	100°F for 24 hrs	Fig. 1	Fig. 6	Fig. 7
Air Temp/Time (low)	0°F for 72 hrs	-10°F for 72 hrs	-40°F for 72 hrs	30°F for 24 hrs
Relative humidity	Fig. 12	Fig. 12	Fig. 12	Fig. 12
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 1/2 hr	Negligible
Corrosive rates	0.1 in. of HRS/yr	0	0.1 in. of HRS/yr	Negligible (time dependent)
Sand and dust (Para 6.3.3)	Negligible	[illegible]t wind [illegible] to 3.2 mm [illegible]a 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		

← MISSILE IS IN SHIPPING CONTAINER →

*Table for illustration only.

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TABLE III. Airfield and Aircraft Carrier Storage and Handling Environmental Criteria*

SAMPLE

ENVIRONMENT/EVENT	AIRFIELD		AIRCRAFT CARRIER	
	Storage	Handling	Storage	Handling
Air Temp/Time (high) (1)	Fig. 6	140°F for 2 hrs	Fig. 3	110°F for 2 hrs
Air Temp/Time (low (1)	-40°F for 72 hrs	-40°F for 72 hrs	40°F for 24 hrs	30°F for 24 hrs
Relative humidity	Fig. 12	Fig. 12	Fig. 12	Fig. 12
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 [illegible] hr	NA	None
Snow	250 mm/hr for 1/2 hr	250 mm/hr [illegible] 1/2 hr	NA	None
Corrosion rates	0.1 in. of HRS/yr	Ne[illegible] [illegible]dent)	0.1 in. of HRS/yr	Negligible (time dependent)
Sand and dust (Para 6.3.3)	45-knot wind .015 to 3.2 mm dia particle size	[illegible] wind [illegible] to 3.2 mm [illegible]a particle size	NA	NA
Acceleration loads	NA	NA	NA	NA
Shock	NA	15 g for 11-18 ms half sine wave	80 g, 4 ms vert	15 g for 11-18 ms half sine wave
Vibration	NA	Negligible	Refer to Fig. 10	Negligible
Electromagnetic environment	To be determined			
Acoustic	Negligible	Negligible	Negligible	Negligible
Fungus	Use non-nutrient materials			
	← MISSILE IN SHIPPING CONTAINER →	← MISSILE OUT OF CONTAINER →	← MISSILE IN CONTAINER →	← MISSILE OUT OF CONTAINER →

*Table for illustration only.

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TABLE IV. Captive and Free Flight Environmental Criteria*

ENVIRONMENT/EVENT	ABOARD AIRCRAFT	
	VA	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 h4	-3°F for 5 min
Relative humidity	Fig. 12	Fig. 12
Rain	Aircraft flight limitations	Aircraft flight limitations
Ice and hail	Aircraft flight limitations	Aircraft flight limitations
Snow	Aircraft fligh[illegible] limitation	Aircraft flight limitations
Corrosion	Negligib[illegible]	NA
Sand and dust (Para 6.3.3)	.015 [illegible] di[illegible] size, [illegible] elative	NA NA
Acceleration	Fi[illegible] 27 and 28	
Shock	15 g for 20 ms ± long, + vert	Fig. 13 & 14
Vibration	Fig. 15 through 25	Fig. 15 through 25
Electromagnetic environment	Appendix A To be determined	
Acoustic	Fig. 26	Fig. 26
Gun blast	2 psi, plane wave 1 ms duration	NA
Ignition shock	NA	Half sine
Altitude		

|←—— MISSILE OUT OF CONTAINER ——→|

SAMPLE

*Table for illustration only.

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APPENDIX B

USE OF ENVIRONMENTAL DATA IN DEVELOPMENT TEST PLANS

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

10.1 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 EPR. The environmental test plan developed includes;

(a) Tests reflecting the environments and parameters in the environmental profile report and environmental design criteria document.

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

(c) Required functionability of the test item during and following the environmental test.

(d) Detailed failure criteria and disposition instructions.

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

20.1 Captive flight dynamic environment, high-performance aircraft. The principal forcing function of the captive flight vibrations is the fluctuating pressures 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.

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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.

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

20.2.1 Aerodynamic heating. When the aerodynamic heating environment is specified in the environmental test plan as a specific test or as part of a combined test, care must be taken in specifying the skin temperature/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.

20.2.2 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. All other surfaces receive less than the maximum heat. 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.

30. Choice of environmental test parameters. Laboratory test levels are converted from the parameters and profiles in the environmental design criteria document. Number of occurrences and test durations are based on the factory-to-target sequence, the use requirement for the weapon, and operational information on similar weapons (see Appendix E). The wide diversity of factory-to-target sequences is illustrated in the following.

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(a) A typical air-to-air missile may be subjected to as many as 600 captive-flight hours, 400 catapult takeoff and arrested landing shocks, and 10 excursions through the transportation, storage and repair cycle prior to being expended or removed from service.

(b) A 1,000-pound bomb normally experiences 1 hour of captive flight, one catapult takeoff, no arrested landings, and one excursion through the transportation and storage portion of the factory-to-target sequence before being expended.

30.1 Time compression. 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.

40. Dynamic test fixturing, control, analysis, and instrumentation.

40.1 Fixturing. 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 situations that require different approaches are these:

(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/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.

40.2 Control and measurement points. 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.

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(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 analysis of the structure, input fixture, and vibration levels.

40.3 Instrumentation and analysis. The environmental test plan should detail the instrumentation, accuracies, 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/dry bulb temperatures.

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

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APPENDIX C

DESIGN USE OF ENVIRONMENTAL DATA

10. Scope. This appendix illustrates some of the uses of environmental data in the design evolution of weapons.

10.1 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.

20. Design verification tests. During the preliminary phases 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.

30. Thermal environment. The thermal environments encountered in the weapon factory-to-target sequence are presented in time/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.

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(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.

30.1 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 (should be concurrent with the structural analysis effort).

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

40. 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 fuzing devices.

(c) Degradation of electronic packaging (such as broken printed circuit boards, broken leads on devices).

(d) Momentary discontinuities in connectors, relays, and switches.

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

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(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 strapdown inertial guidance schemes.)

50. 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 conjunction with a laboratory modal vibration study.

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

60. 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 vibrations. For design purposes the container and hardware are considered as a unit and the transmissibility characteristics of the container/weapon are established at various temperatures. When these transfer characteristics are determined, the weapon response to shocks and vibrations is calculated and included in the load analysis document.

70. 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 (humidity, corrosion, fungus) that degrade the weapon materials.

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APPENDIX D

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

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

10.1 Introduction. A captive- or free-flight environmental measurement program will 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 environmental design criteria document.

20. Data required. Specific data requirements should be determined from the EPR. The minimum data acquisition program should cover:

(a) Vibration

(b) Temperature

(c) Acceleration

(d) Acoustics

(e) Shock

20.1 Data acquisition devices. A typical instrumentation system for measuring, acquiring, and processing captive- or free-flight environmental data is shown in Figure 26.

30. 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

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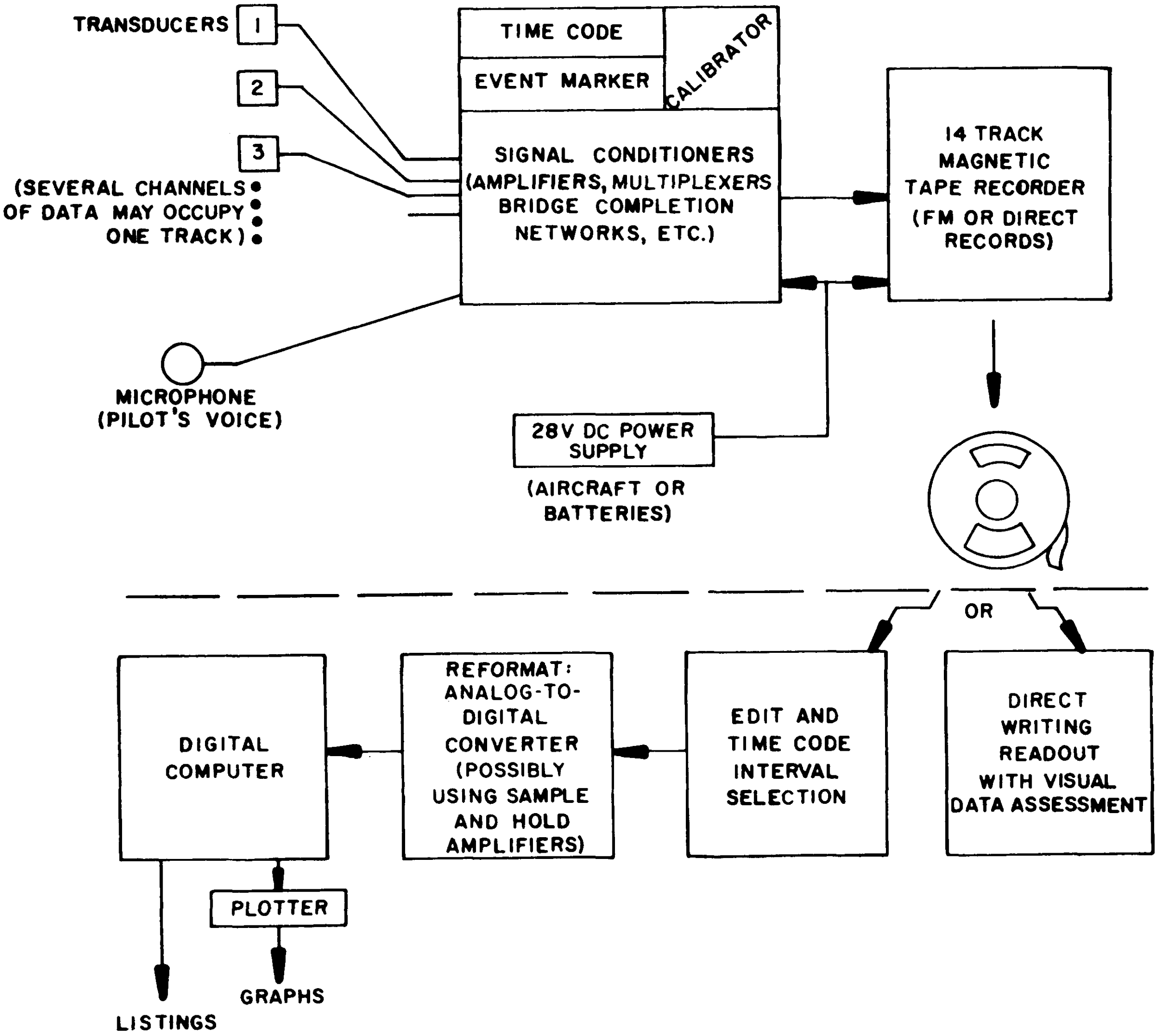

Figure 26. Typical Instrumentation System.

30.1 Accelerometers. Accelerometers are used to measure response vibrations. The accelerometers can have errors associated with improper mounting methods, temperature and acoustic effects, cable motions, and accelerometer mass loading effects. The useful frequency response is from 0 to 5,000 Hz, depending on the specific type. Accuracy of the accelerometers is ±5 percent.

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30.2 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.

30.3 Microphones. Microphones are high-frequency pressure transducers used to measure the acoustic environment in a weapon section or on the weapon surface. Errors can be caused by temperature, vibration, and ambient pressure changes.

30.4 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 nonlinear.

40. Signal conditions. 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, adequate frequency response, and stability under real environmental operating conditions and packaging constraints. The signal conditioner conforms to IRIG Telemetry Standard 106.

50. Magnetic tape recorders. Magnetic tape recorders conform to IRIG Telemetry Standard 106. Data are usually recorded in some code or modulation, with several channels of data combined on one tape track for greater efficiency. In addition to the data, a reference signal is recorded to enhance subsequent data processing using tape compensation techniques at a ground facility. Prior to use airborne recorders are carefully evaluated under realistic operating environmental conditions.

60. System calibration. Calibration of the total system shall be completed prior to any field measurement. The total system includes transducers, signal conditioners, tape recorder, and wiring. The system calibration determines the frequency response of each channel.

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70. Weapon/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

80. Analysis. Analysis of the measured environmental data includes:

(a) Filtering or scaling

(b) Transformation to the frequency, time, or amplitude domain

(c) Conversion from analog to digital or digital to analog the techniques range from visual examination of oscillograph records to implementing sophisticated Fourier transform techniques with a digital computer.

90. 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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APPENDIX E

OPERATIONAL USE DATA

10. 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.

10.1 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 residences and time spent in each residence for a specific air-to-air missile, SPARROW III AIM-7E/7E-2, is presented as an example of the type of information needed.

20. 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, 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 check-out performed on board attack aircraft carrier (CVA), at Naval Weapons Station (NWS), or at Naval Air Rework Facility (NARF).

(c) The number of captive flights, number of captive flight hours, and number of catapults and arrestments.

20.1 FAC sample data. An example of a computer run performed by FAC shows the type of information that can be developed from this source.

(a) FAC data on a subsample of 174 SPARROW III AIM-7E/7E-2 missiles were analyzed to determine the probable number of days each missile spent in NWS or overseas storage, in surface transportation (rail or truck), on an ammunition ship (AE), and on a CVA.

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(b) The data on the 174 missiles included the NWS factory acceptance test date of each TSG/FCG (target seeker group/flight control group) unit, the firing data and location, and dates of test and captive flights at successive locations between 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 days elapsed between the last record at the first location and the first record at the second location were 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/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 (2) above, the number of days of surface (rail or truck) and/or AE transportation 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 at the second activity; the result was divided by two and added to the time at each of the two activities as in (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.

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(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 in Figures 27-32. These statistics are summarized in Table V.

20.2 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 limitation in different store mix configurations. Some of the possible sources for this information are

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

(b) OPEVAL/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.

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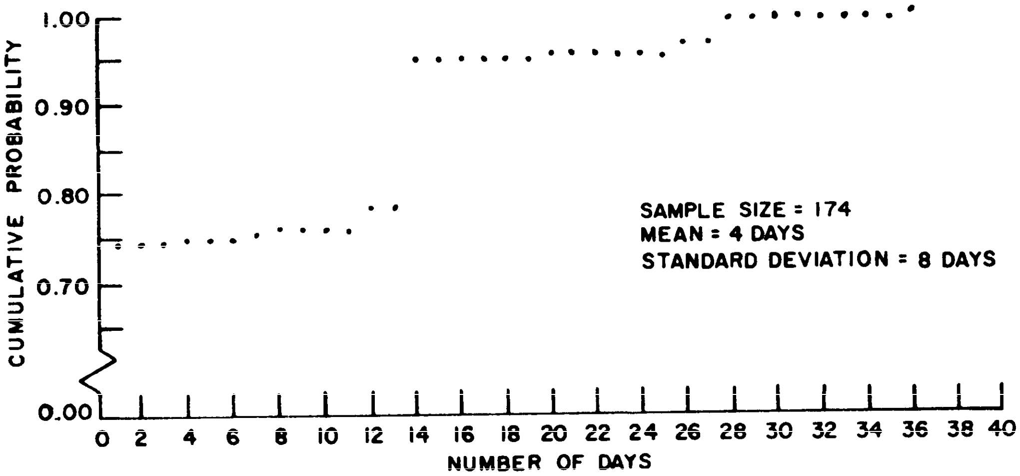

Figure 27. SPARROW III AIM 7E/7E-2 Time in Rail/Truck Transportation

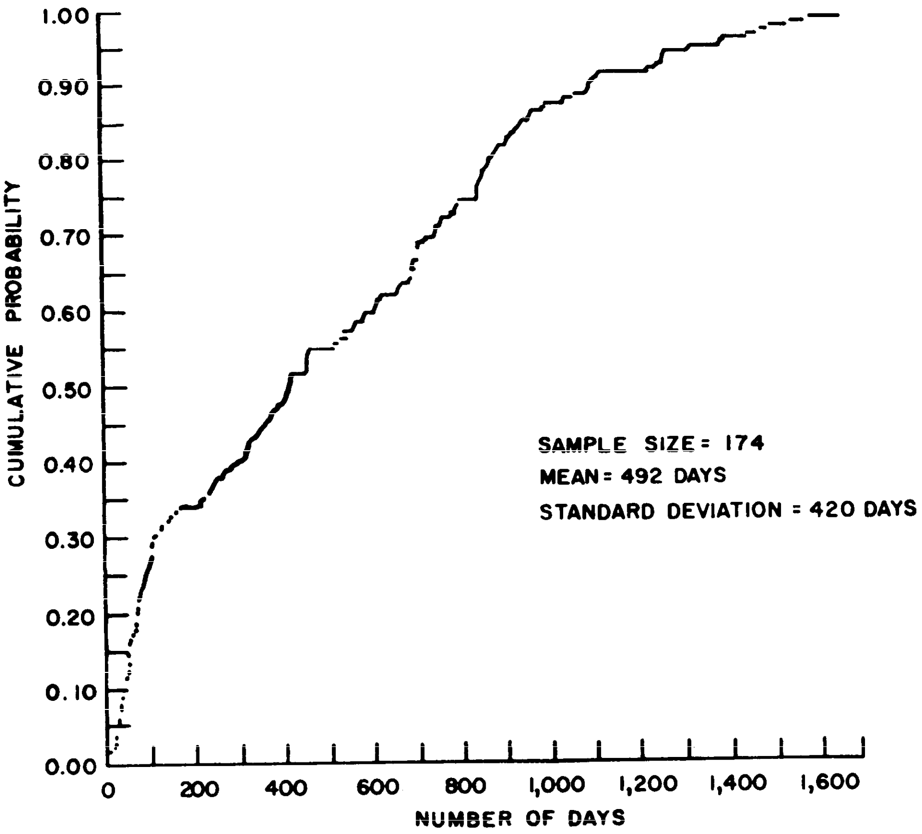

Figure 28. SPARROW III AIM 7E/7E-2 Time at Naval Weapons Station

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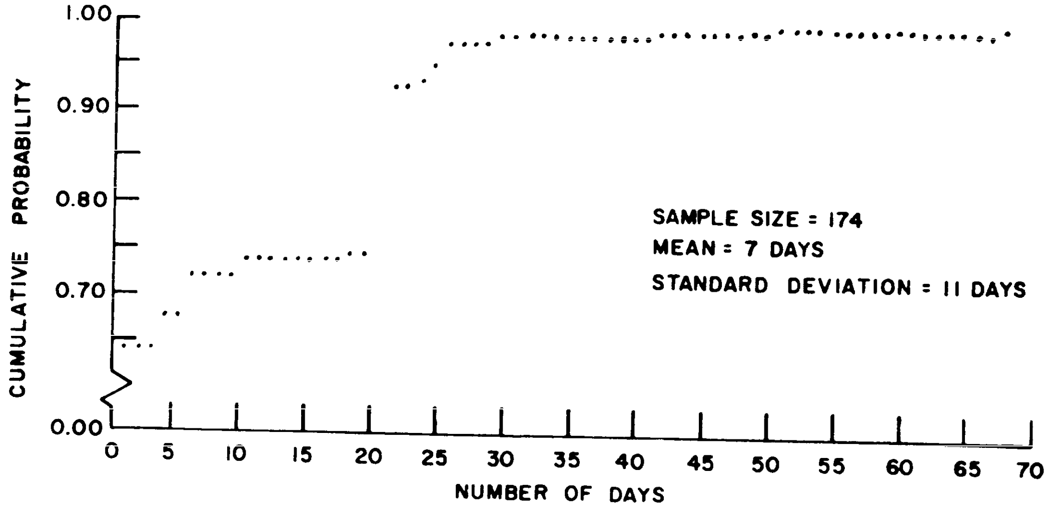

Figure 29. SPARROW III AIM 7E/7E-2 Time on Ammunition Ship

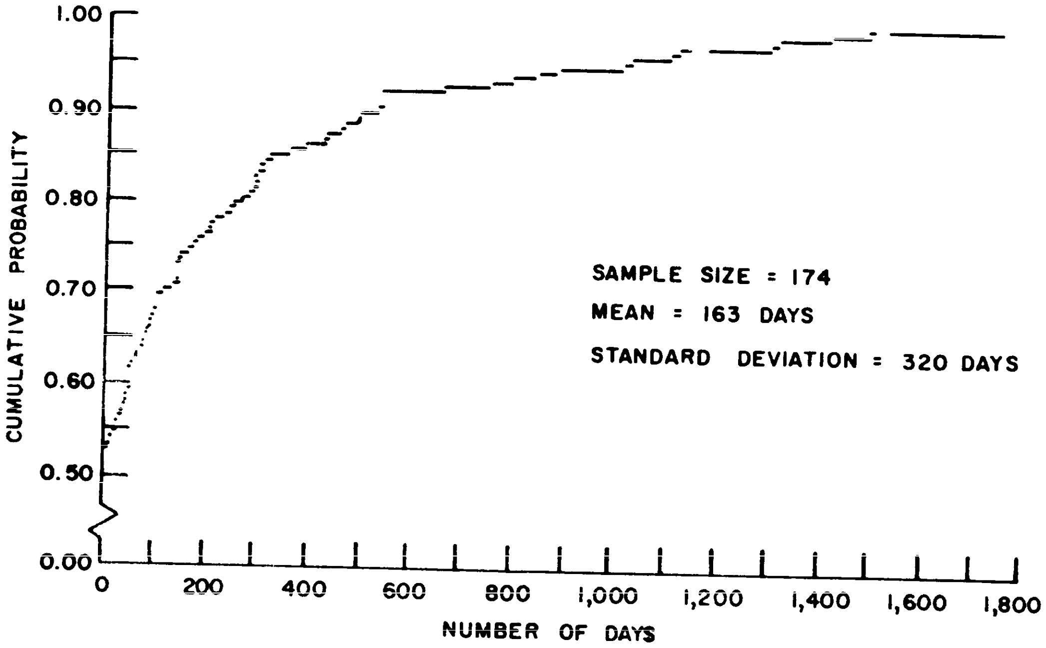

Figure 30. SPARROW III AIM 7E/7E-2 Time in Overseas Storage

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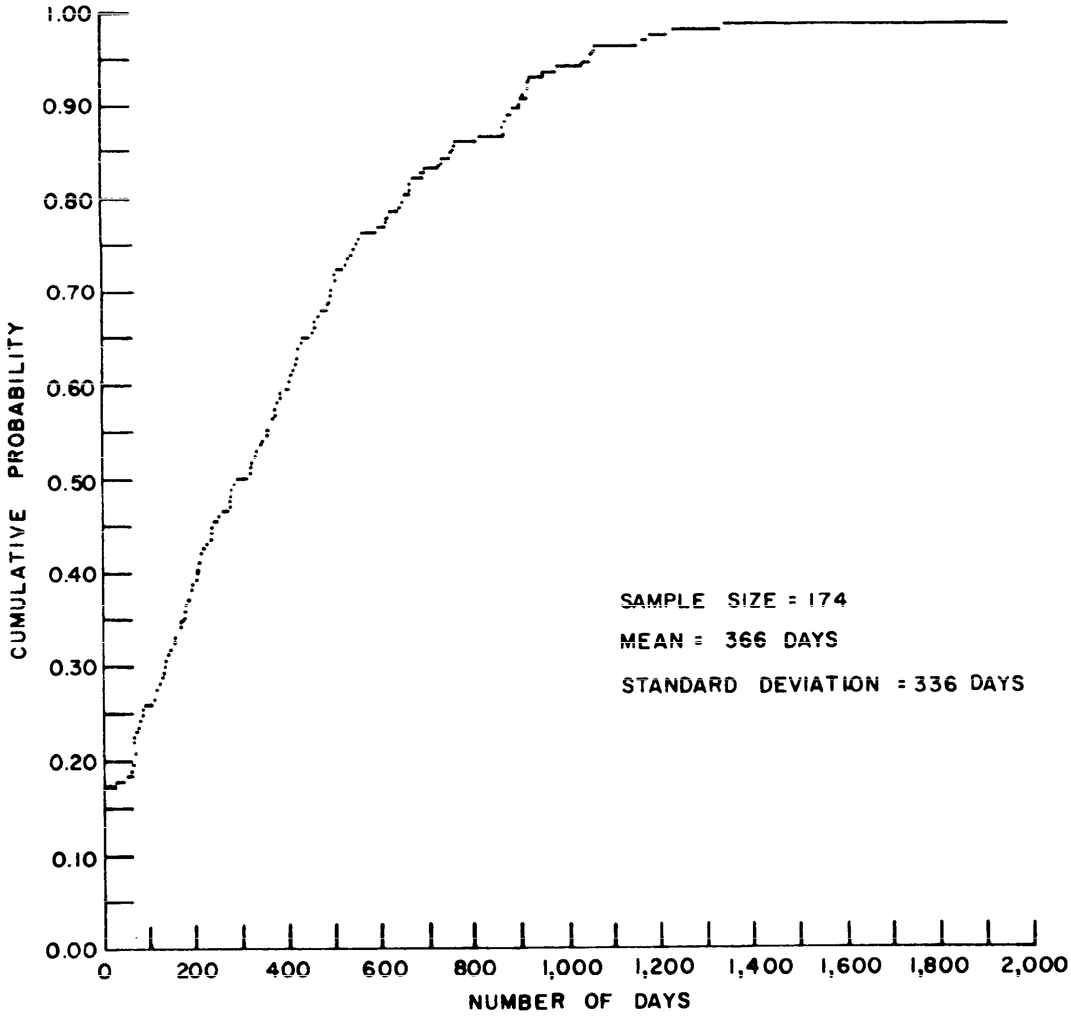

Figure 31. SPARROW III AIM 7E/7E-2 Time on Attack Aircraft Carrier.

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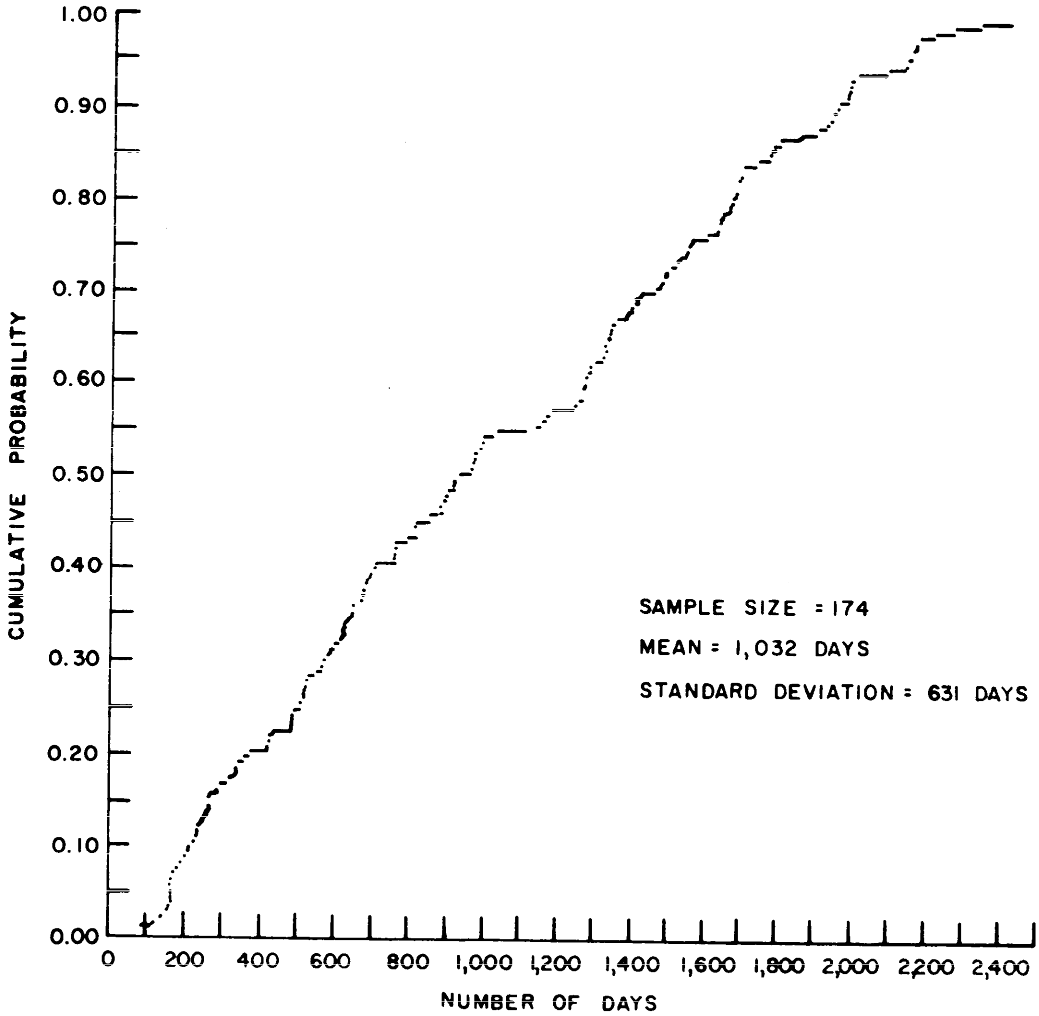

Figure 32. SPARROW III AIM 7E/7E-2 Time in Factory-to-Target Sequence

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TABLE V. 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[a]	0.26	4	8	14	1

[a] Does not include time required to transport missiles between NWS and CVA or AE.

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APPENDIX F

BIBLIOGRAPHY OF ENVIRONMENTAL DOCUMENTS

10. Scope. This appendix presents a partial list of recommended reports for use with this document. (Note: bibliographical documents listed herein may be obtained from the originating agency or from the National Technical Information Service (NTIS).

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