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DEVELOPMENT OF ENVIRONMENTAL PROFILES FOR TESTING EQUIPMENT INS--ETC(U)

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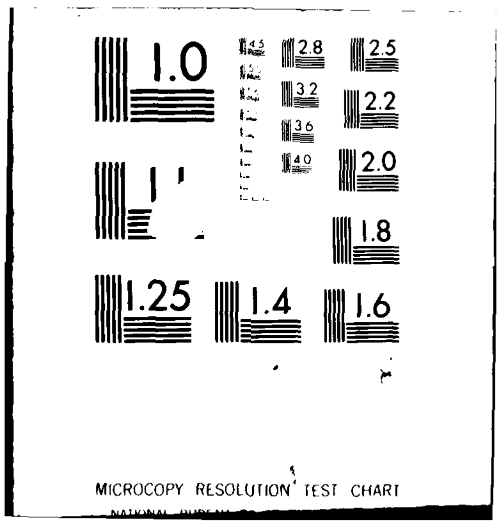
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DEVELOPMENT OF ENVIRONMENTAL PROFILES FOR TESTING EQUIPMENT INSTALLED IN NAVAL AIRCRAFT (FIXED WING)

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Final Report for Period September 1977 - September 1978
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This study was undertaken to provide supplementary documentation to assist users when applying MIL-STD-781C requirements for testing electronic equipment installed in naval fixed-wing aircraft. This has been accomplished by providing: typical mission profiles, a review and modification of Appendix B, MIL-STD-781C to assure compatibility with naval aircraft applications; a sample test profile derived from each mission profile; a detailed procedure to guide the user in constructing test profiles from mission and environmental information; and a procedure for constructing a composite test profile for those equipments that have multi-mission applications.

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Summary

This study was undertaken to provide supplementary documentation to assist users when applying MIL-STD-781C requirements for electronic equipment installed in naval fixed-wing aircraft. This standard adopted the concept of "mission analog testing" as the method of achieving a higher degree of test realism than those achieved by its predecessors. However, the implementation of this standard requires that the user have access to information regarding the expected conditions an equipment will be exposed to during field usage. Furthermore, an orderly method is needed to translate anticipated field conditions into laboratory test requirements.

MIL-STD-781C requires that expected environmental levels, sequencing of environments, and duration of exposure at each level be known to the user. The objective of this study is to provide this information to the user for those situations where actual details are unavailable and he must resort to an analogous situation to develop test requirements. This has been accomplished by providing:

- typical mission profiles (altitude and speed schedule vs. time) for each type of naval aircraft (fighter, attack, ASW, etc.)
- a review and modification, where necessary, of the applicable portions of Appendix B, MIL-STD-781C to assure consistency of test profile and naval aircraft application
- a sample test profile derived from each mission profile
- a detailed procedure to guide the user in constructing test profiles from mission and environmental information
- a procedure for constructing a composite test profile for those equipments that have multi-mission application.

Preface

This Final Technical Report was prepared by the Grumman Aerospace Corporation, Bethpage, New York, under contract number N00014-77-C-0662, for the Naval Research Laboratory, Washington, D.C. Mr. Lionel I. Moskowitz, Code 5326, was the NRL Project Engineer.

The effort described was accomplished during the period, September 1977 through September 1978.

In addition to Messrs. Dantowitz and Hirschberger, other Grumman study team members were: Mr. Lawrence Flanagan, Mr. Harroll Major, Mr. Joseph Popolo and Mr. Herbert Quartin.

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Section 1

INTRODUCTION

1.1 Background

Historically the concerns that the laboratory environment was not compatible with that encountered in the field, date back many years. This situation was thoroughly reviewed by the reliability test work group at the Joint Logistics Commanders (JLC) Electronic Systems Reliability Workshop held at Airlie House in Warrenton, Virginia during May of 1975. The development of a methodology for establishing reliability demonstration test profiles tailored to mission profiles, was one of the recommended tasks defined by the work group.

In September 1975, Grumman completed a 19 month study for Rome Air Development Center, Report No. RADC-TR-75-242 (Defense Documentation Center Number AD B007946L). Many of the recommendations were incorporated into MIL-STD-781C. The purpose of this program was to evaluate environmental profiles currently used for reliability demonstration testing and to provide recommendations for improving these profiles based on a review and analysis of laboratory and field data.

The report recommended that a "mission profile analog" approach be taken in developing test profiles for reliability demonstration, i.e., the test environments be tailored to those encountered by the equipment during actual field use. An approach was developed which would permit the construction of an environmental test profile providing certain basic information concerning aircraft and equipment characteristics where available. Tables and graphs keyed to the above characteristics were included in the report to permit construction of test profiles. That study resulted in a technical report that did not lend itself to direct inclusion in an existing specification or standard either as an amendment or in appendix form. Further, the preparation of specific profiles utilizing the report data is a laborious process due to the organization of the information presented and the lack of a detailed step by step procedure which would normally appear in a specification or standard.

1.2 MIL-STD-781C Limitations

Military standard, MIL-STD-781C, reflects the mission analog approach for developing a test profile and includes certain guidelines and data required to establish an environmental test profile. Contained in the document are three procedures for defining test conditions listed in order of preference, based on the amount of stress data available. The first procedure requires that measured stress data, for a specific platform and equipment location, be used to define the test profile. When this type of information is not available, procedure two recommends that profiles be established using measured data from similar equipment locations in similar platforms. Finally, if no stress information can be obtained, either actual or from similar applications, stress types and levels are to be selected in accordance with Appendix B of the standard. A test profile could be developed utilizing one of the above procedures, but the lack of explicit instructions would make the process cumbersome and result in severe inconsistencies between test profiles. What is needed is an implementing document which describes, in detail, the explicit procedures (including ground rules) to be used when defining an environmental test profile. This document must also contain a methodology for establishing a test profile for platforms that fly many types of missions.

1.3 Study Objective

The purpose of this study was to define the precise methodology to be employed by a user in establishing environmental test profiles for avionics installed in Navy jet aircraft. The information presented has been structured to provide guidance for the user and supply specific information when such data is not available. The report satisfies the objective by including:

- Detailed, step-by-step procedures for defining test profiles
- Mission profiles for a variety of Navy jet aircraft
- Sample test profiles for each of the mission profiles
- Environmental information consistent with Navy experience.

Section 2

MISSION ANALYSIS

2.1 Approach

As indicated previously, MIL-STD-781C advocates the concept of "mission analog" testing. To implement this concept properly the user must have detailed information on the mission during which the equipment is intended to function. This information is needed to enable the user to specify environmental test levels, their duration and proper sequencing.

In particular, he must have an awareness of the major events, or phases, of the mission and the duration of each such phase. If the anticipated environmental levels are also known for each phase, the user may directly combine this information to define a test profile. If such environmental information is not available, he must then have aircraft altitude and speed during each phase, to enable him to apply the method outlined in Appendix B of MIL-STD-781C to determine environmental levels. If this mission information is also unavailable the user must use the details of an analogous mission situation.

It was felt that a collection of typical naval aircraft mission descriptions and profiles would be a beneficial output of this study. The presentation of each mission would identify its major phases and include the altitude, speed and duration of each phase. This type of collection would assist the user in those situations where he had no or incomplete mission information for his equipment. It would provide a single source reference document from which he could select that mission, or missions, that he felt most nearly represented his specific situation.

2.2 Mission Development

A review of applicable documentation and discussions with cognizant personnel indicated that each mission actually flown is essentially a "unique" situation. Its ex post facto description is dependent upon many interrelated factors that existed at the time of the flight and includes:

- aircraft capability
- threat/target type
- enemy tactics
- range

- armament carried
- fuel loading
- pilot preference
- topography
- weather
- etc.

It was therefore decided to develop generalized missions for each type of aircraft considered in the study. Each such mission is a stylized representation of a group of missions, in that it identifies the elements shared in common and depicts these in a simplified manner. It was felt that this approach would be adequate for this study since the mission definition is merely a means for determining the test environments. The main objective was to assure that the mission would yield a reasonable and practical test profile. Thus, approximate fidelity to "real world" missions was considered sufficient.

It was determined that the missions performed by each type of aircraft could be broadly classified according to certain spatial aspects they shared in common. These describe the relative altitude and speed of the aircraft enroute to the target area, during combat, and return to the carrier. Presented below are the missions, and their characteristics, for each type of aircraft considered.

Attack Aircraft:

- Lo-Lo-Lo
  (Low altitude cruise out, combat, and cruise back)
- Close Support
  (High altitude cruise out; low altitude loiter; high altitude cruise back)
- Hi-Lo-Hi
  (High altitude cruise out; low altitude combat; high altitude cruise back)
- Hi-Hi-Hi
  (High altitude cruise out, combat, and cruise back)
- Hi-Lo-Lo-Hi
  (High altitude cruise out; low altitude run-in, combat and run-out; high altitude cruise back)
- Ferry
  (High altitude cruise).

Anti-Submarine Warfare (ASW) Aircraft:

- Contact Investigation - Hi
  (High altitude cruise out; low altitude loiter; high altitude cruise back)
- Contact Investigation-Int
  (Higher speed and intermediate altitude cruise out; low altitude loiter; high altitude cruise back)
- Mine Laying
  (High altitude cruise out; low altitude run-in; low altitude run-out; high altitude cruise back)
- Hi-Hi-Hi
  (High altitude cruise out, combat and cruise back)
- Search and Attack
  (High altitude cruise out, loiter and cruise back)
- Surface Surveillance
  (Low altitude cruise out, loiter and cruise back)
- Ferry
  (High altitude cruise).

Electronic Countermeasures (ECM) Aircraft:

- Penetration
  (High altitude cruise out; low altitude run-in; low altitude run-out; high altitude cruise back)
- Stand-off
  (High altitude cruise out, loiter and cruise back)
- Ferry
  (High altitude cruise).

Fighter Aircraft

- Hi-Hi-Hi
  (High altitude cruise out, combat and cruise back)
- Escort
  (High altitude cruise out; intermediate altitude combat; high altitude cruise back)

- Air Defense/CAP
  (High altitude cruise out, loiter, combat and cruise back)
- Intercept
  (High altitude and high speed dash out and combat; high altitude cruise back)
- Hi-Lo-Lo-Hi
  (High altitude cruise out; low altitude run-in, combat and run-out; high altitude cruise back)
- Lo-Lo-Lo
  (Low altitude cruise out, combat and cruise back)
- Lo-Lo-Hi
  (Low altitude cruise out and combat; high altitude cruise back)
- Close Support
  (High altitude cruise out; low altitude loiter; high altitude cruise back)
- Ferry
  (High altitude cruise).

Reconnaissance Aircraft

- Hi-Lo-Hi
  (High altitude cruise out; low altitude run-in; low altitude run out; high altitude cruise back)
- Lo-Lo-Hi
  (Low altitude cruise out; low altitude run-in; low altitude run-out; high altitude cruise back)
- Lo-Lo-Lo
  (Low altitude cruise out, run-in, run-out, and cruise back)
- Hi Altitude Supersonic
  (High altitude cruise out; run-in and run-out of higher altitude and supersonic speed; return of cruise altitude and speed)
- Hi Altitude Subsonic
  (High altitude cruise out, run-in, run-out, and cruise back)
- Ferry
  (High altitude cruise).

Tanker Aircraft

- Hi-Lo-Hi Refuel
  (High altitude cruise out; fuel transfer at lower altitude; high altitude cruise back)
- Lo-Lo-Lo Refuel
  (Low altitude cruise out, fuel transfer and cruise back)
- Strike Refueling
  (Cruise out, fuel transfer and cruise back at intermediate altitude).

Analyses were performed to determine the specific numerical values needed to adequately describe each of the above missions. The parameters that required evaluation included:

- Phase altitude
- Phase Mach No.
- Durations
- Transition rates between steady state conditions.

The determination of each value required a review of the available documentation and then selecting, or deriving, that value considered representative for that specific parameter. Derivation, for example, of phase times were required where only distances and average speeds were provided. In those cases where the choice of a representative value was not apparent, the following guidelines were applied:

- If the available choices resulted in negligible differences in resulting environmental levels, use an average value
- If the available choices resulted in real differences in resulting environmental levels, use the choice that yields the more severe environment (worst case).

The resulting mission profiles developed from this analysis are presented graphically in Appendix A.

Section 3

ENVIRONMENTAL ANALYSIS

3.1 Introduction

Both Appendix B of MIL-STD-781C and RADC-TR-75-242 provide the means for establishing temperature and vibration levels as a function of altitude and Mach number. The relationships presented in these documents were generally empirically established and derive from observation and analysis of instrumented flight data.

Additional flight measurement data has become available since the technical analyses were performed for the above documents. This additional data was acquired during various flight test programs performed on Navy aircraft and was used during this study to validate and refine the information appearing in MIL-STD-781C. This was accomplished for both temperature and vibration by comparing each new data point with the value indicated in the standard for the same condition of flight.

3.2 Vibration Analysis

3.2.1 Data Collection and Analysis - A sampling of vibration data was acquired for several different types of aircraft and was collected for many locations in each vehicle. The study aircraft included mid-fuselage and aft-end mounted engines. The vibration data was obtained during various flight test programs conducted on each aircraft and in most cases, accelerometers were located in the aircraft's vertical, lateral and fore-aft directions.

The specific conditions of flight and aircraft location were obtained for each measurement point so that direct comparisons with MIL-STD-781C could be made. Aircraft locations included the nose, cockpit, adjacent to engine compartment, and aft of the engine exhaust. The available data was generally acquired at worst case flight conditions, i.e., take off, cruise at maximum power setting, high speed Mach No. variation, maneuvers, and landings. In the absence of measurements at the more benign flight conditions it was agreed that if this worst case data compared favorably with MIL-STD-781C requirements, it would be assumed that a comparison at the benign conditions would also be favorable. The data thus obtained on the study aircraft was then partitioned and summarized for each combination of flight condition and location considered. Within each partitioned section the measurement points were divided into 1/3 octave bands out to 2000 Hz for the vertical, lateral and fore-aft direction. Data was compiled within each 1/3 octave band to permit calculation of the min and max values. These levels were then plotted at the center frequency (fc) of each partitioned 1/3 octave band for each situation.

3.2.2 Results - Figs. 1 thru 7 are typical of the plots made for each situation. Each figure shows the average measured vibration level and the highest and lowest value noted in each band. The comparable vibration requirement, determined by the method described in MIL-STD-781C, is superimposed to show the comparison.

Inspection of these curves indicate that the MIL-STD-781C vibration requirement compared favorably with the data acquired and analyzed during the study. It appears that the standard defines a level that is somewhat conservative in that it is always moderately higher than the average value and almost always higher than the maximum value. This situation is considered acceptable for reliability-type testing.

3.3 Temperature Analysis

3.3.1 Data Collection and Analysis - Compartment temperature data acquired during the flight test programs of several aircraft was collected and summarized. The specific conditions of flight (i.e., altitude and Mach number) associated with each temperature value were also determined. This would permit a direct comparison between the values provided in MIL-STD-781C, Appendix B and this additional temperature data for comparable flight conditions.

The collected temperature data consisted of actual flight measurements and, in many cases, extrapolation of flight measurement to equivalent hot and cold day environments. Extrapolation of flight data is frequently performed and is an accepted method used to analytically verify compliance with design temperature requirements. Since actual hot or cold day environments are not usually encountered during the conduct of a flight test program, this verification method is often used. A detailed description of the extrapolation procedure may be found in RADC-TR-75-242. Essentially it is an iterative technique which seeks to find that temperature value for which a thermal balance equation is at equilibrium.

3.3.2 Results - The temperature data that was available during this study was for ram air cooled and Class II compartments. The comparison of these values with MIL-STD-781C levels for equivalent flight conditions is shown in the following graphs. Fig. 8 is a plot of measured or extrapolated data vs MIL-STD-781C level for RAM air cooled compartments. The figure indicates close correlation between the two over a wide temperature range.

Figs. 9 - 12 are plots of measured or extrapolated values vs altitude for Class II compartments. Each figure represents a different aircraft speed range of speed. Superimposed on each graph are the 781C levels for both hot day and cold day. A review of these graphs

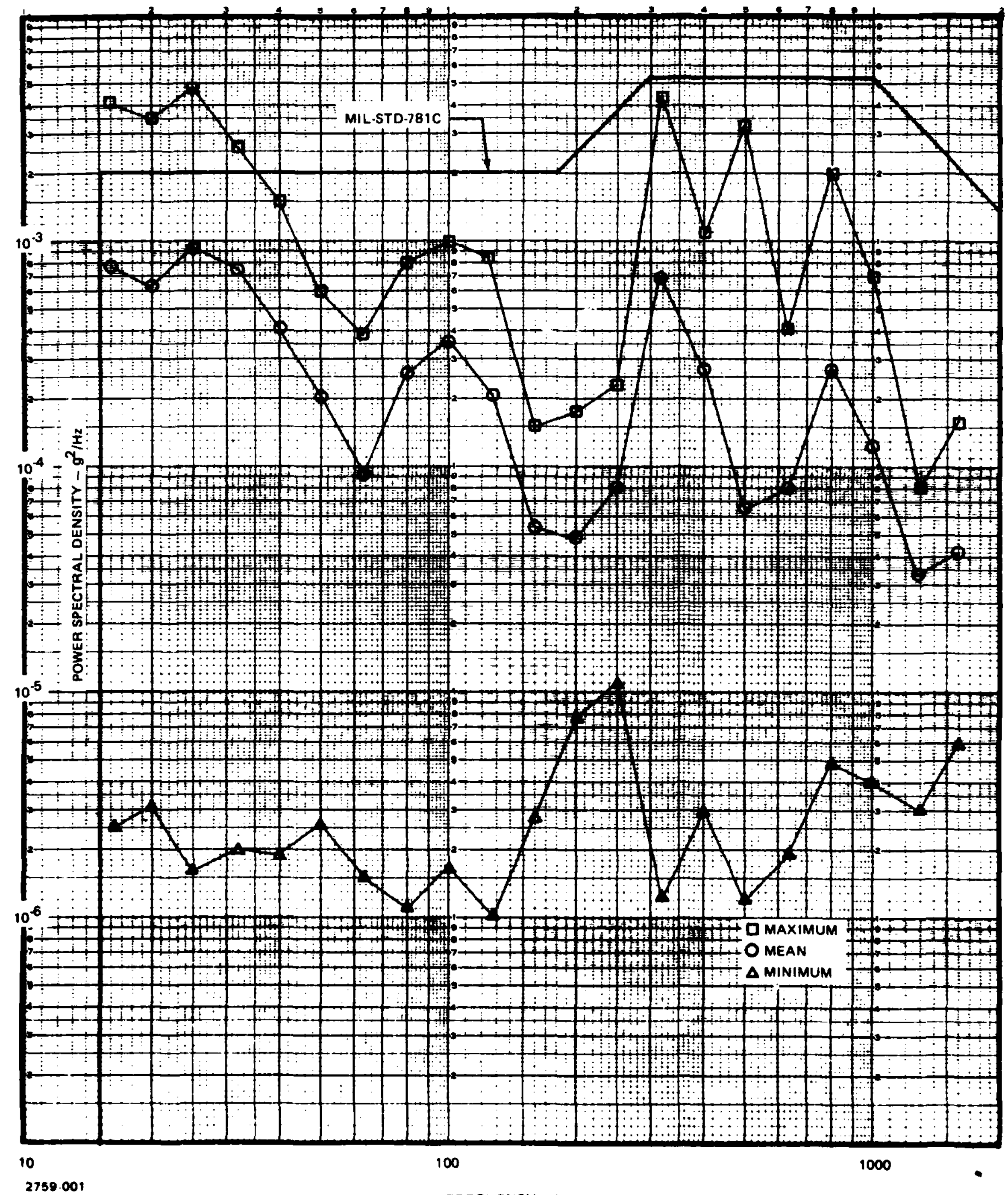

Figure 1 Measured In Flight Environment
Condition: Subsonic
Location: Nose and Forward Compartments

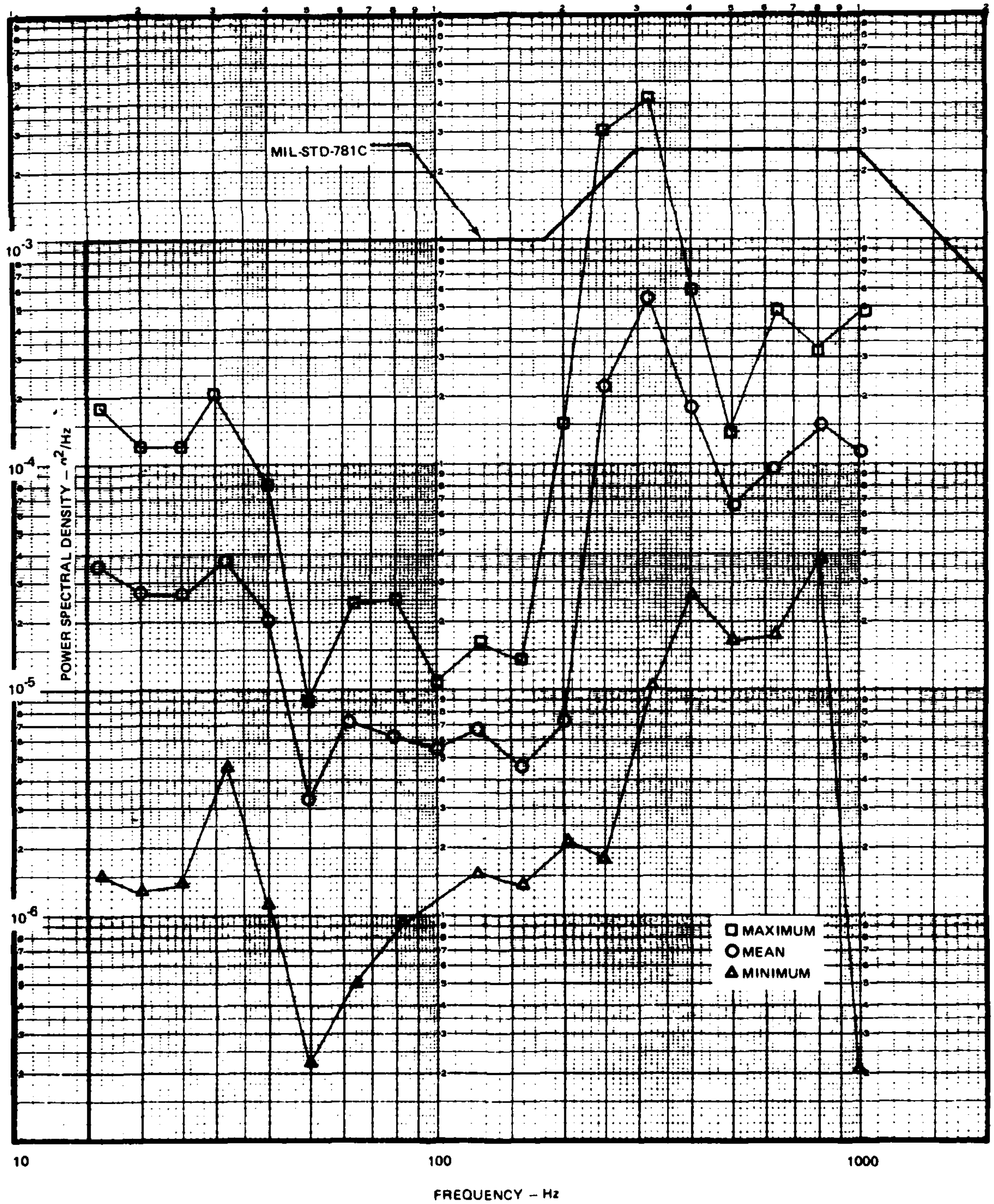

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Figure 2 Measured In Flight Environment
Condition: Acceleration
Location: Nose and Forward Compartments

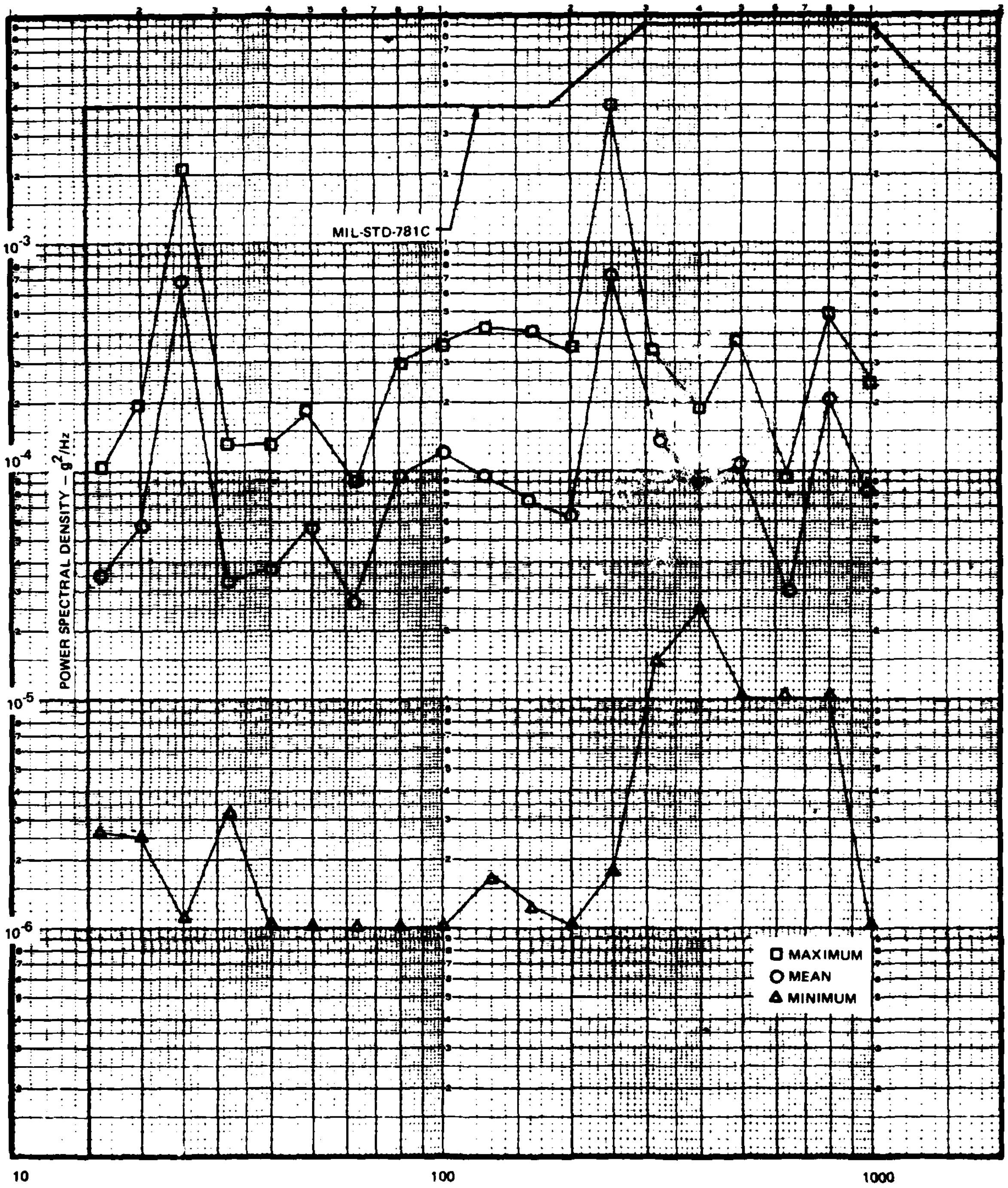


Figure 3 Measured In Flight Environment
Condition: Supersonic
Location: Nose and Forward Compartments

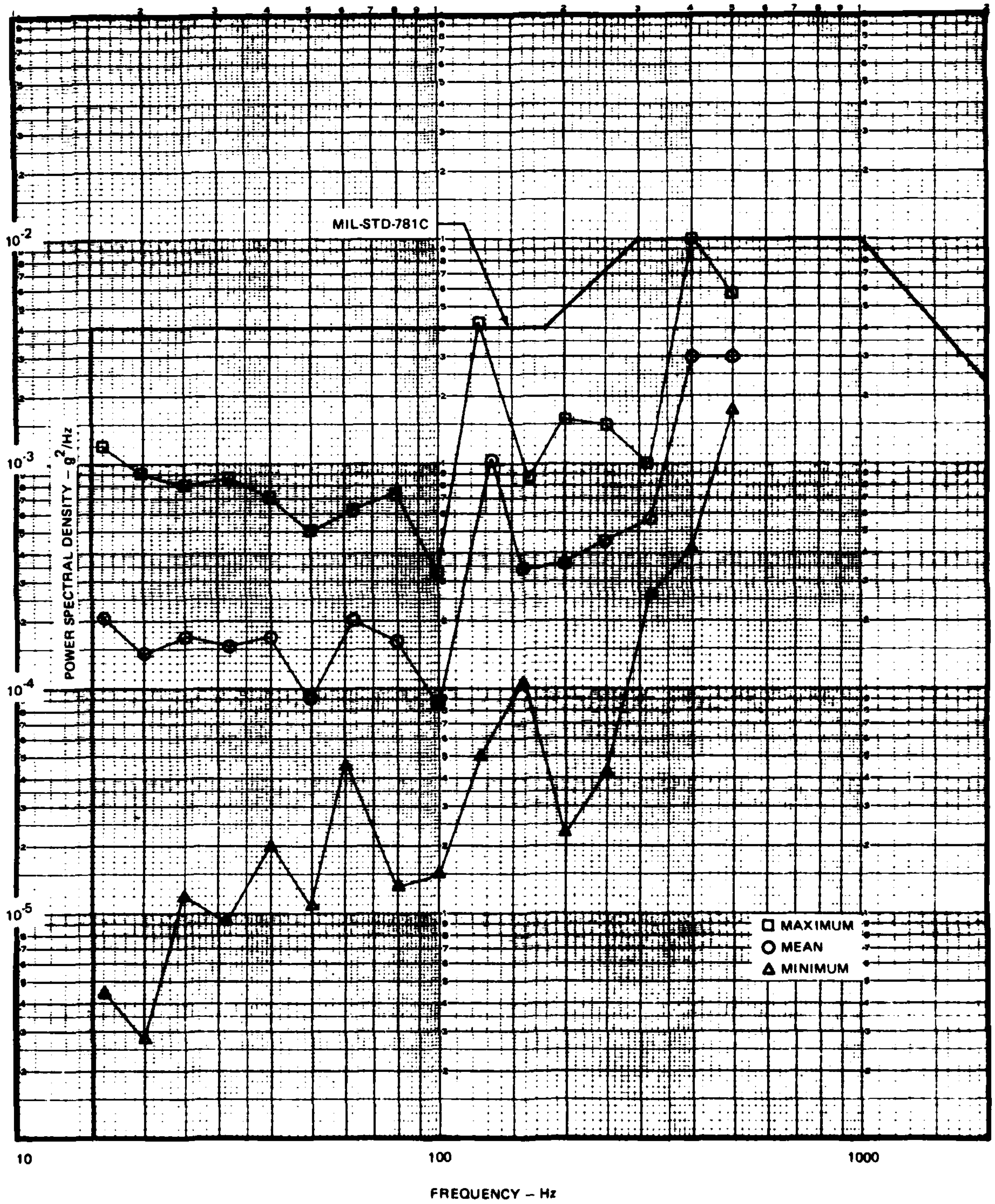


Figure 4 Measured In Flight Environment
Condition: Maximum Power In Flight
Location: Nose and Forward Compartments

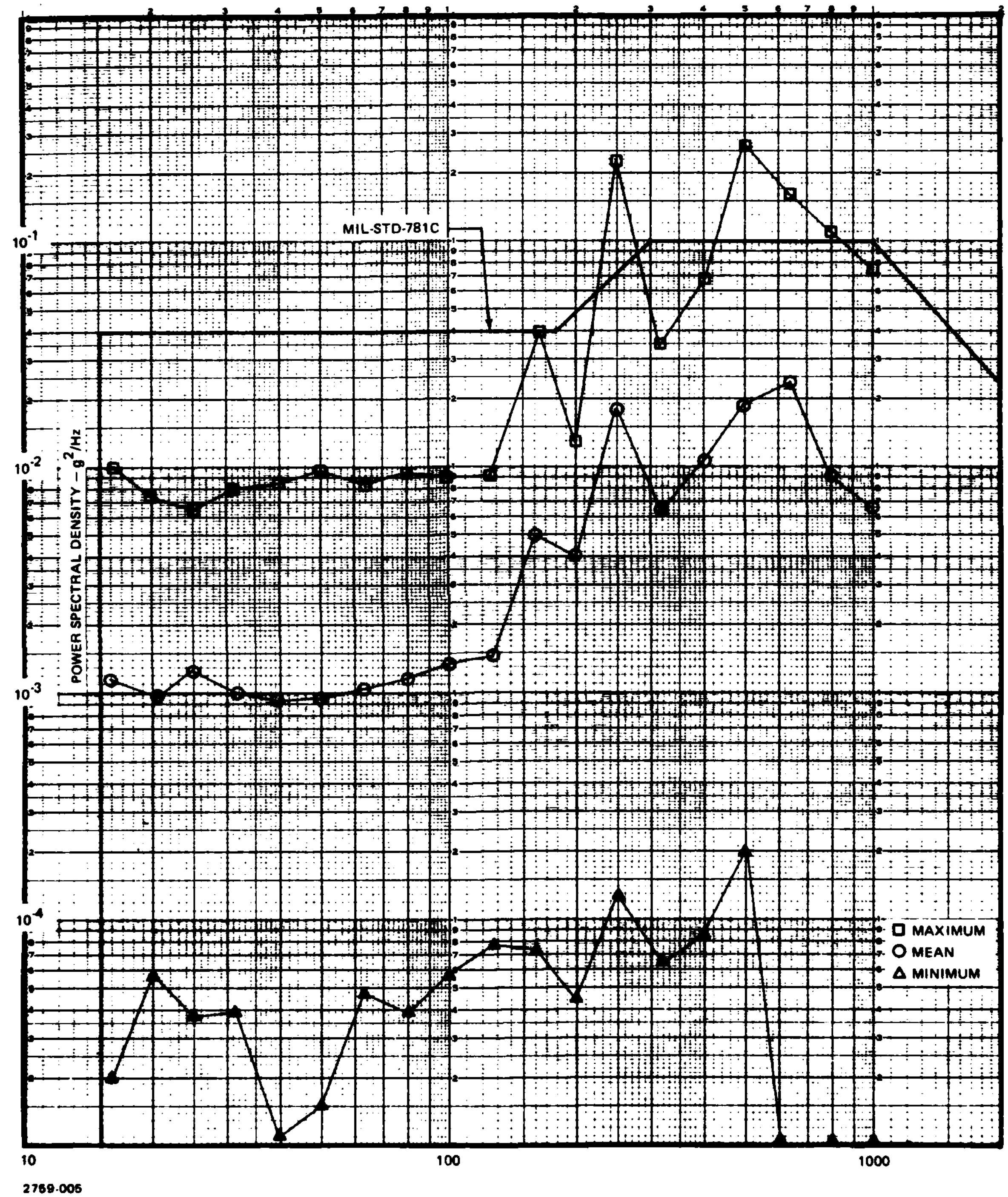


Figure 5 Measured In Flight Environment
Condition: Take-Off With A/B
Location: Adjacent To Engine Compartment

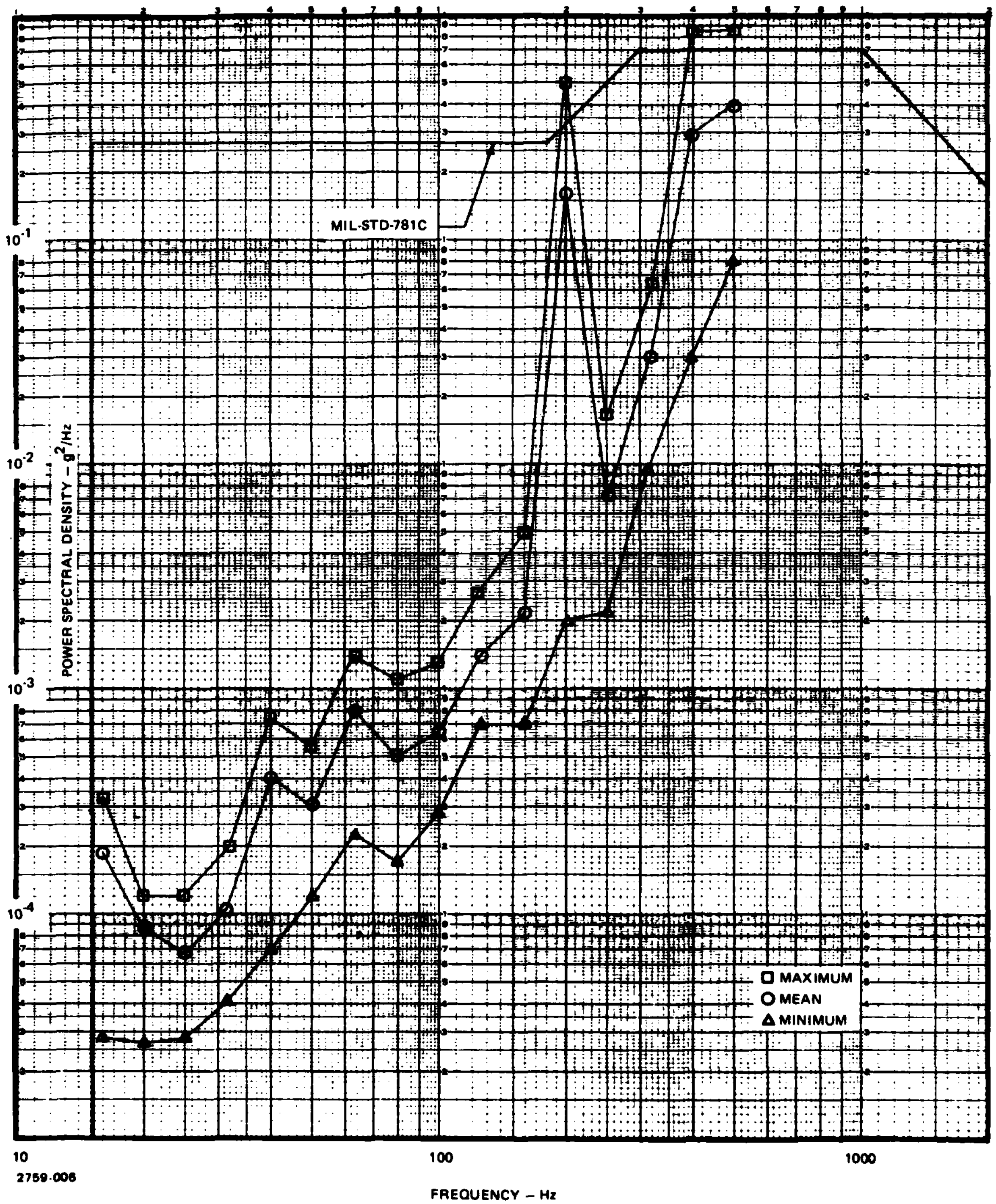


Figure 6 Measured In Flight Environment
Condition: Take-Off
Location: Aft Of Engine Exhaust

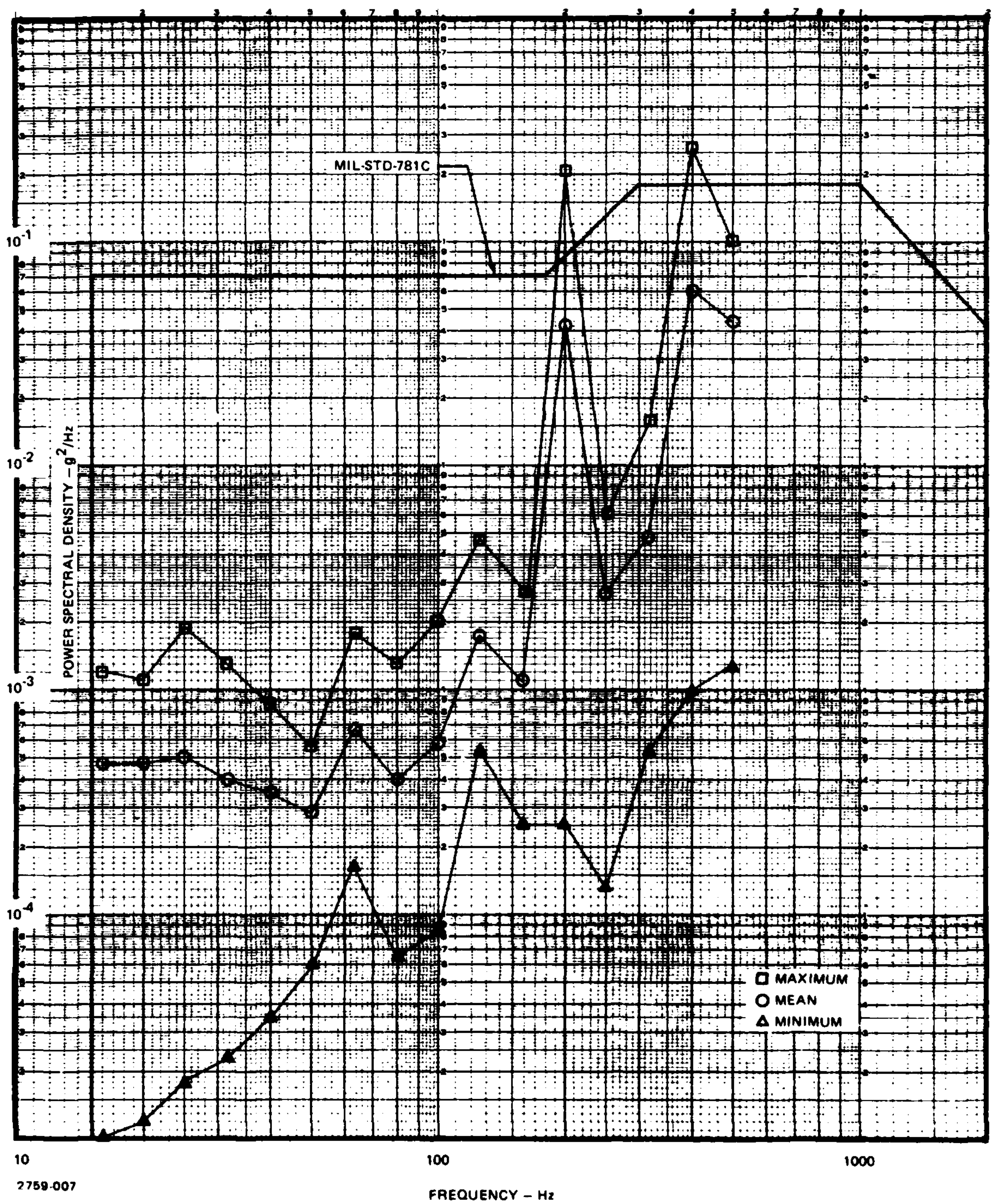


Figure 7 Measured In Flight Environment
Condition: Maximum Power In Flight
Location: Aft Of Engine Exhaust

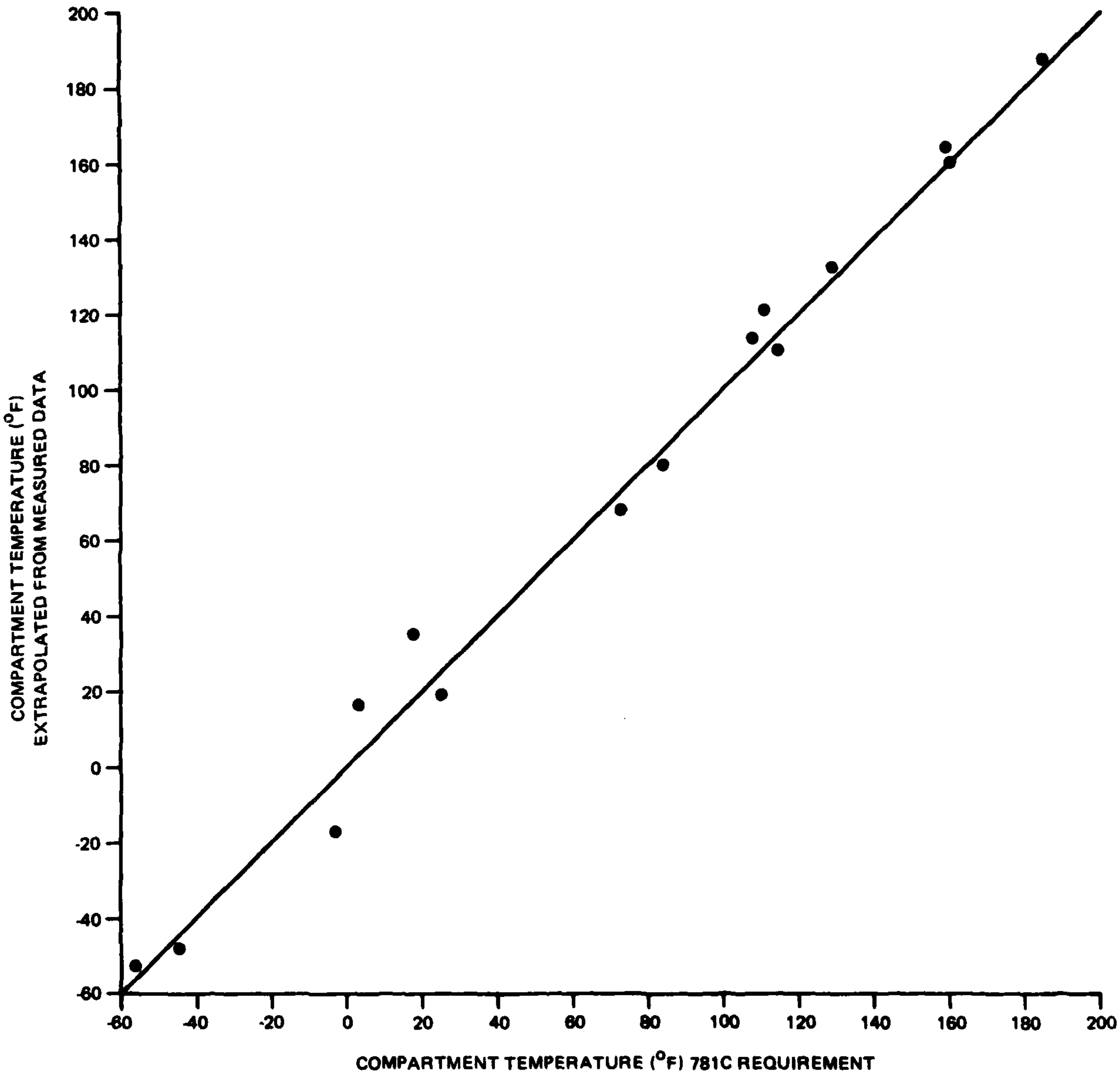


Figure 8 Ram Air Cooled Compartment Temperature Comparison

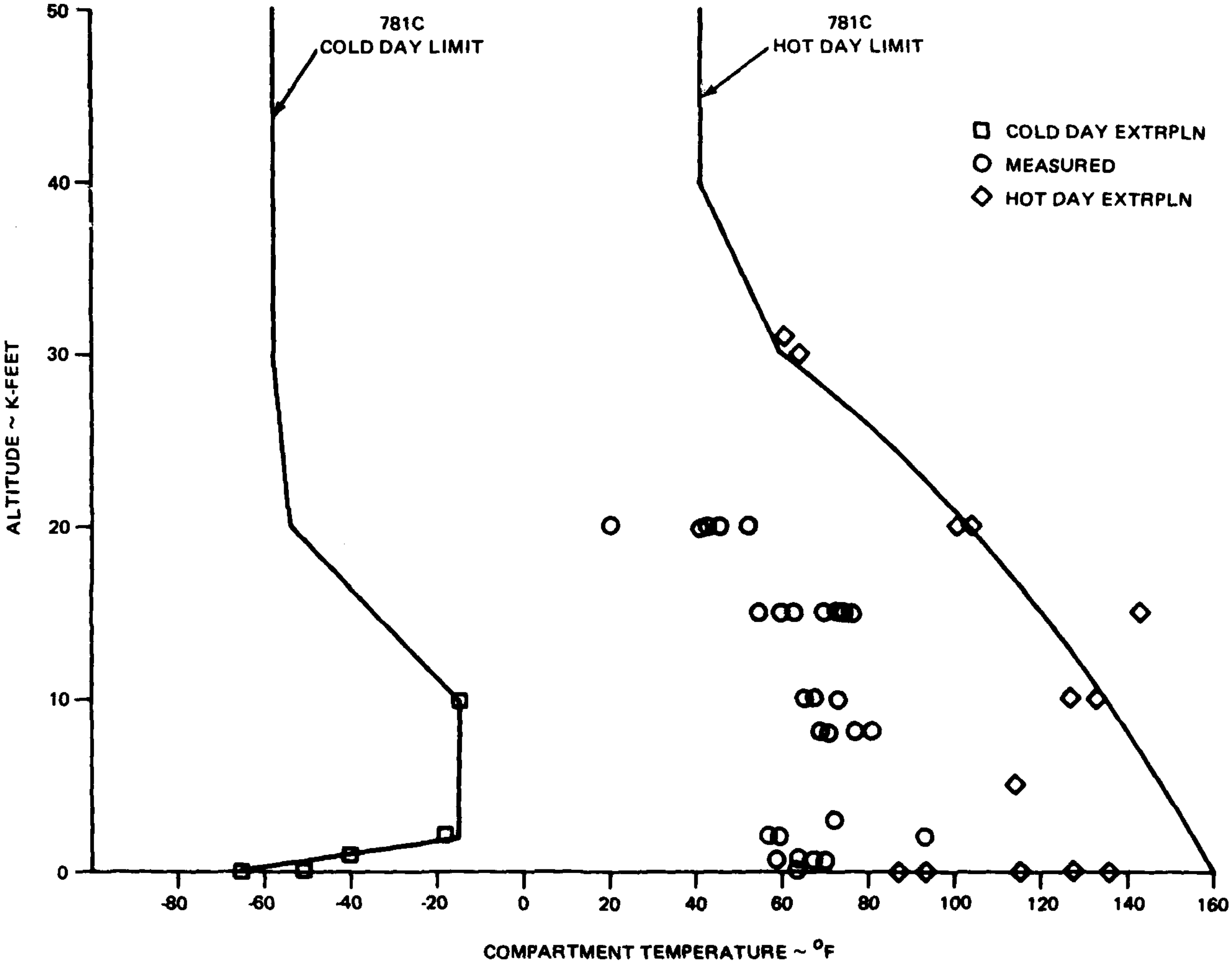


Figure 9 Class II Compartment Temperature Comparison (< 0.6M)

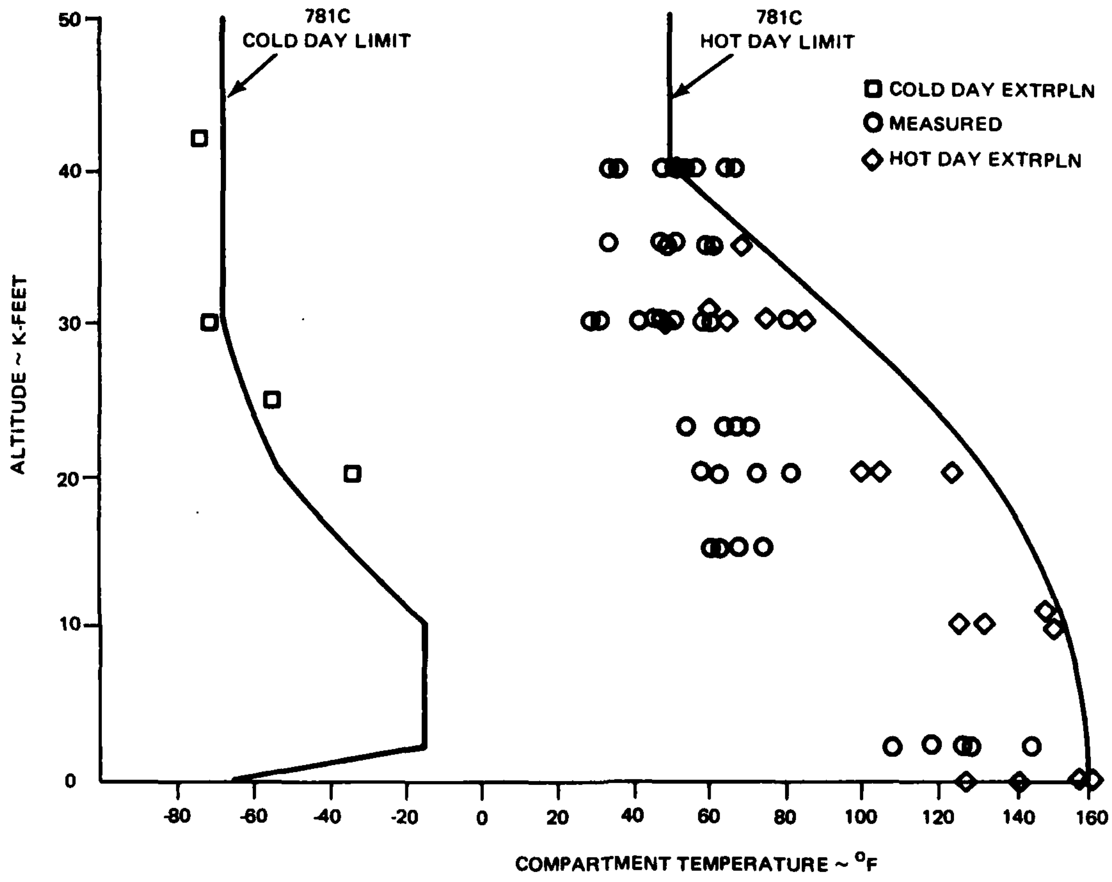


Figure 10 Class II Compartment Temperature Comparison (0.6M – 0.8M)

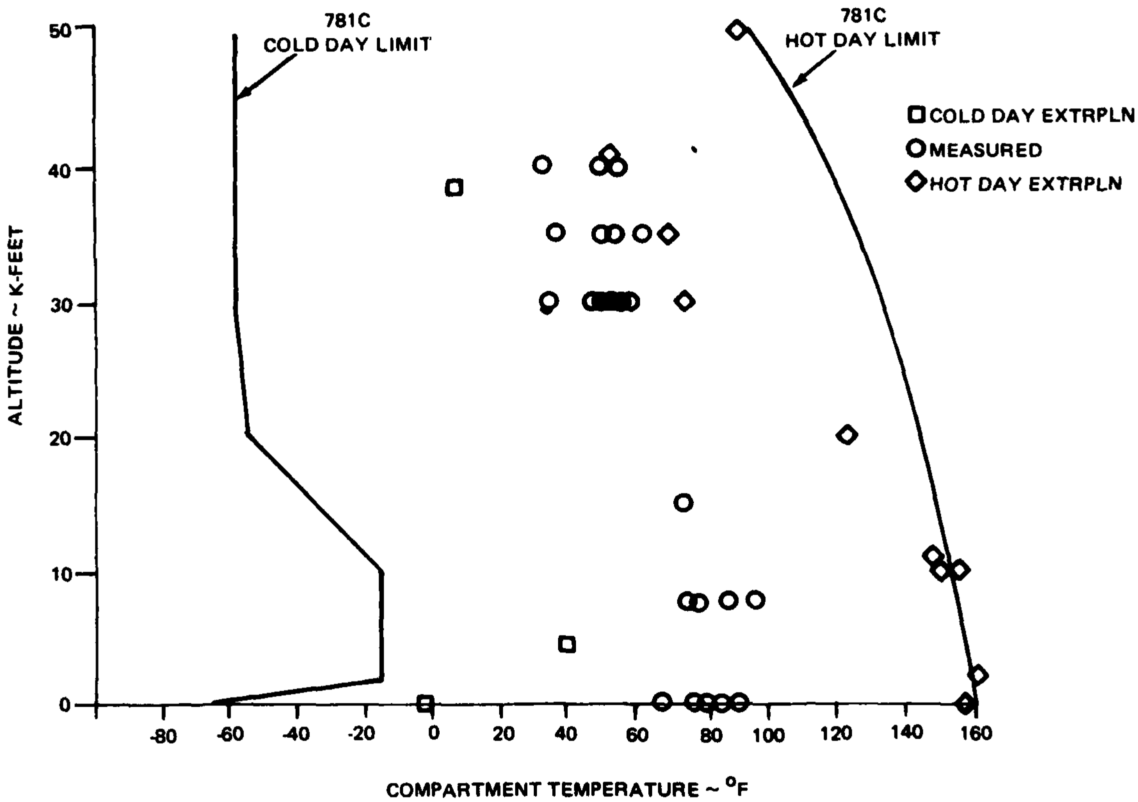


Figure 11 Class II Compartment Temperature Comparison (0.8M – 1.0M)

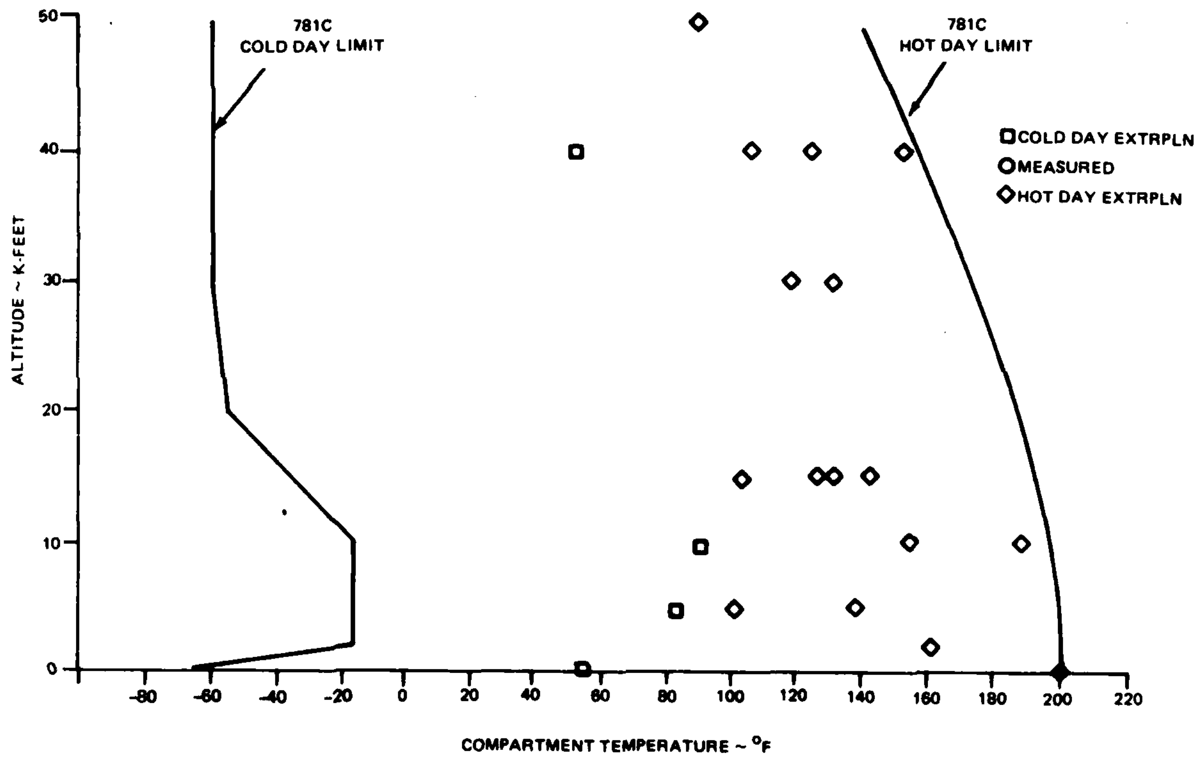


Figure 12 Class II Compartment Temperature Comparison (>1.0M)

indicates that the MIL-STD-781C hot day levels are a reasonable representation of the hot day environments for all aircraft speeds considered. However, the MIL-STD-781C cold day limit becomes a poorer descriptor of that environment as aircraft speed is increased. A review of MIL-STD-781C and RADC-TR-75-242 reveals that the method for determining cold day requirements for Class I and II compartments considered only altitude. The effects of Mach No. were completely ignored. This is inconsistent with the physical realities indicated in the above figures and suggests the need to develop Class I and II cold day levels as a function of both altitude and Mach No.

3.3.3 Cold Day Analysis - The aim of the analysis was to provide a table of cold day temperature values for various combinations of altitude and Mach No. similar in structure to those currently appearing in MIL-STD-781C for hot day and RAM air cooled compartments. As a first step a predicting equation was developed which provides the relationship between altitude and Mach No. with compartment steady state temperatures. The derivation of the equation is as follows:

Rate of heat in = rate of heat out

Sources of heat in

Electronic: Q_{elec} (watts)

Flow in: $(W_{in})\ (C_p)\ (T_{in})$

where: W_{in} = flow rate of conditioned air into compartment, (lbs/min)

C_p = specific heat of air (BTU/lb-°F) = 0.24

T_{in} = air conditioning inlet temperature (°C)

Sources of heat out

Heat loss to compartment exterior: $(U)\ (A)\ (T_{comp} - T_R)$

where: U = overall heat transfer coefficient between compartment and aircraft (BTU/Hr/Ft^2/°F)

A = exposed skin area of compartment to the exterior (Ft^2)

T_{comp} = compartment bulk air temperature (°C)

T_R = recovery temperature, i.e., temperature of the air in boundary layer on the exterior skin of the aircraft (°C)

Flow Out: $(W_{out})\ (C_p)\ (T_{comp})$

where: W_{out} = flow rate of conditioned air out of compartment (lbs/min)

Equating: Rate of Heat In = Rate of Heat Out

$$(3.41)\ (Q_{elec}) + (60)(1.8)(W_{in})(C_p)(T_{in}) = (U)(1.8)(A)(T_{comp} - T_r) + (60)(1.8)(W_{out})(C_p)(T_{comp})$$

NOTE: The coefficient 3.41 is for the conversion of watts to BTU/hr and 1.8 is the conversion from °F to °C. The coefficient 60 is for the conversion of minutes to hours.

Substituting: 0.24 BTU/lb-°F for C_p and noting that $W_{in} = W_{out} = W$ for conservation of mass we get:

$$(3.41)\ (Q_{elec}) + (14.4)(1.8)(W)(T_{in}) = (U)(1.8)(A)(T_{comp} - T_r) + (14.4)(1.8)(W)(T_{comp})$$

Solving for T_{comp}:

$$T_{comp} = \frac{(3.41)\ (Q_{elec}) + (14.4)\ (1.8)\ (W)\ (T_{in}) + (U)\ (1.8)\ (A)\ (T_r)}{1.8\ \left[(U)\ (A) + (14.4)\ (W)\right]}$$

Note that: U can be obtained from:

$$U = 2.0 - \left(\frac{0.6}{50,000}\right)(Alt)$$

where: Alt = aircraft altitude (ft)

T_r can be obtained from:

$$T_r = (T_{amb} + 273)\ (1 + 0.18\ M^2) - 273$$

where: T_{amb} = free stream ambient (static) temperature (°C)

M = aircraft Mach No.

NOTE: Inherent in this derivation are the following assumptions:

1. The inter-compartment heat transfer is zero (i.e., the adjacent compartment is at the same temperature).
2. There is perfect mixing of air in the compartment (i.e., the temperature of the air leaving the compartment is T_{comp}).

These assumptions were considered reasonable for this analysis.

Although this equation provides a relationship between compartment temperature and flight conditions (altitude and Mach No.) it is dependent on knowledge of certain other aircraft parameters, viz:

- Compartment electronics heat load (Q_{elec})
- Flow rate of conditioned air (W)

- Inlet temperature of conditioned air (T_{in})
- Area of skin exposed to exterior (A)

If these parameters are known when the environmental test profile is being developed, then the above equation may be used to determine cold day temperature requirements.

A further analysis was performed to determine if a generalized relationship could be found that was independent of advanced knowledge of these parameters. It was also argued that such a relationship would be more consistent with the material in MIL-STD-781C for hot day conditions. To accomplish this analysis, the specific values of the above parameters were determined for various actual equipment compartments of several aircraft. This information is presented in Table 1. The predicting equation was used to determine each compartment temperature for a variety of altitude and Mach No. conditions.

Fig. 13 is typical of the plots that were made. It shows the predicted compartment temperatures as a function of altitude for a Mach 1.0 condition. A review of these graphs, particularly at the higher speed condition, indicates the existence of two types of compartments. It appears that, given the constraints, practices, geometry, etc. associated with aircraft compartment design, the resulting effect is either a "warm" compartment or "cool" compartment. It was decided to capitalize on this observation and provide temperature levels for each. This was accomplished by averaging the predicted values in each group for each combination altitude and Mach No. The recommended cold day levels are presented in Table 2.

TABLE 1 AIRCRAFT COMPARTMENT THERMAL PARAMETERS

COMPARTMENT	ELECTRONIC HEAT LOAD (WATTS)	COOLING AIR FLOW RATE (LBS/MIN)	COOLING AIR INLET TEMPERATURE (°C)	EXPOSED SURFACE AREA (FT^2)
1	1160	4.5	24	15.6
2	8800	31.0	4	51.0
3	14000	31.0	4	161.0
4	4644	10.7	24	96.0
5	595	3.6	24	14.1
6	138	–	–	3.5
7	4000	12.0	24	130.0
8	805	2.0	16	13.2
9	524	1.8	16	9.7
10	3830	12.0	24	79.2
11	299	–	–	9.7
12	50	–	–	1.7
13	1290	9.5	4	68.0
14	110	1.5	16	13.2
15	1175	1.9	24	77.2
16	35	–	–	1.7
17	278	1.8	4	53.0
18	2217	–	–	199.2
19	190	–	–	50.0

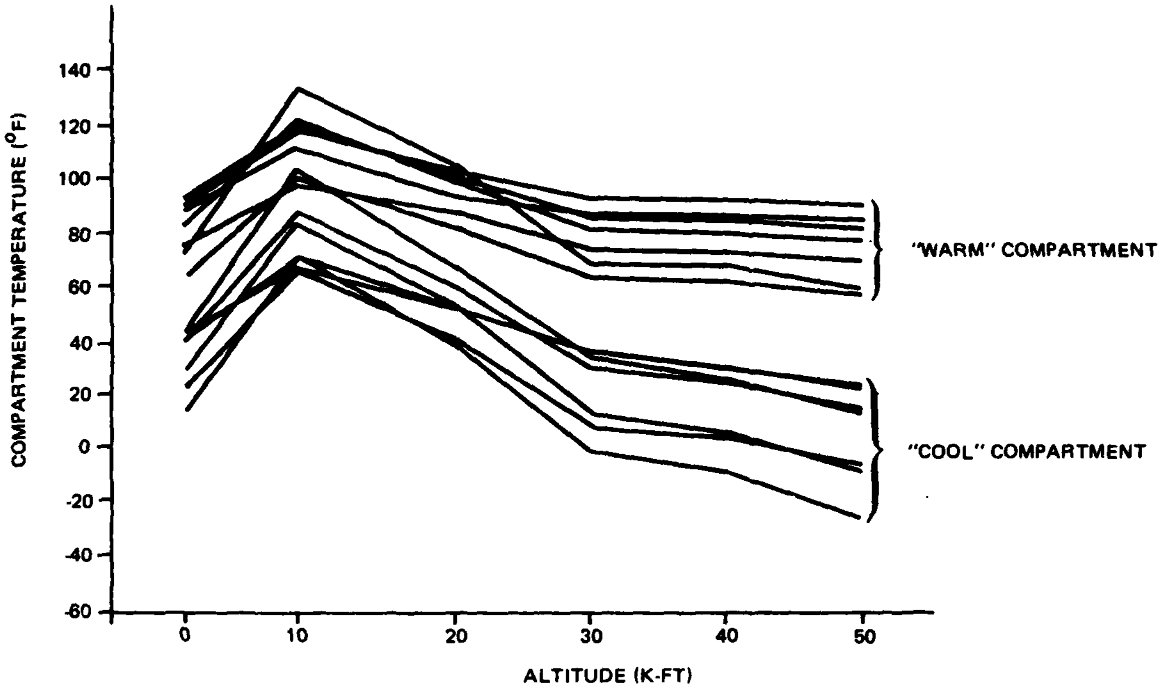


Figure 13 Predicted Cold Day Compartment Temperature (1.0M)

TABLE 2 RECOMMENDED COLD DAY COMPARTMENT TEMPERATURES (°C)

"WARM" COMPARTMENT

ALTITUDE (K FEET) \ MACH NUMBER	<0.6	<0.8	<1.0	HIGH PERFORMANCE >1.0
0	8	12	19	27
2 TO 10	24	29	36	44
20	16	20	27	35
30	7	11	17	24
40	8	12	17	24
50	6	9	14	21

"COOL" COMPARTMENT

ALTITUDE (K FEET) \ MACH NUMBER	<0.6	<0.8	<1.0	HIGH PERFORMANCE >1.0
0	-26	-19	-10	2
2 TO 10	-4	3	13	27
20	-17	-10	-1	11
30	-32	-26	-17	-6
40	-33	-27	-18	-8
50	-38	-32	-24	-14

2759-015

Section 4

DEVELOPMENT OF METHODOLOGY

4.1 Introduction

This section describes the study effort required to develop methodologies and their documentation in the form of procedures for:

- Developing a test profile for a mission
- Developing a composite test profile for multi-mission application.

The portion of the effort for developing a test profile from a mission profile was performed earlier and is documented in RADC-TR-75-242 and MIL-STD-781C. The effort for this study concentrated on clarifying some outstanding issues and developing a set of ground rules to assist the user in the development of a test profile.

No universal approach to the problem of providing a test profile for equipments involved in more than one mission has been documented. This study seeks to remedy this situation by developing a methodology for this situation and providing a procedure for its implementation.

4.2 Individual Test Profile

Military standard MIL-STD-781C defines a methodology for developing a test profile from a mission profile. During this study it became apparent that some additional guidance and organization of material was necessary to implement this methodology since precise application of the requirements could result in profiles that were unduly severe, too benign, or unrealistic in terms of environmental stress level. A detailed procedure was therefore prepared that defined the specific steps required to establish a test profile, and also included certain criteria and ground rules necessary to assure consistency and realism in the final profile. The development of the test profile was accomplished in two steps. A tabulation and graphic environmental profile was first prepared using data obtained from the mission profile and MIL-STD-781C. Two exceptions were taken in the data prescribed for use by the standard. The non-operate period of three minutes was changed to 30 minutes to assure a reasonable soak time at thermal extremes. A new table (ref. Table 2) was used in defining cold day compartment temperatures.

The initial tabulation and graphic representation were then modified in accordance with the ground rules and criteria established during this study. The profile resulting from this modification was established as the actual test profile to be simulated in the laboratory when conducting reliability demonstration tests.

The following modifications were applied in converting the environmental profile into a test profile:

Temperature

- Steady State Conditions - Any steady state thermal condition that was less than 10° C (18° F) in magnitude, or less than 20 minutes in duration, was deleted from the test profile. These rules were established to assure meaningful application of thermal exposures. Values of temperature and duration less than those defined would have little if any impact on hardware reliability, and implementation would unnecessarily complicate the test.
- Rate of Change - The chamber temperature rate of change range for transient conditions has been established at 5° C (9° F)/Min. to 30° C (54° F)/Min.

The lower rate of 5° C (9° F)/Min. has been set to provide a reasonable thermal stress during transition periods. Values less than this amount would not adequately exercise the equipment.

The upper limit of 30° C (54° F)/Min. has been defined to assure that a thermal effect will be experienced by the hardware. Since a thermal lag (temperature response) exists between chamber air and equipment components, too rapid a change in temperature would not even be felt by the constituent piece parts. Further, most existing facilities used for reliability demonstration tests have been designed to provide rates of 5° C (9° F)/Min. With a reasonable amount of modification (plenums for short term increases) this rate could be increased to 30° C (54° F)/Min. Higher rates would involve substantial changes in chamber design and severely impact facility costs.

Vibration

The methodology used in MIL-STD-781C to obtain vibration test levels generally has been retained and a maximum of four levels can theoretically be established for any particular test. However, for certain aircraft and mission phases, utilization of this approach could result in <u>all</u> or <u>most</u> vibration test levels (W_o) being less than 0.001 g^2/Hz (MIL-STD-781C requires deletion of all W_o's less than 0.001) and vibration could only be required during the take-off periods for which a 0.002g^2/Hz minimum value is required.

In order to stress the equipment adequately and provide vibration during all flight phases (mission analog), a rule was added requiring that a $W_o = 0.001\ g^2/Hz$ be used for all mission flight phases not accounted for by any of the four W_o's described above.

The methodology, including special ground rules, for developing a test profile from a mission profile is presented as a procedure in Appendix B.

This procedure has been applied to each of the general mission profiles appearing in Appendix A which have been established for equipment used in jet propelled Navy aircraft and attached to structure adjacent to the external surface of the aircraft.

The resulting test profiles are presented graphically in Appendix C.

4.3 Multi-Mission Test Profile

Generally an aircraft is designed to perform more than one mission type. Consequently, the equipment on board will have to perform during several operating conditions and its environmental exposure will change as the mission changes. Laboratory environmental test requirements must be developed that accommodate this situation so that they address the totality of environmental exposure the equipment will experience throughout the operational phase. The study effort to develop a methodology for multi-mission situations and its formalization in terms of a procedure are described below.

4.3.1 Evaluation Criteria - In order for a method to be useful it must be technically sound, reasonable, and easily implemented. To assure the achievement of these ideals, a set of criteria was established for evaluating candidate approaches. These can be classified as:

- Representative: The derived environmental levels must closely approximate those experienced during actual use. This requires that both extreme and intermediate conditions be included, magnitudes and durations relate to total field exposure, and the sequential application of these levels be performed in such a manner as to simulate a mission.

- Simple: The method for determining test levels must be relatively simple to accomplish without a burdensome amount of research or calculation. Furthermore, the explanation of the method in a procedure, or such similar document, must be clear and not overly involved. Since MIL-STD-781C is familiar and established, it is desirable that the method retain as much of the philosophy and details of the standard as possible.

- Economical: The attendant risks to the equipment producer must approximate those associated with MIL-STD-781C therefore precluding any attempt to over design and/or increase price to assure profits. The derived test requirements are within the capability of laboratory equipment and are easily and inexpensively implemented by laboratory personnel.

4.3.2 Evaluation of Alternative Approaches - Several candidate approaches were considered and evaluated against the above criteria. All approaches assume that the relative frequency of occurrence of each mission can be determined or estimated by the user. The identification and evaluation of each candidate is presented below.

- Most Frequent Mission: This approach requires that the test profile derived from the most frequently occurring mission (highest frequency of occurrence) be used exclusively. Although it is a simple and economical approach it does not pass the test of being representative. The most frequent mission may not represent the overwhelming majority of missions. Furthermore, in terms of environmental exposure, the levels of this mission may be too benign in which case the extreme conditions are not addressed; or they may be too severe, in which case, the equipment would be unduly penalized.

- Every Mission: This approach requires that the test profiles of each mission be used in the same proportion as its frequency of occurrence. This approach is certainly representative since each environmental level would be accounted for to the same degree as anticipated in field use. This approach is simple since it directly uses all the information in each test profile. Testing economy would suffer however, since implementation of this approach would be cumbersome and expensive.

- Most Severe Conditions: This approach requires that a composite profile be constructed using the most severe environmental conditions of the individual test profiles. This is a conservative approach and its merit is in the claim, "if the equipment passes this test, it will most likely perform adequately in the field." The issue is, "at what cost?", for it certainly is not representative of the totality of field environmental exposure and it would require the equipment manufacturer to overdesign just to pass this test.

- Composite Mission Profile: This approach would require the user to take the information of the applicable mission profiles (altitudes, speeds, durations), develop a composite mission profile and then apply MIL-STD-781C to develop a test profile. It was felt that, while having merit, it would be difficult to do or explain. Furthermore since it was difficult to relate extremes in environment with extremes in mission profile conditions (e.g., Mach 1.2 at 46,000 ft. altitude results in the same vibration requirement as Mach 0.5 at 5,000 ft.), it was not clear how to assure representative exposure at environmental extremes without first converting the mission profile information to environmental requirements.

- Composite Test Profile: This approach suggests itself from the objections raised to the "composite mission" approach and requires that a composite test profile be constructed from the individual test profiles. Since the user would be working with resulting environment requirements, all extremes can be properly identified. It was felt that a representative profile could be constructed from this information if the relative frequency of occurrence of each mission were used as weighting factors to determine the proper exposure times. Additionally, it appears that determination of levels could be accomplished with minimal effort and the method could be both readily documented and implemented in the laboratory.

4.3.3 Development of Methodology - A review of the above approaches and their evaluations indicated that the "Composite Test Profile" approach most completely satisfied the selection criteria. Thus, it was decided that it would serve as the foundation for the multi-mission methodology. Furthermore, for the sake of familiarity and adequacy, it was decided that construction of the composite profile should be based, as much as possible, on the philosophy and methods embodied in MIL-STD-781C. The implications of this decision on the final profile are:

- Provisions for Cold Day and Hot Day missions in one test cycle

- Each mission to start with a 30 minute period of equipment non-operation followed by a 30 minute period of equipment operation at a temperature level corresponding to the Class limits defined in MIL-E-5400

- Provisions for sequencing environmental levels in a manner similar to a mission
- A standard method for selecting environmental levels and their durations.

Three important and interrelated issues must be resolved in the determination of the test profile for the flight analog portions of the test cycle. These are:

- Number of levels and their identification
- Duration of exposure to each level
- Sequencing of levels.

They must be addressed for each type of environment. Thus, for example, Hot Day levels should be determined independently from Cold Day levels.

It was decided that the method outlined in MIL-STD-781C for selecting vibration levels could adequately serve as a basis for the multi-mission methodology. This method requires the selection of the maximum (MAX) level and the minimum (MIN) level each for a duration equal to its anticipated exposure. An intermediate (INT) level is determined by a time-weighted averaging procedure with its duration being the sume of the time periods going into the determination of the average. For vibration, a fourth level (representing take-off conditions) is included. It should also be noted that a weighting of times by mission frequency must be incorporated to assure that relationships concerning the contribution of each level to the total are preserved. Thus the steps necessary for determination of levels and durations are outlined below:

- Identify the levels and durations for each mission from a review of the individual test profiles
- Determine the relative frequency of occurrence of each mission
- Weigh each duration by its corresponding relative frequency
- Summarize by listing each unique level and sum the corresponding weighted times
- MAX is the highest level and its total weighted duration is the test time
- MIN is the lowest level and its duration is the total weighted duration
- INT is determined by a time weighted average of all levels between MAX and MIN. Its duration is the sum of the times going into its determination.

In order to represent a mission adequately, in that temperature cycling and variations in temperature rate of change are accommodated, it was determined that a sequencing of INT, MAX, MIN should apply. This would provide for two temperature reversals and four opportunities to apply a temperature rate of change during each mission analog.

The entire methodology including ground rules for contingency situations is documented in the procedure appearing in Appendix D.

APPENDIX A

AIRCRAFT MISSION PROFILES

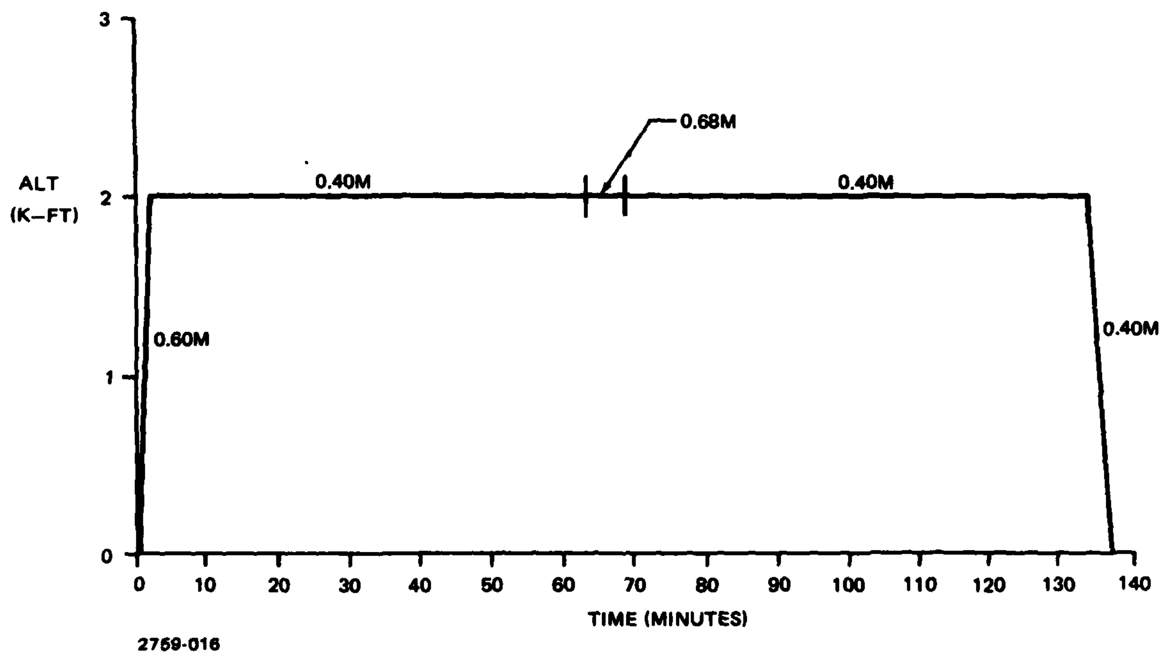


Figure A-1 Attack Aircraft Mission Profile (Lo-Lo-Lo-)

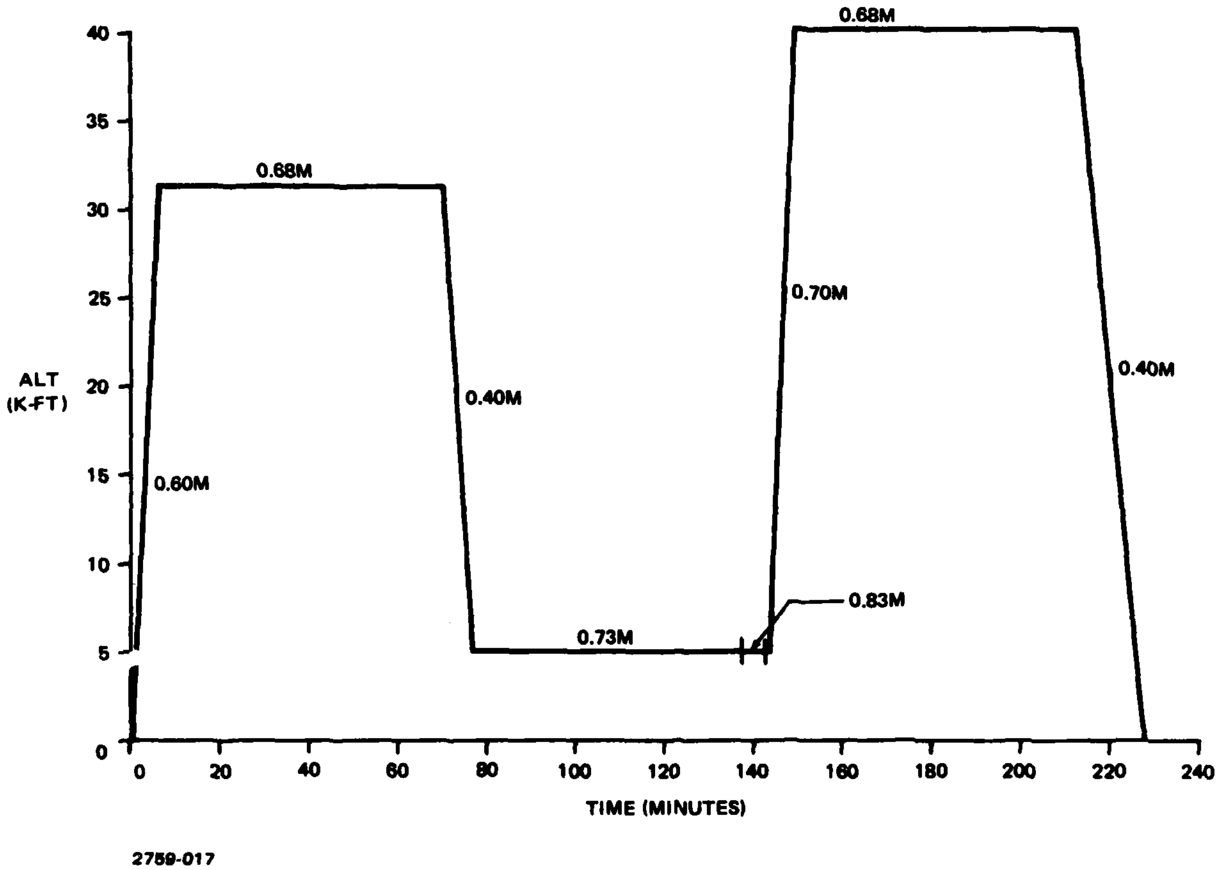
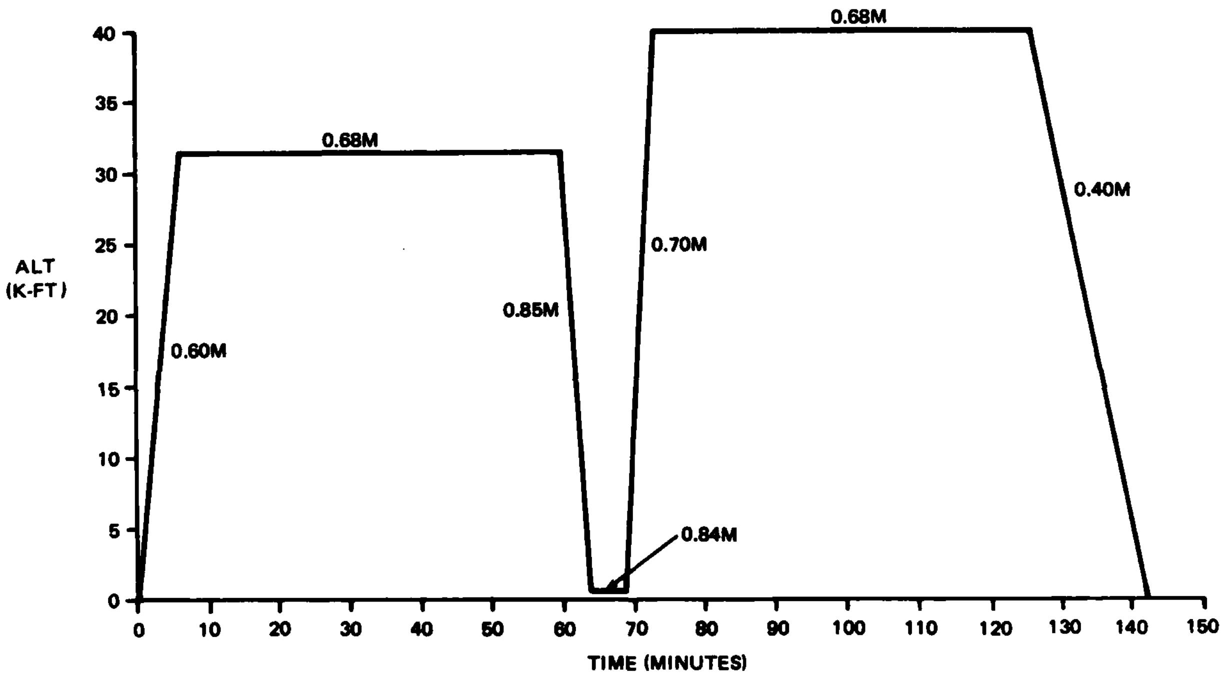


Figure A-2 Attack Aircraft Mission Profile (Close Support)



2759-018

Figure A-3 Attack Aircraft Mission Profile (Hi-Lo-Hi)

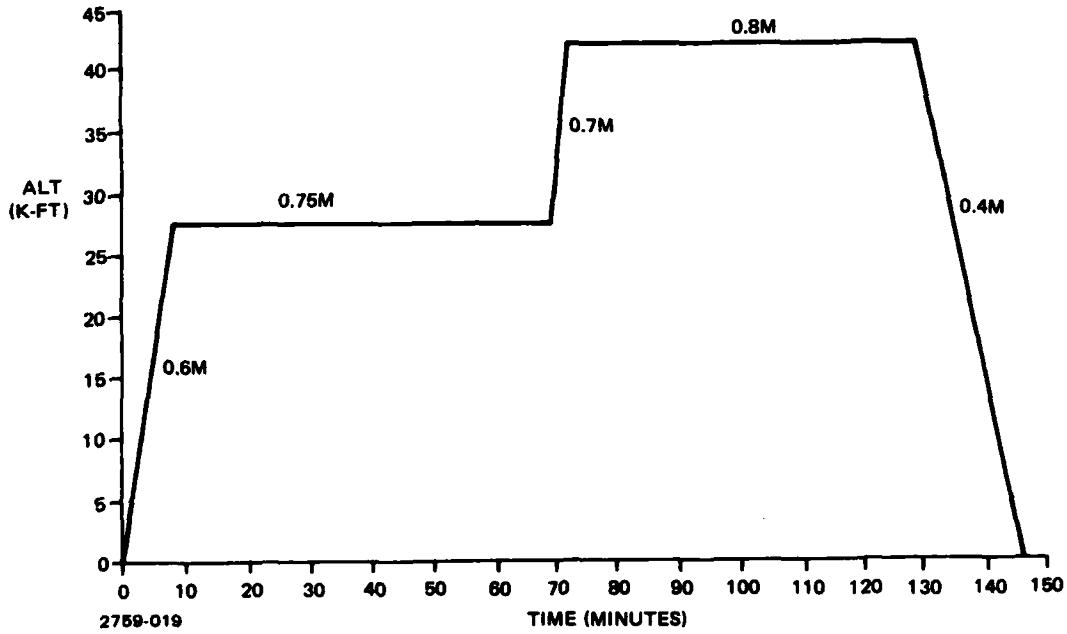


Figure A-4 Attack Aircraft Mission Profile (Hi-Hi-Hi)

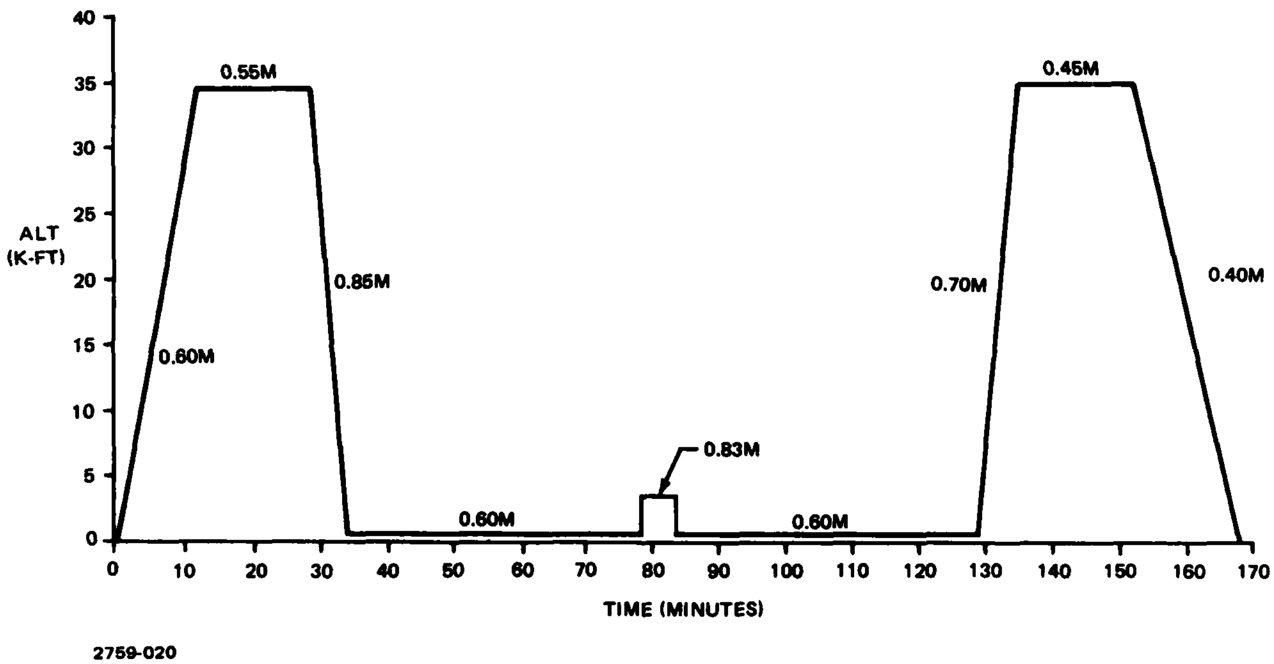


Figure A-5 Attack Aircraft Mission Profile (Hi-Lo-Lo-Hi)

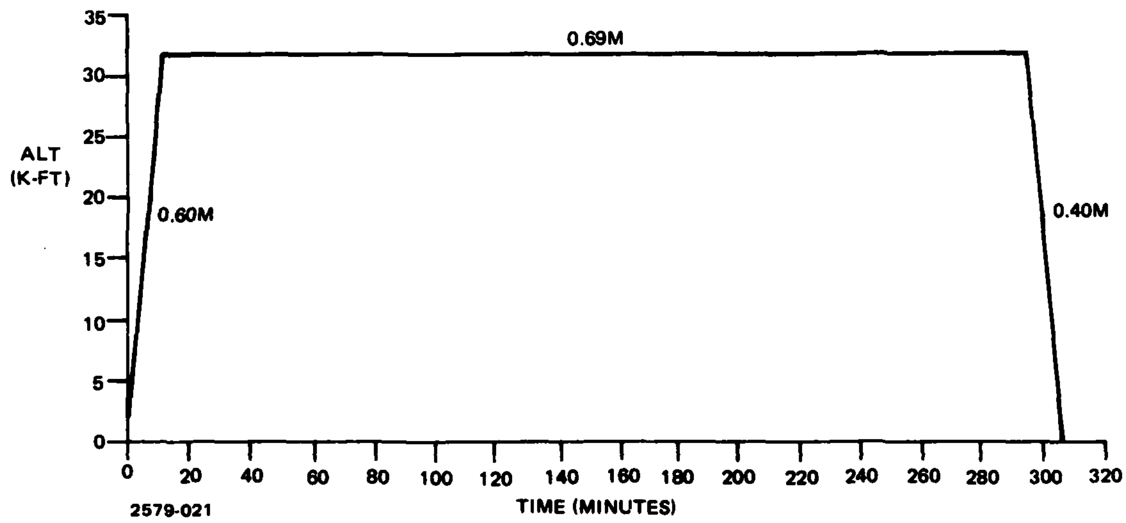


Figure A-6 Attack Aircraft Mission Profile (Ferry)

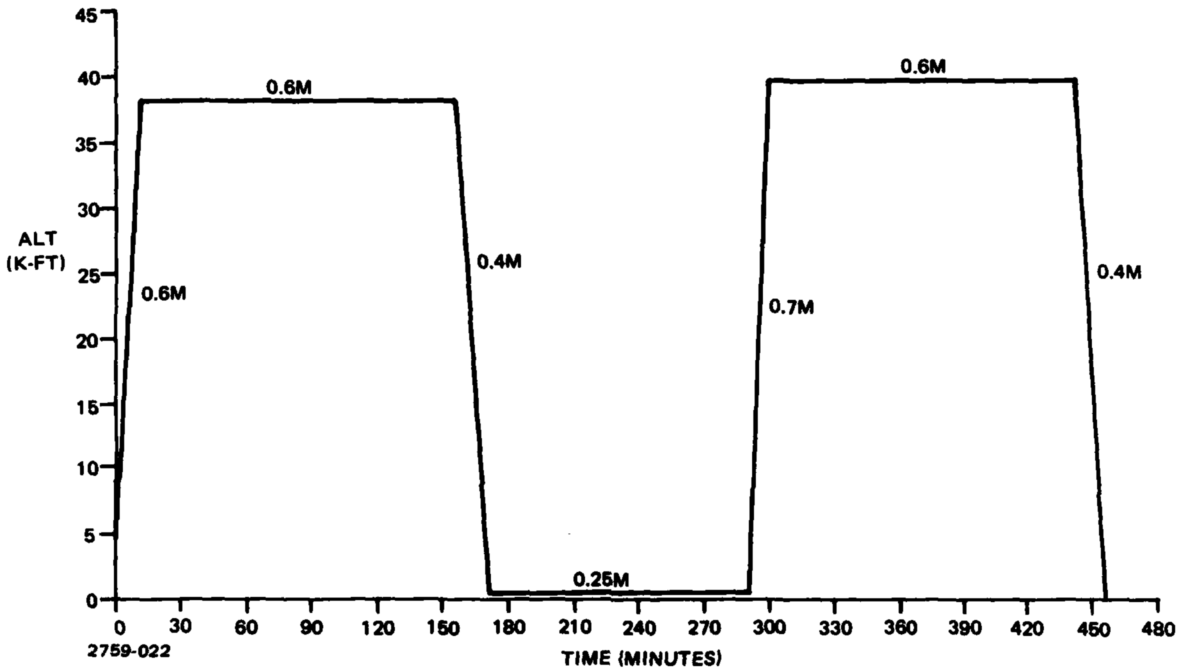
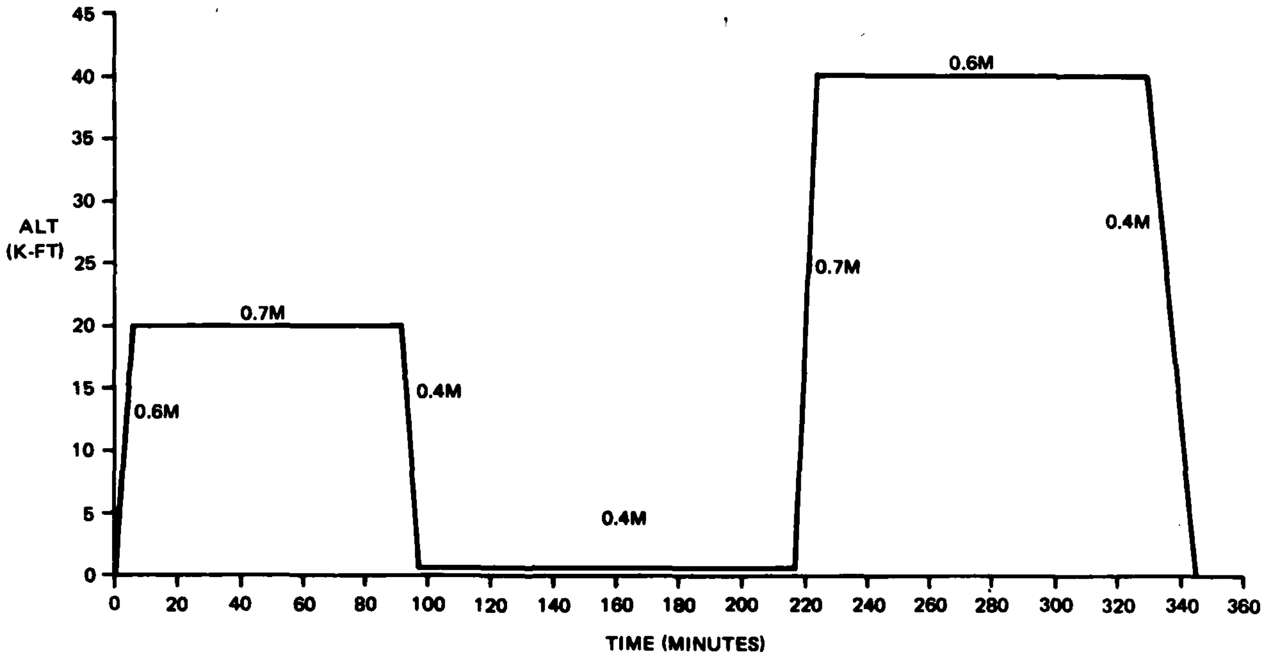


Figure A-7 ASW Aircraft Mission Profile (Contact Investigation – Hi)



2759-023

Figure A-8 ASW Aircraft Mission Profile (Contact Investigation - Int)

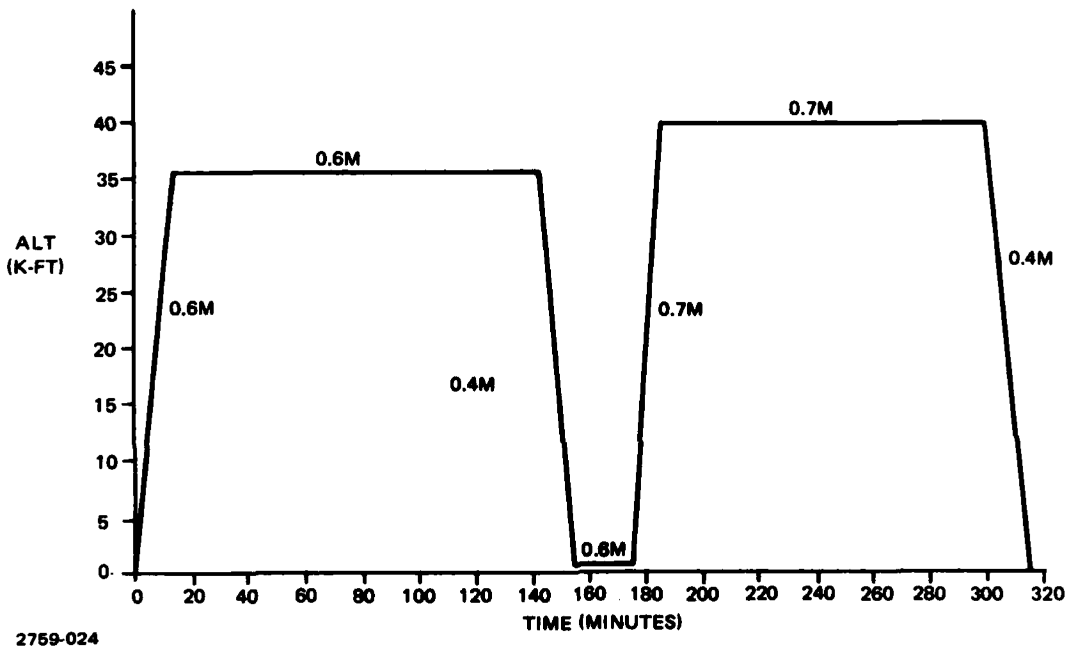
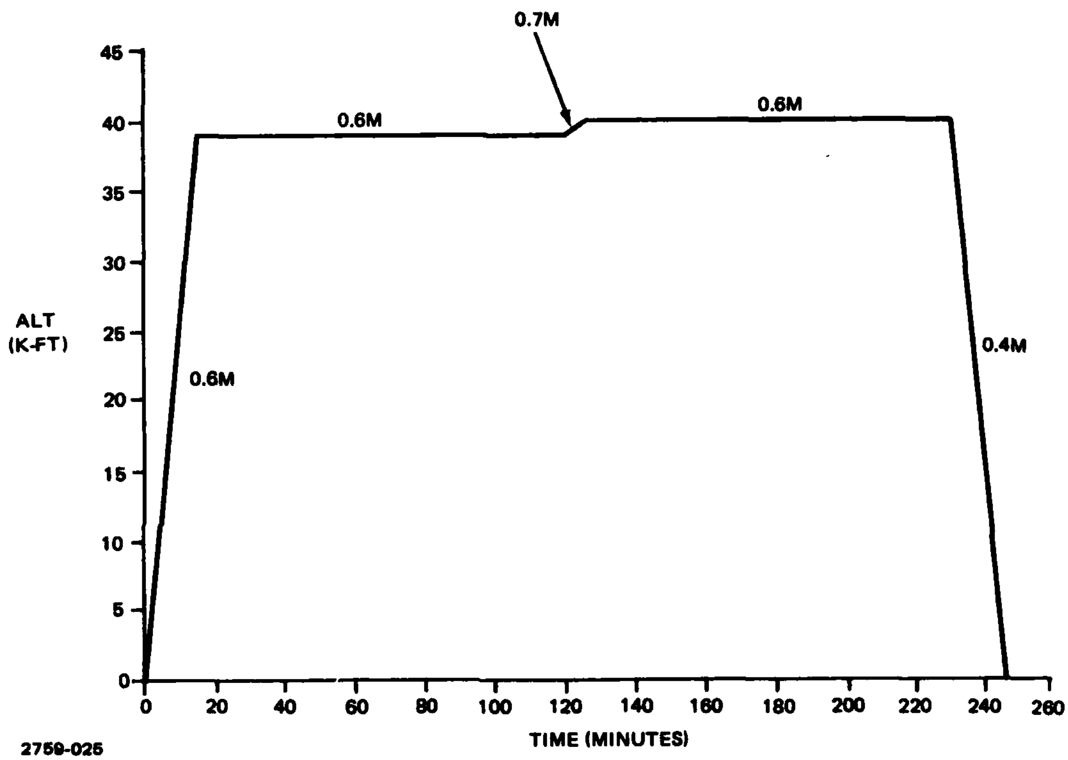


Figure A-9 ASW Aircraft Mission Profile (Mine Laying)



2759-025

Figure A-10 ASW Aircraft Mission Profile (Hi-Hi-Hi)

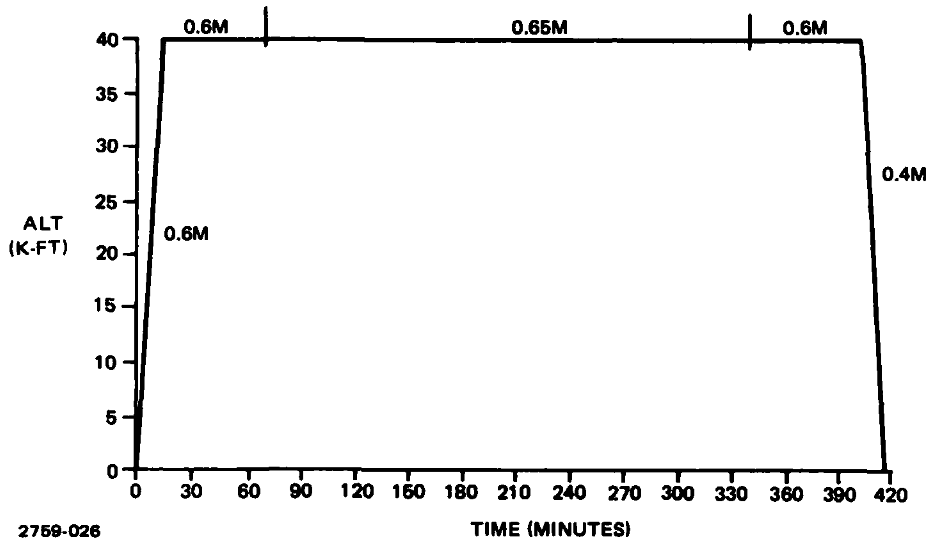
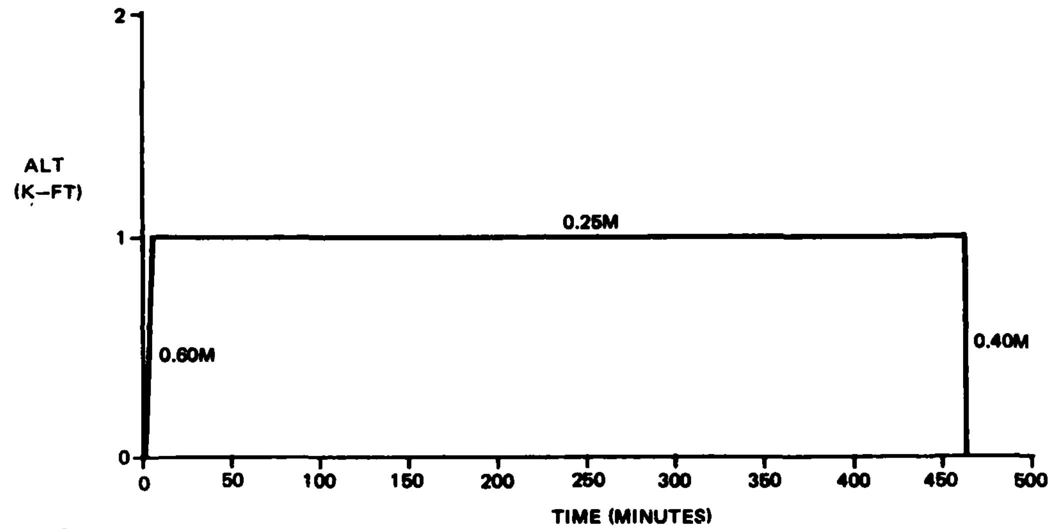
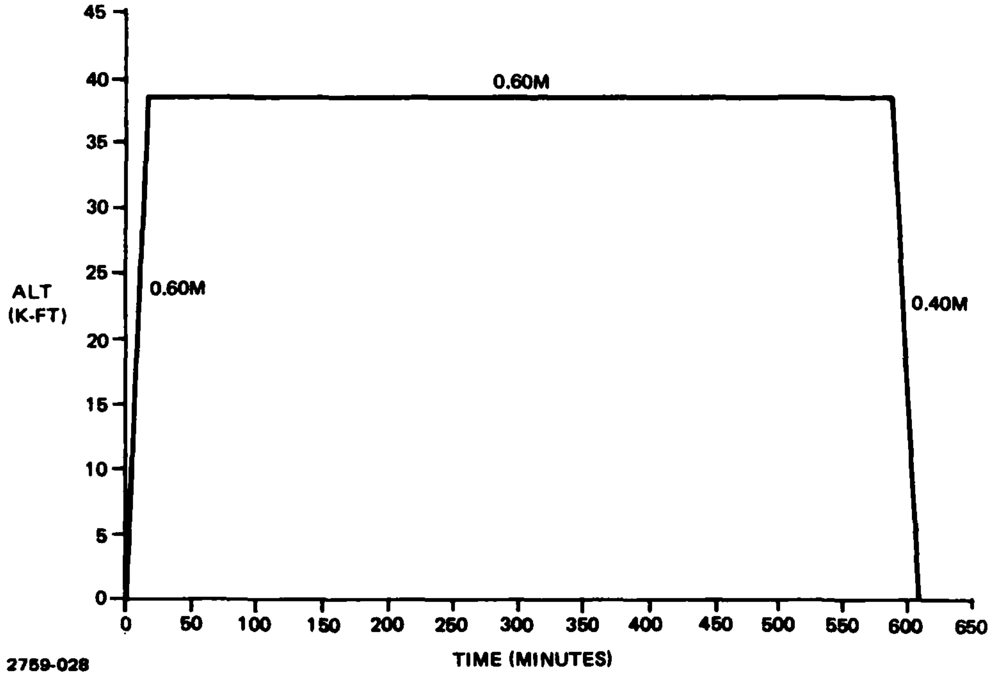


Figure A-11 ASW Aircraft Mission Profile (Search & Attack)



2759-027

Figure A-12 ASW Aircraft Mission Profile (Surface Surveillance)



2759-028

Figure A-13 ASW Aircraft Mission Profile (Ferry)

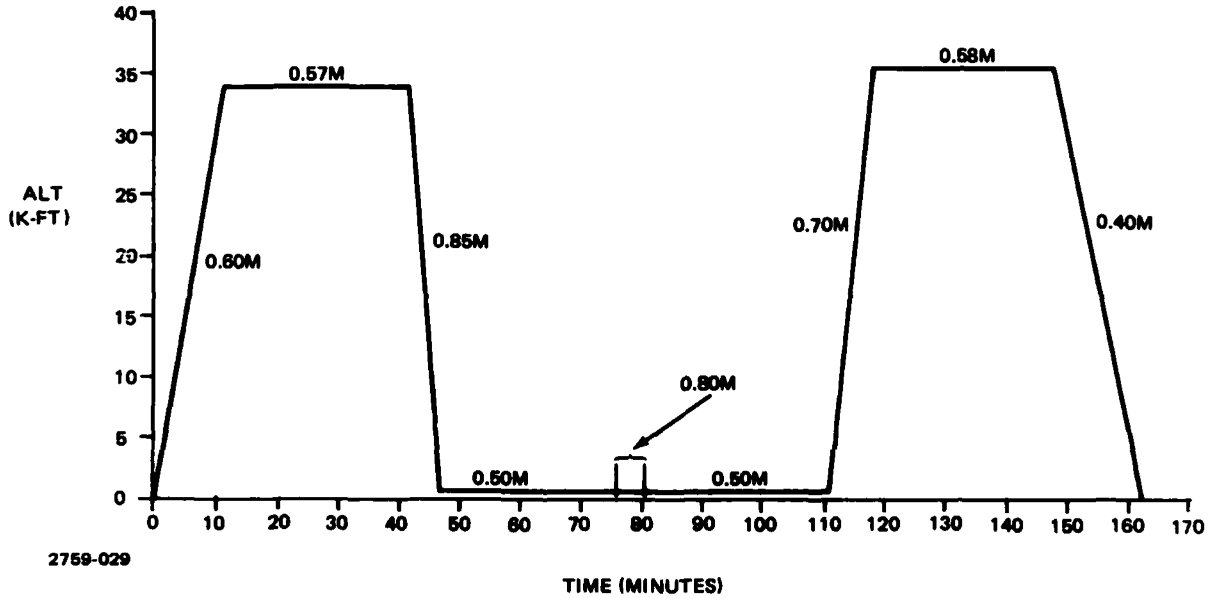
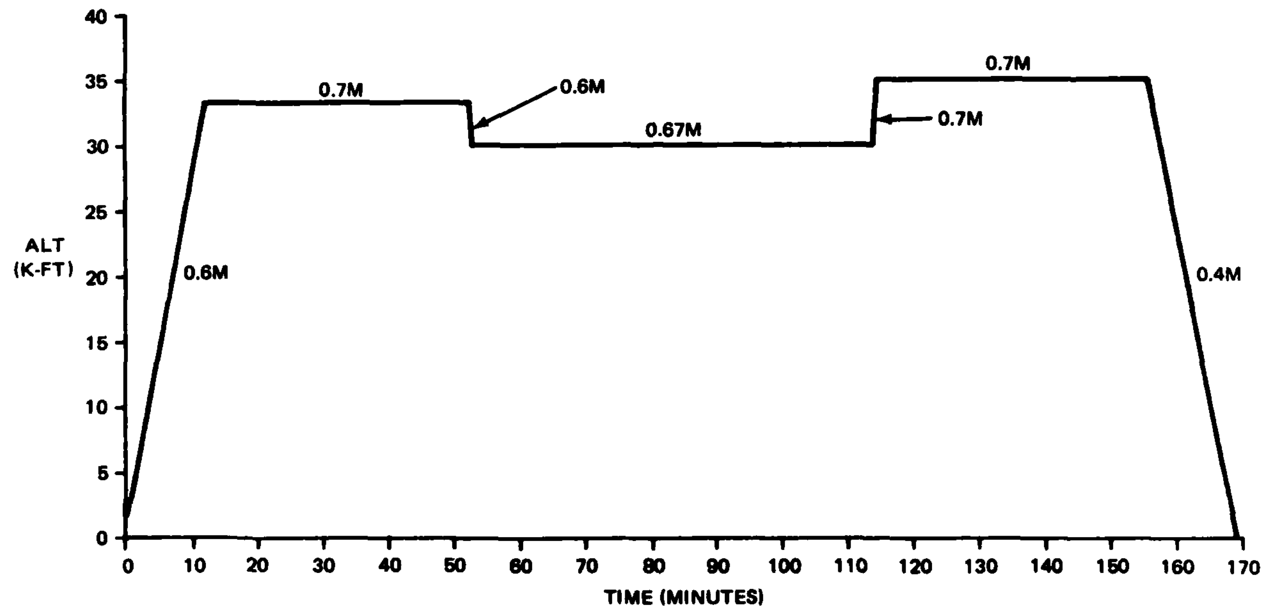
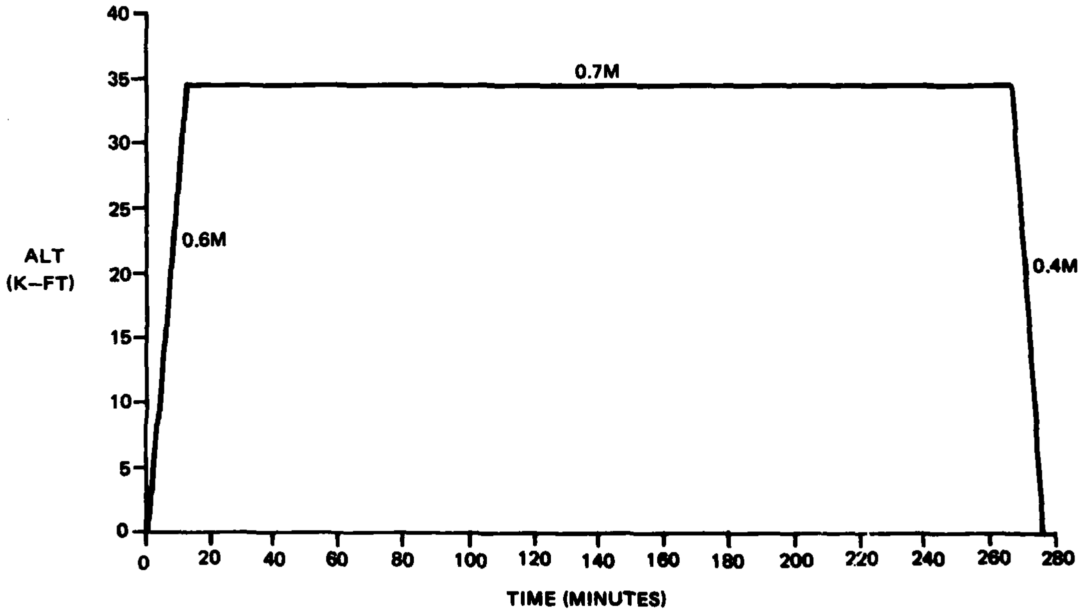


Figure A-14 ECM Aircraft Mission Profile (Penetration)



2759-030

Figure A-15 ECM Aircraft Mission Profile (Stand-Off)



2759-031

Figure A-16 ECM Aircraft Mission Profile (Ferry)

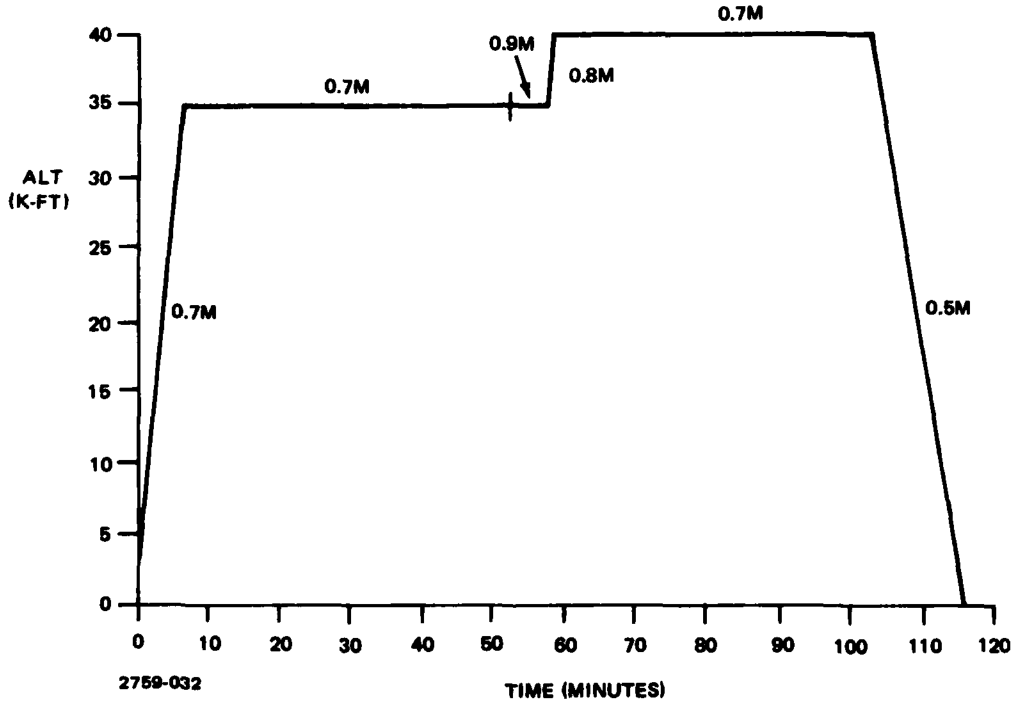


Figure A-17 Fighter Aircraft Mission Profile (Hi-Hi-Hi)

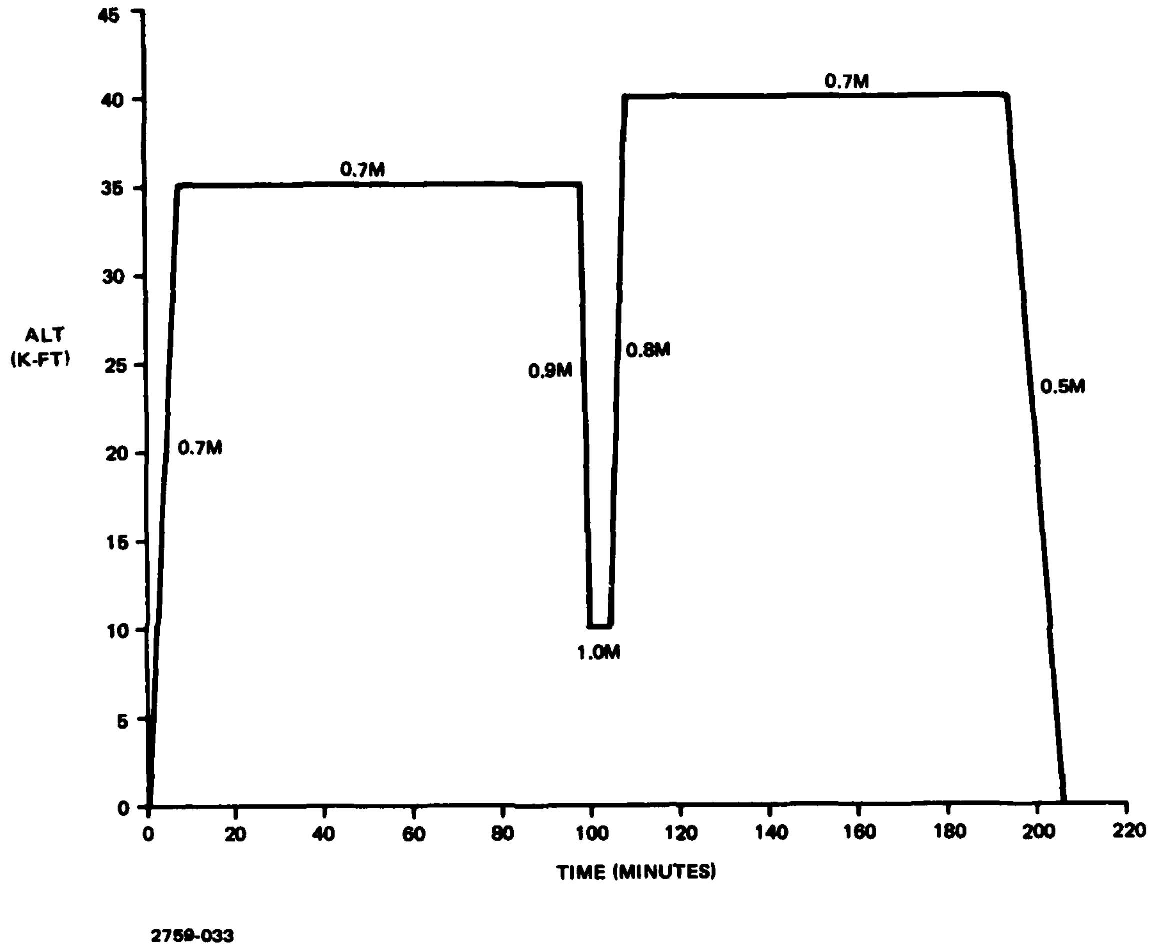


Figure A-18 Fighter Aircraft Mission Profile (Escort)

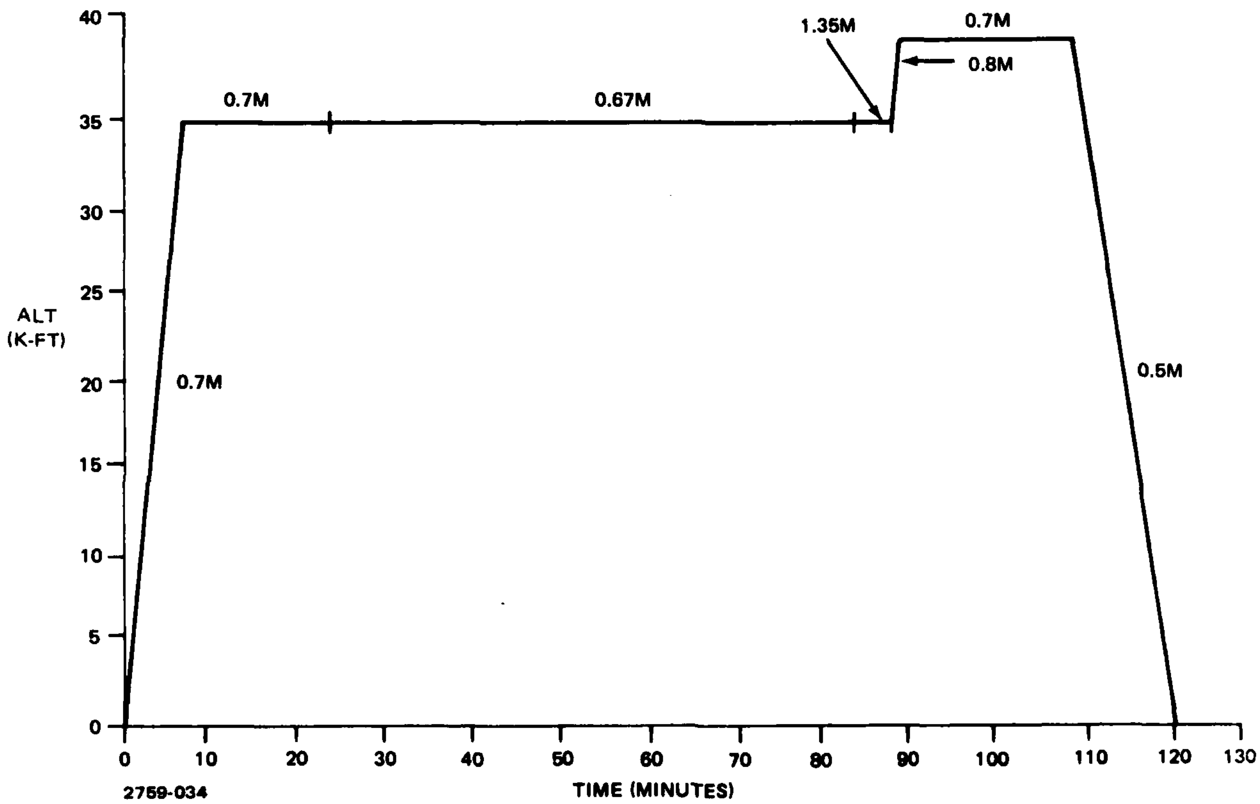


Figure A-19 Fighter Aircraft Mission Profile (Air Defense/CAP)

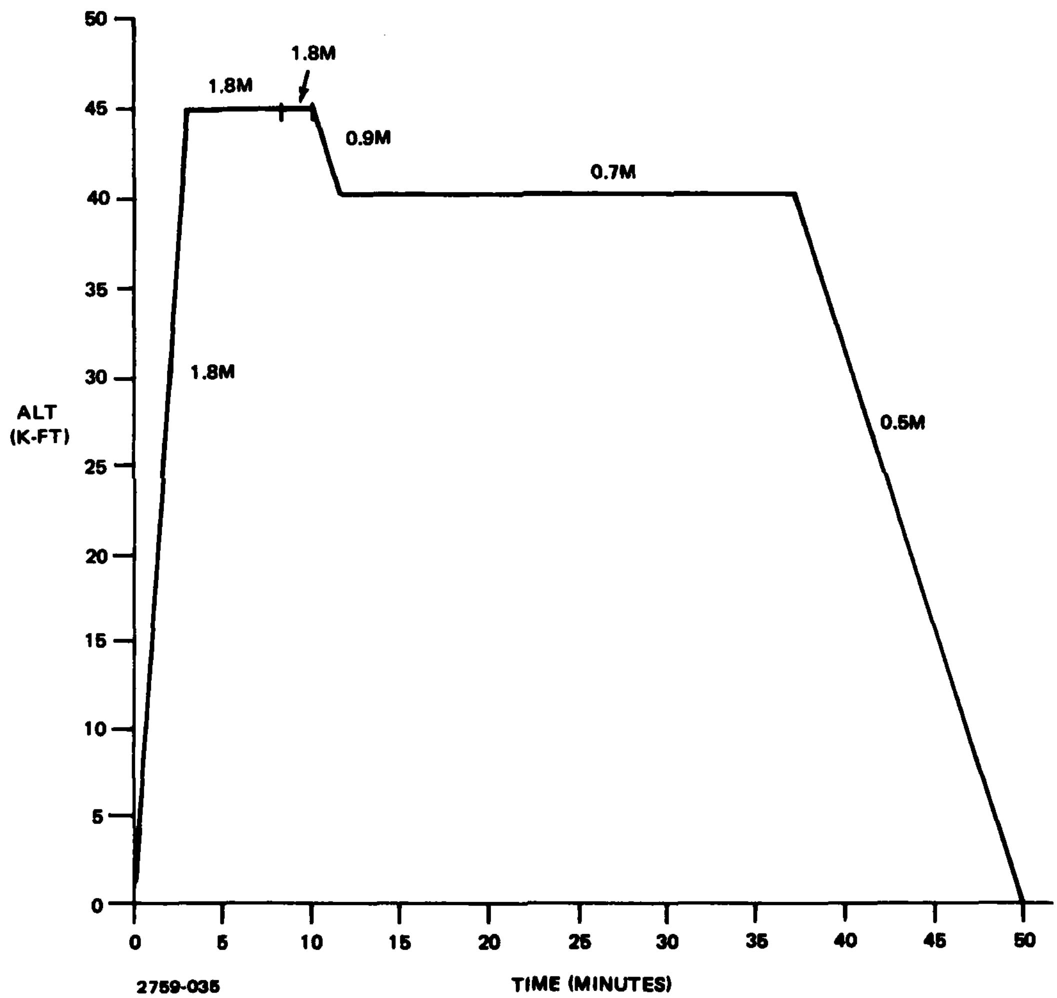
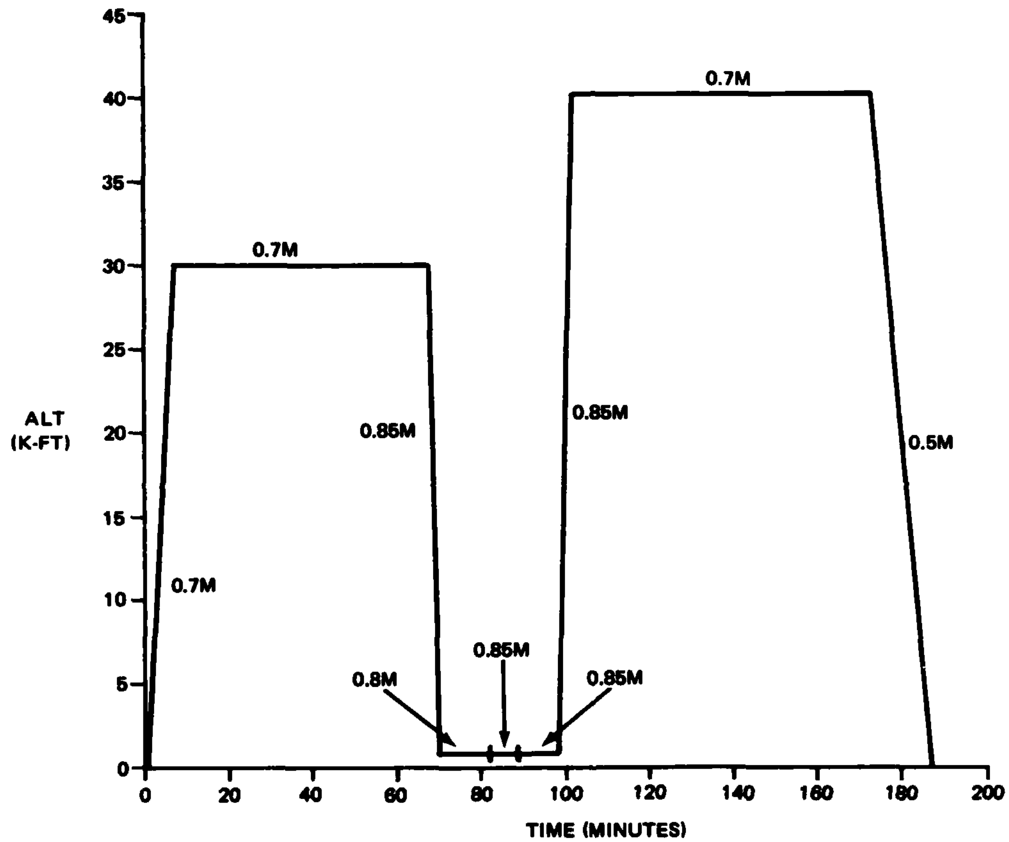


Figure A-20 Fighter Aircraft Mission Profile (Intercept)



2759-036

Figure A-21 Fighter Aircraft Mission Profile (Hi-Lo-Lo-Hi)

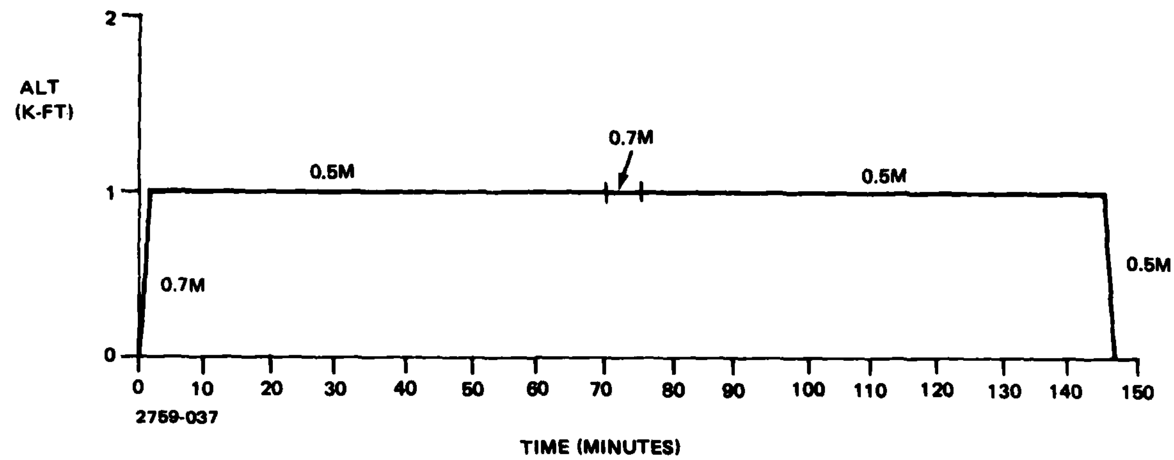


Figure A-22 Fighter Aircraft Mission Profile (Lo-Lo-Lo)

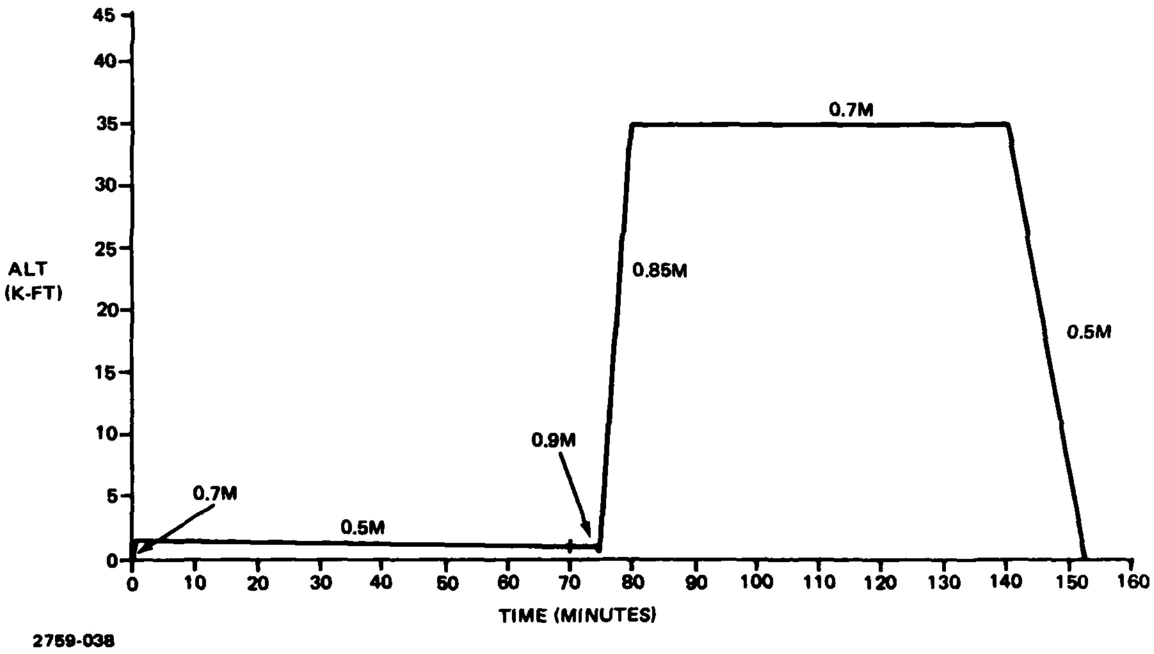


Figure A-23 Fighter Aircraft Mission Profile (Lo-Lo-Hi)

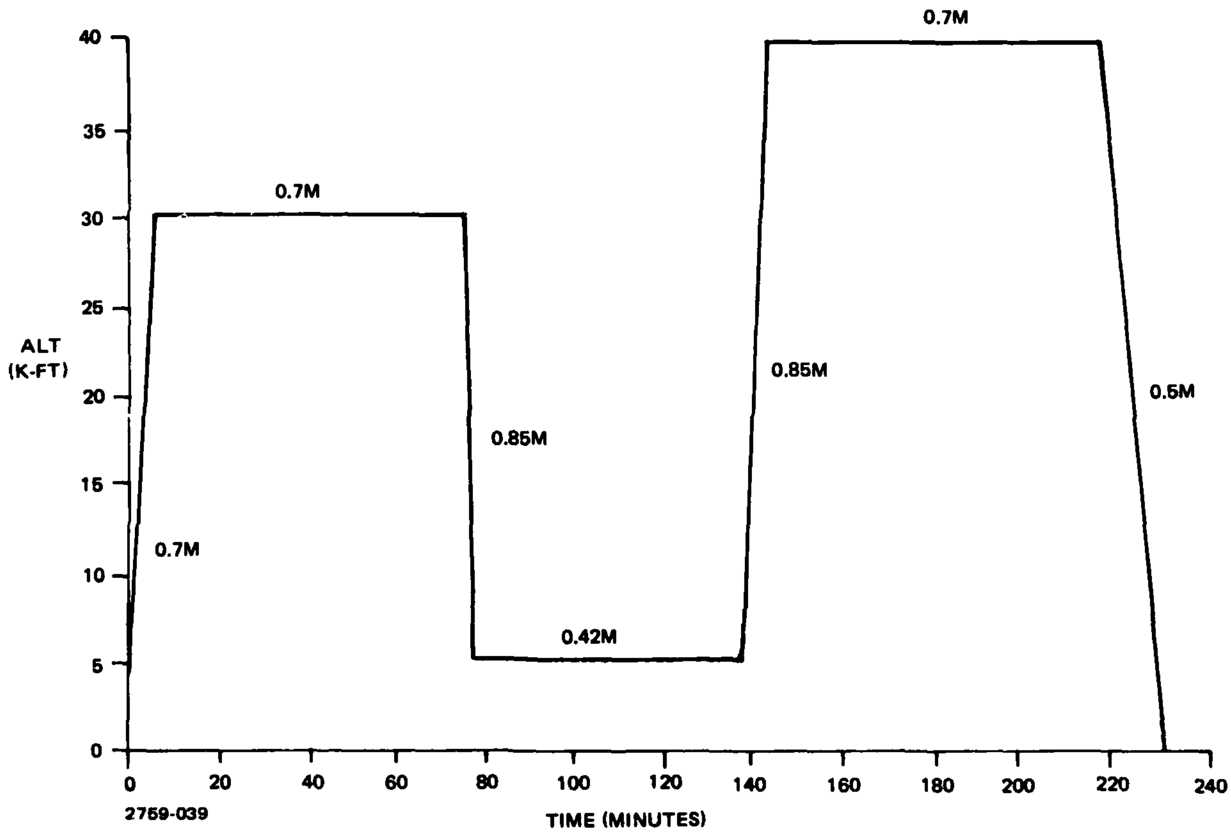
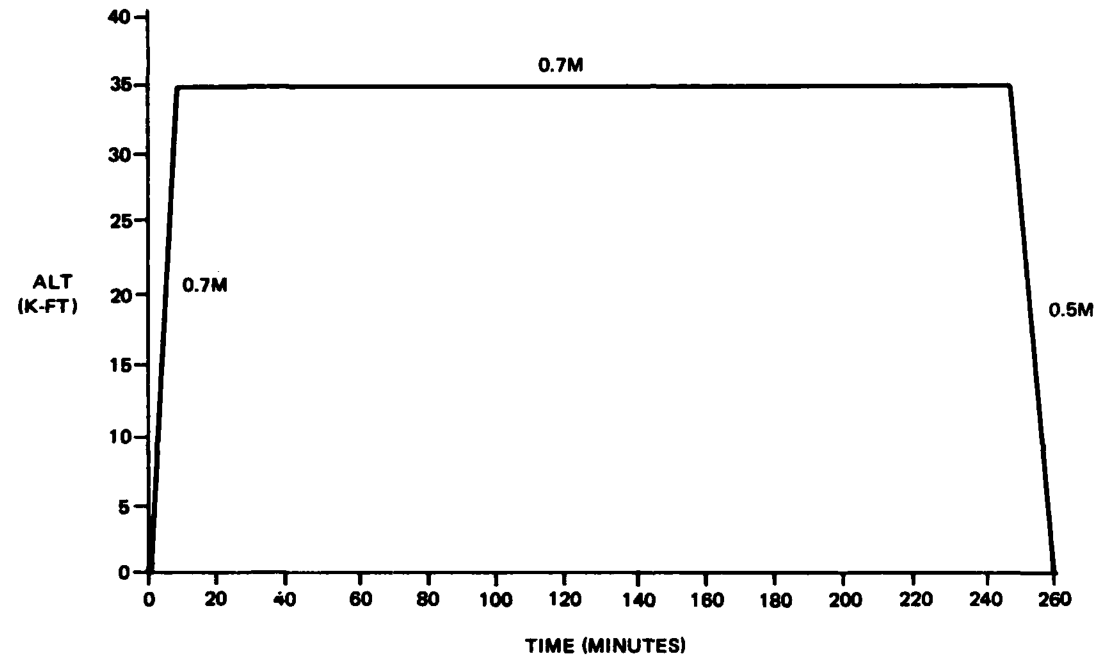


Figure A-24 Fighter Aircraft Mission Profile (Close Support)



2759-040

Figure A-25 Fighter Aircraft Mission Profile (Ferry)

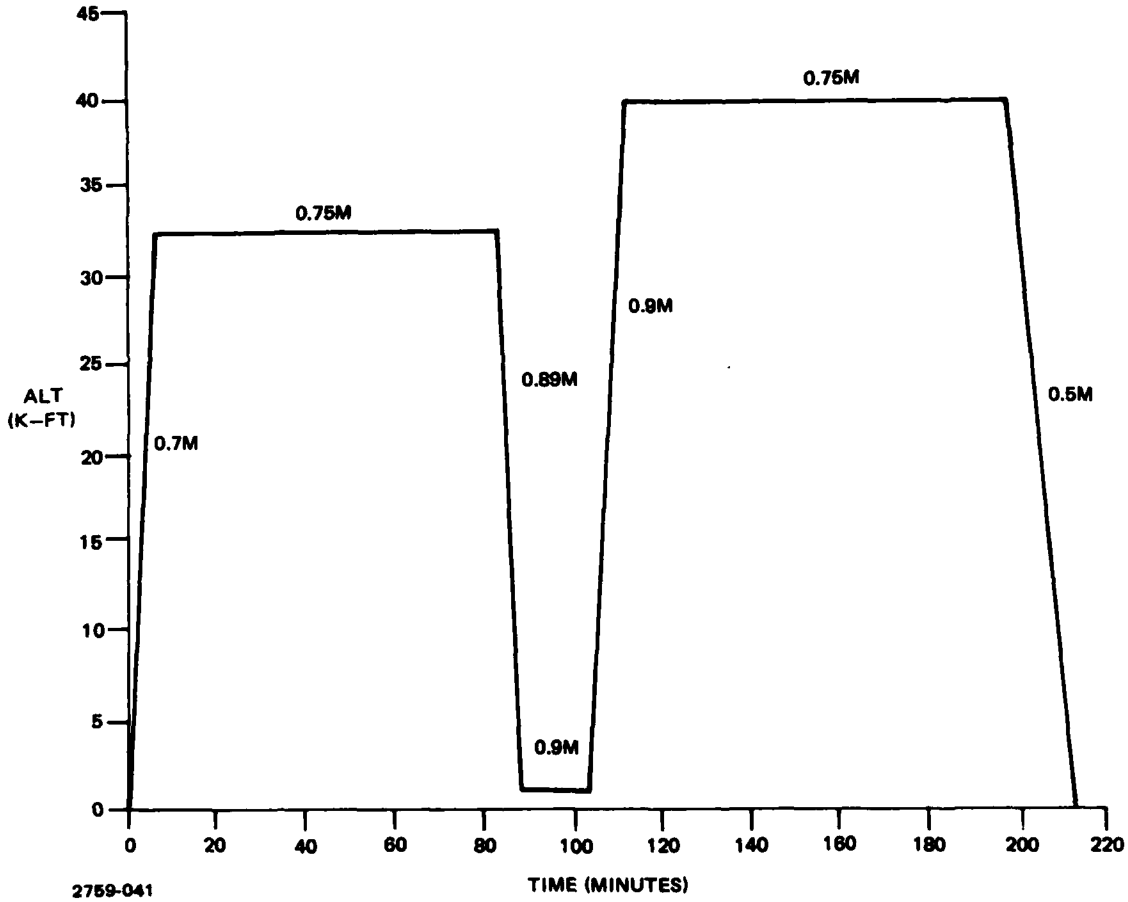
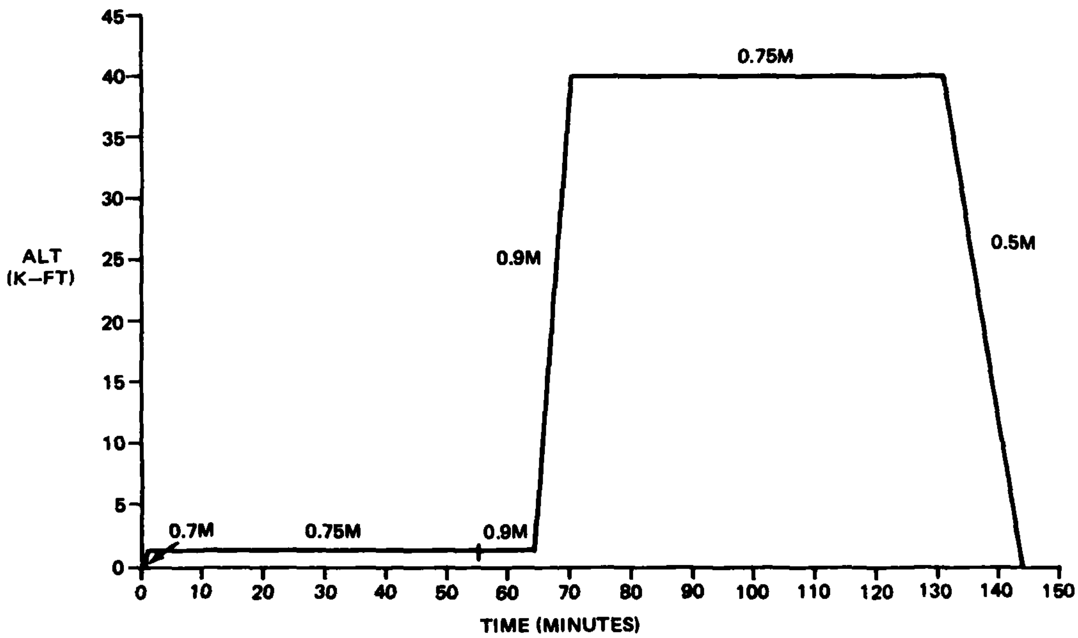
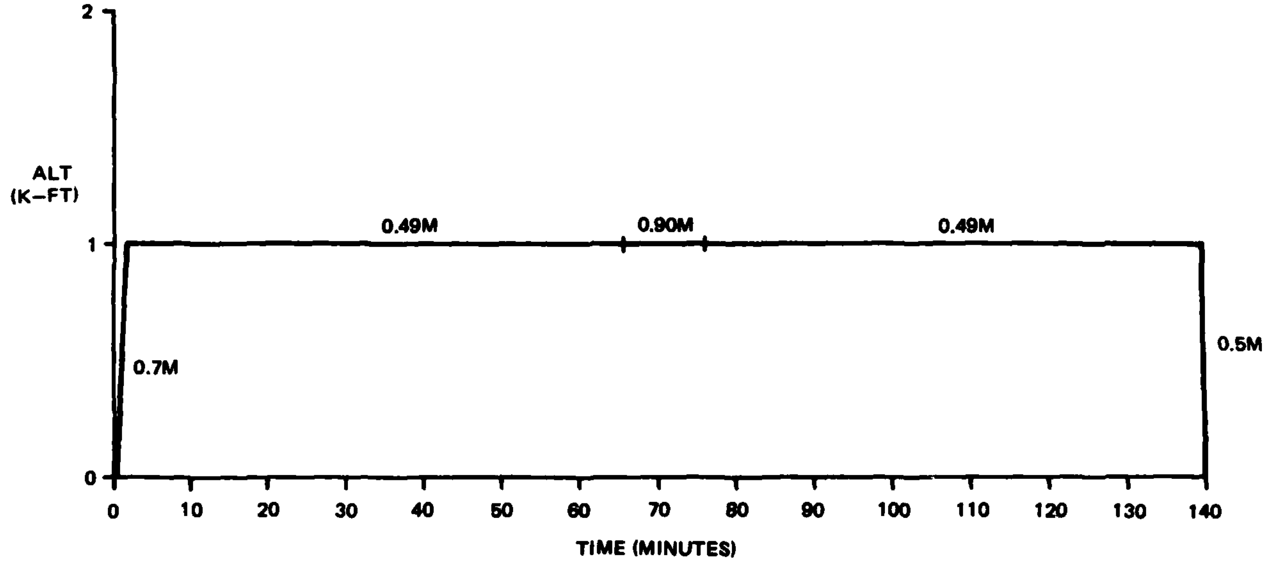


Figure A-26 Reconnaissance Aircraft Mission Profile (Hi-Lo-Hi)



2759-042

Figure A-27 Reconnaissance Aircraft Mission Profile (Lo - Lo - Hi)



2759-043

Figure A-28 Reconnaissance Aircraft Mission Profile (Lo-Lo-Lo)

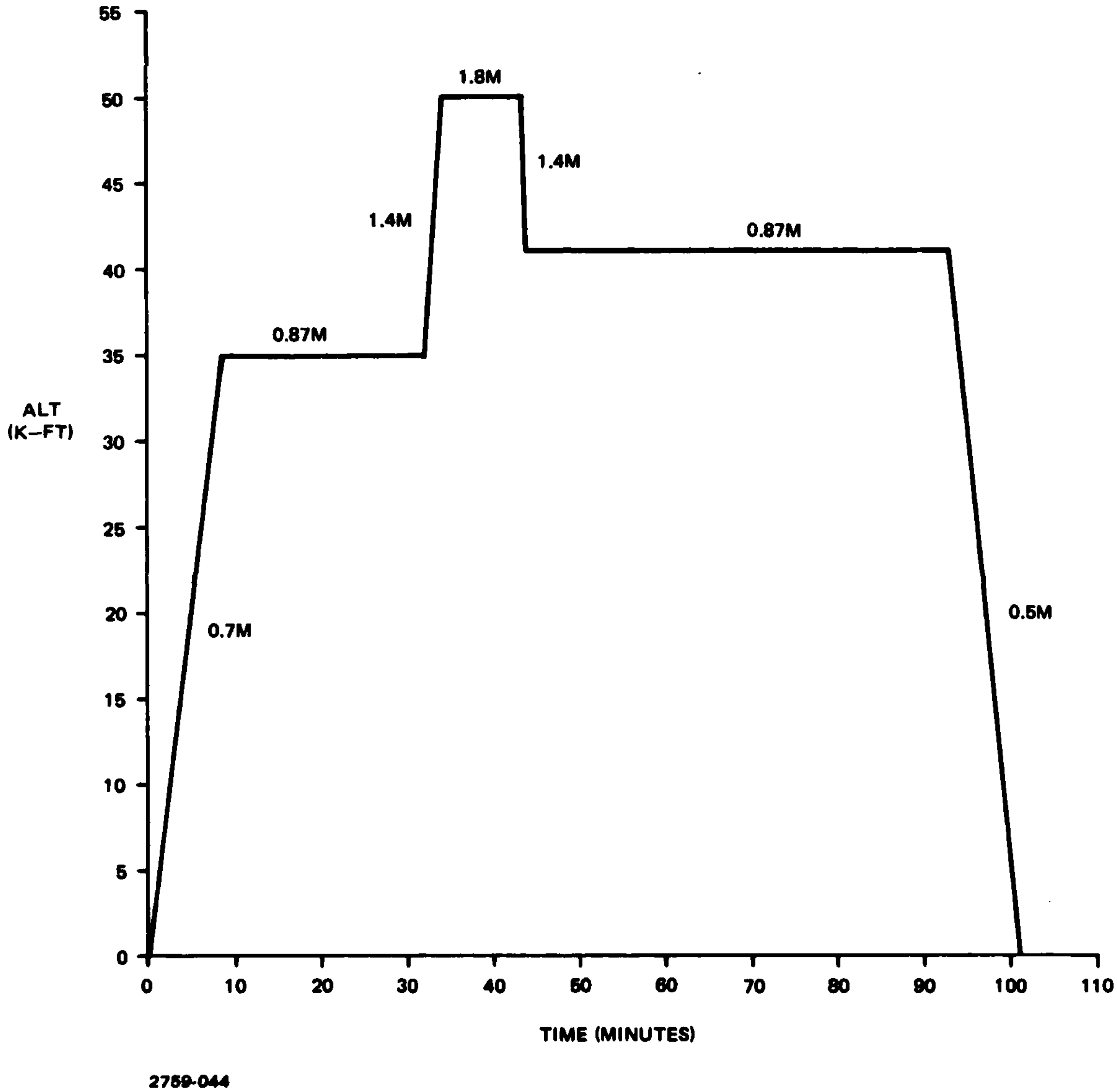


Figure A-29 Reconnaissance Aircraft Mission Profile (Hi - Supersonic)

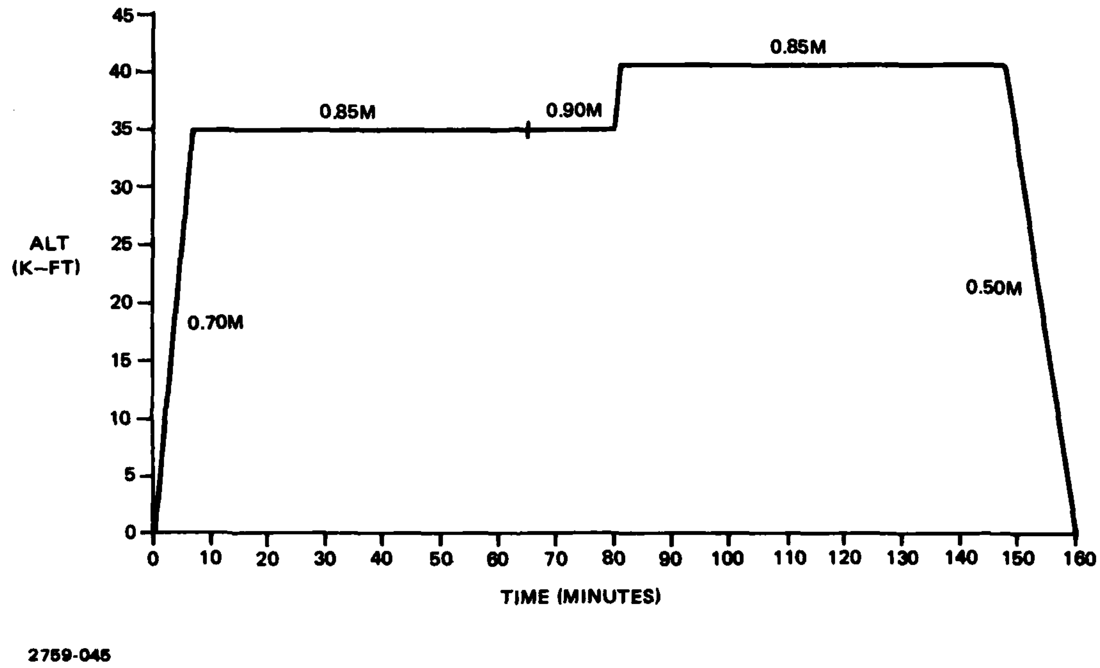


Figure A-30 Reconnaissance Aircraft Mission Profile (Hi – Subsonic)

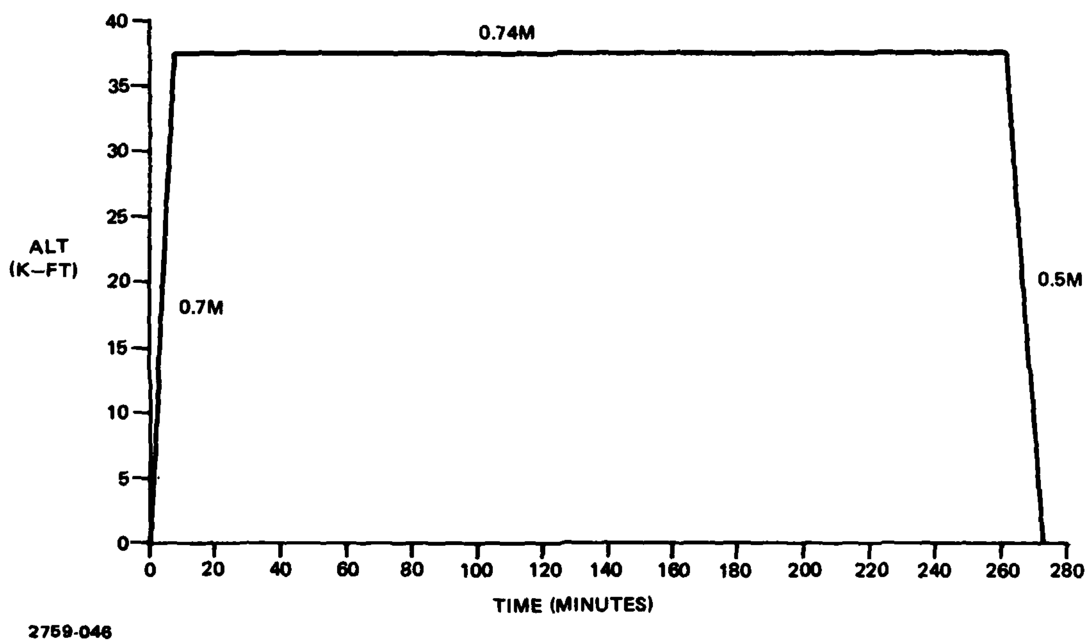


Figure A-31 Reconnaissance Aircraft Mission Profile (Ferry)

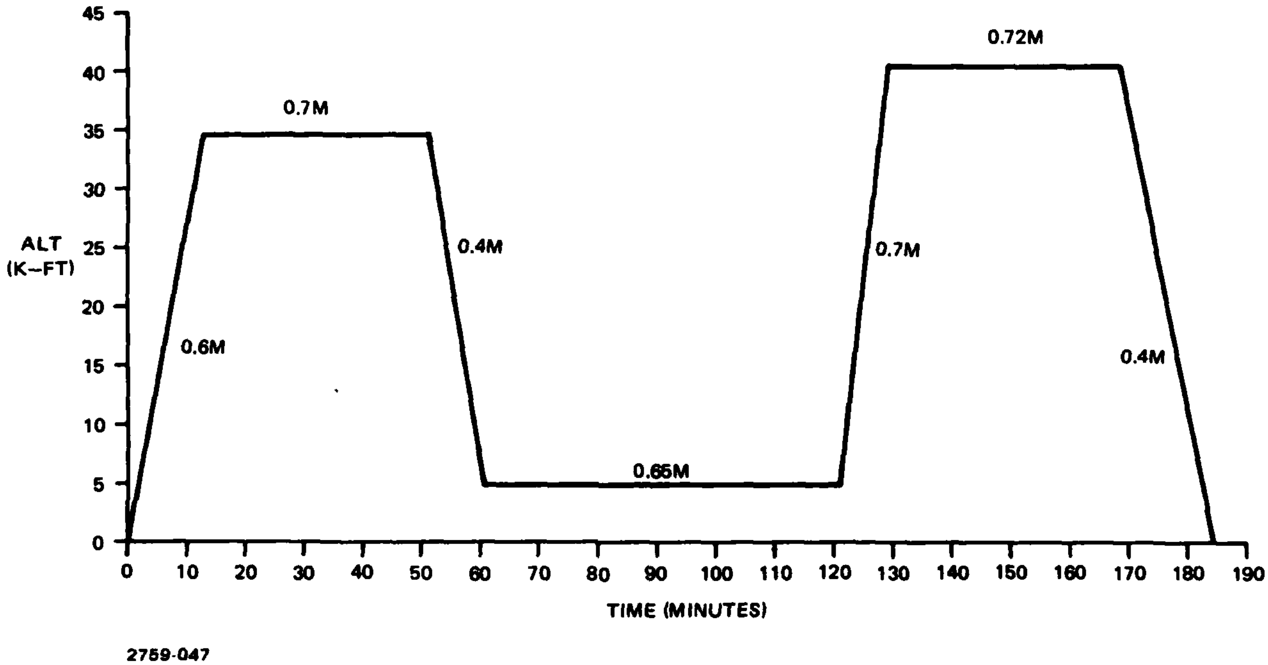
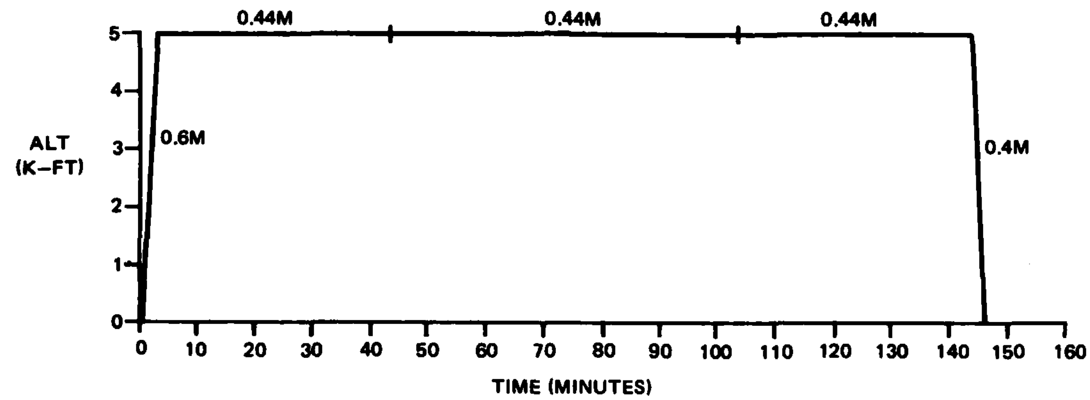


Figure A-32 Tanker Aircraft Mission Profile (Hi - Lo - Hi Refuel)



2759-048

Figure A-33 Tanker Aircraft Mission Profile (Lo-Lo-Lo Refueling)

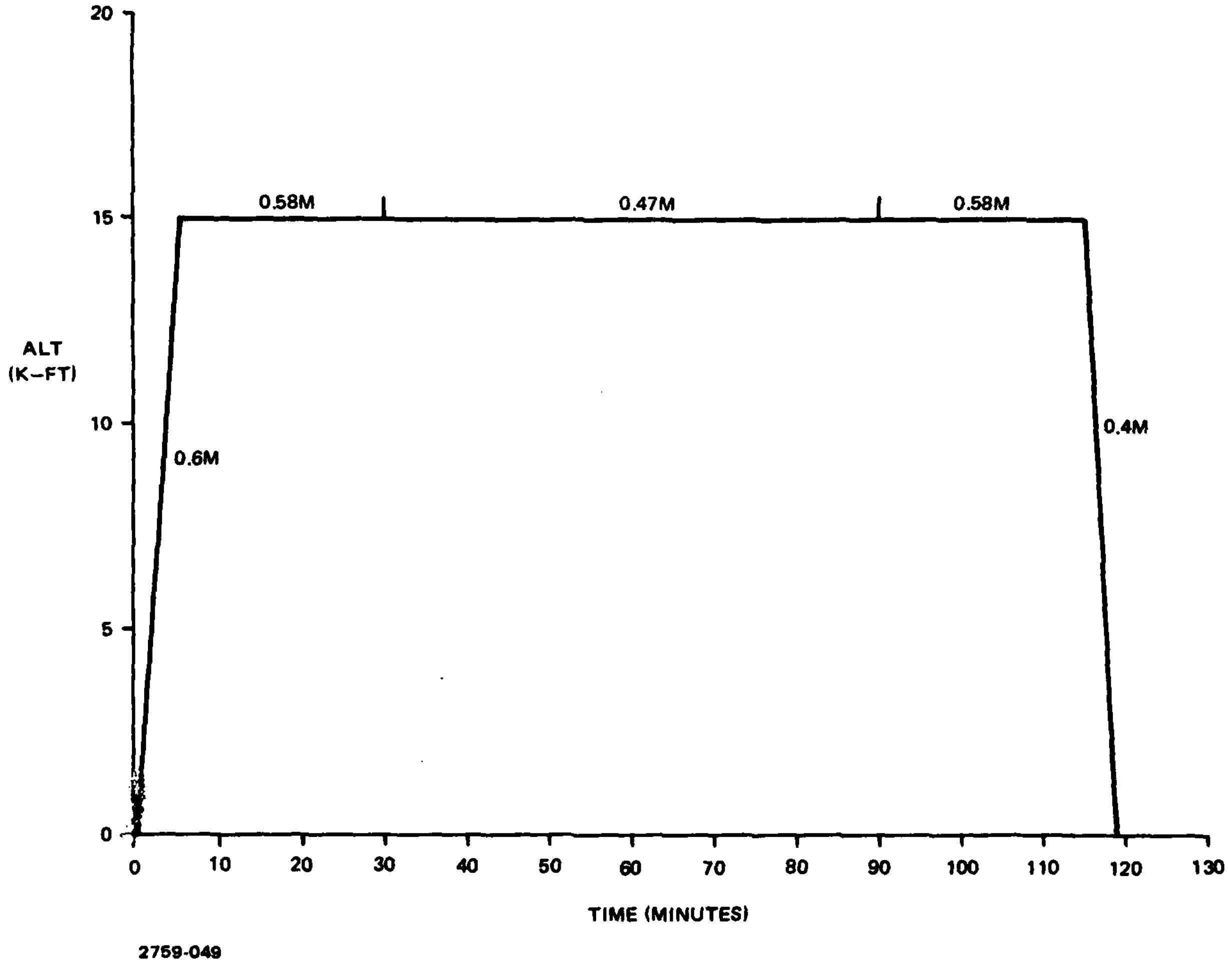


Figure A-34 Tanker Aircraft Mission Profile (Strike Refuel)

APPENDIX B

PROCEDURE FOR THE DEVELOPMENT
OF ENVIRONMENTAL TEST PROFILES

PROCEDURE FOR THE DEVELOPMENT OF ENVIRONMENTAL TEST PROFILES

1. INTRODUCTION

The test profile shall be developed from the aircraft mission profile which has been established in terms of altitude, Mach No. and duration.

The conditions which must be defined are temperature, vibration, humidity and input voltage. Each test cycle shall consist of two missions. One mission starts from a cold environment and proceeds to a hot environment. The second starts in a hot environment and returns to a cold environment. Analysis of the mission profile shall be undertaken to determine the specific environmental stress levels for each of the mission flight phases, e.g., take-off, climb, combat, landing, etc., as well as for the ground conditions. In addition to the information available from the mission profile, certain other facts must be known. These include:

- Equipment class (per MIL-E-5400)
- Equipment location within the aircraft
- Type of cooling for compartment in which equipment is located (air conditioned or ram air cooled)
- Type of equipment cooling (ambient or supplemental air).

2. DETAILED PROCEDURE

2.1 Tabulation

A table, similar to that shown in Table B-1 (which has been included as an example using mission profile information from a jet-propelled Navy attack aircraft for equipment attached to structure adjacent to the external surface of the aircraft) shall be prepared for the specific aircraft and equipment under consideration. This tabulation shall include:

- Mission Phase
- Duration (minutes)
- Altitude (K feet)
- Mach No.

Table B-1 Environmental Profile Data (Example)

MISSION PHASE	DURATION (MIN)	ALTITUDE (K-FT)	MACH NO.	COMPART. TEMP. (°C)	TEMP. RATE OF CHANGE (°C/MIN)	DYN. PRES. (q)	W_0 (g^2/Hz)	W_1 (g^2/Hz)	HUMIDITY DEWPT. TEMP (°C)	EQUIP. OPER.
GROUND NON-OPER., COLD DAY	30	0	–	-54		–	–	–	N/A	OFF
GROUND OPER., COLD DAY	30	0	–	-54		–	–	–	N/A	ON
TAKE OFF	1	0	0.60		1.83	–	0.002	0.001	N/A	ON
CLIMB TO ALTITUDE	11	1-34	0.60			280	0.0005	0.00025	N/A	ON
CRUISE	18	34	0.55	-32		110	0.00008	0.00004	N/A	ON
DIVE	4.25	34-S.L.	0.85		3.05	541	0.0019	0.0009	N/A	ON
CRUISE	45	S.L.	0.60	-19		541	0.0019	0.0009	N/A	ON
CRUISE (COMBAT)	5	S.L.	0.83	-10		1024	0.007	0.0035	N/A	ON
CRUISE	45	S.L.	0.60	-19		541	0.0019	0.0009	N/A	ON
CLIMB	7	S.L.-35	0.70		1.85	375	0.0009	0.00045	N/A	ON
CRUISE	18	35	0.45	-32		76	0.00004	0.00002	N/A	ON
DESCEND TO HOT DAY	14	35-0	0.40		7.35	124	0.0001	0.00005	N/A	ON
GROUND NON-OPER., HOT DAY	30	0	–	+71		–	–	–	31	OFF
GROUND OPER., HOT DAY	30	0	–	+71		–	–	–	31	ON
TAKE OFF	1	0	0.60		5.00	–	0.002	0.001	N/A	ON
CLIMB TO ALTITUDE	11	1-34	0.60			280	0.0005	0.00025	N/A	ON
CRUISE	18	34	0.55	+11		110	0.00008	0.00004	N/A	ON
DIVE	4.25	34-S.L.	0.66		14.1	541	0.0019	0.0009	N/A	ON
CRUISE	45	S.L.	0.60	+71		541	0.0019	0.0009	N/A	ON
CRUISE (COMBAT)	5	S.L.	0.83	+71		1024	0.007	0.0035	N/A	ON
CRUISE	45	S.L.	0.60	+71		541	0.0019	0.0009	N/A	ON
CLIMB	7	S.L.-35	0.70		8.71	375	0.0009	0.00045	N/A	ON
CRUISE	18	35	0.45	+10		76	0.00004	0.00002	N/A	ON
DESCEND TO COLD DAY	14	35-0	0.40		4.57	124	0.0001	0.00005	N/A	ON

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- Compartment Temperature (°C)
- Temperature Rate of Change (°C/Min.)
- Dynamic Pressure (q)
- Power Spectral Density - W_o (g^2/Hz.)
- Power Spectral Density - W_1 (g^2/Hz.)
- Humidity
- Equipment Operation
- Input Voltage

2.2 Completing the Table

The following paragraphs discuss the sources from which data shall be obtained and the methodology to be utilized in entering this data in the Table. This methodology, which describes how each stress level shall be obtained, presumes that no measured data, either specific or for similar applications is available and utilizes the information contained in Appendix B, of Mil-Std-781C (as amended herein) as the source of information. If measured data, specific or similar is available, then those stress level values shall be entered directly into Table B-1, "Environmental Profile Data." Table B-2, Test Profile Data shall then be developed by applying those special vibration and thermal ground rules defined herein.

2.2.1 Mission Phase - The specific mission phases shall be obtained from the mission profile. The number, type and duration of the phases are a function of the particular aircraft type being utilized. The ground conditions for all aircraft and equipment types shall include a non-operating period followed by a period of operation. Since the equipment will be at either low or high temperature in a non-operate mode followed by a turn-on while still at that thermal condition, both "hot" and "cold" starts will be included in the test profile.

2.2.2 Duration - The duration of each mission flight phase shall be obtained from the mission profile. The test time for the ground conditions shall apply to all aircraft types and missions and shall be:

- Non-Operate - The duration for this phase shall be 30 minutes.
- Operate - The duration for this phase shall be 30 minutes.

TABLE B-2 TEST PROFILE DATA (EXAMPLE)

	DURATION (MIN.)	COMPART. TEMP. (°C)	TEMP. RATE OF CHANGE (°C/MIN)	W_0 (g^2/Hz)	DEWPT. TEMP. (°C)	EQUIP. OPER.
GND. NON-OPER., COLD DAY	30	-54	–	–	N/A	OFF
GND. OPER., COLD DAY	30	-54	–	–	N/A	ON
TAKE OFF	1	–	5.0	0.002	N/A	ON
CLIMB TO ALTITUDE	3.4	–		0.001	N/A	ON
CRUISE	18	-32		0.001	N/A	ON
DIVE	2.6	–	5.0	0.0019	N/A	ON
CRUISE	45	-19		0.0019	N/A	ON
CRUISE (COMBAT)	5	-10		0.007	N/A	ON
CRUISE	45	-19		0.0019	N/A	ON
CLIMB	2.6	–	5.0	0.001	N/A	ON
CRUISE	18	-32		0.001	N/A	ON
DESC. END TO HOT DAY	14	–	7.35	0.001	N/A	ON
GND. NON-OPER., HOT DAY	30	+71		–	31	OFF
GND. OPER., HOT DAY	30	+71		–	31	ON
TAKE OFF	1	–	5.0	0.002	N/A	ON
CLIMB TO ALTITUDE	11	–		0.001	N/A	ON
CRUISE	18	+11		0.001	N/A	ON
DIVE	4.25	–	14.1	0.0019	N/A	ON
CRUISE	45	+71		0.0019	N/A	ON
CRUISE (COMBAT)	5	+71		0.007	N/A	ON
CRUISE	45	+71		0.0019	N/A	ON
CLIMB	7	–	8.71	0.001	N/A	ON
CRUISE	18	+10		0.001	N/A	ON
DESCEND TO COLD DAY	13	–	5.0	0.001	N/A	ON

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2.2.3 Altitude and Mach No. - Altitude and Mach No. shall be obtained from the mission profile analysis.

2.2.4 Compartment Temperature - The following information shall be obtained prior to establishing the compartment temperature levels:

Data	Need	Obtained From
• Altitude and Mach No.	Mandatory	Para. 2.2.3
• Equipment Class Per MIL-E-5400	Mandatory	Equip. Design Control Spec.
• Equipment Cooling Method (Ambient or Supplemental)	Mandatory	Equip. Design Control Spec.
• Compartment Cooling Method (Air Conditioned or Ram Air)	Mandatory	Equip. Design Control Spec.
• Power Dissipation	Desirable	Equip. Design Control Spec.
• Equipment Density in Compt. (Crowded or Uncrowded)	Desirable	A/C Design Spec.
• Air Flow Into Compartment	Desirable	Thermal Design Spec.
• Temp. of Air Flowing Into Compt.	Desirable	Thermal Design Spec.
• Compt. Area Exposed	Desirable	A/C Design Spec.

2.2.4.1 Ambient Cooled Equipment - (a) Hot Day Temperature - Using the altitude and Mach No. data and the MIL-Class and compartment cooling information, enter Tables B-3, B-4 or B-5 as appropriate to determine hot day compartment temperatures for each of the mission flight phases. For the ground conditions (non-operate and operate) a temperature of + 55° C (+ 131° F) shall be used for Class I equipment and + 71° C (+ 160° F) for Class II equipment.

(b) Cold Day Temperature - The selection of cold day compartment temperatures for equipment in ram cooled compartments shall be selected from Table B-6. For equipment located in air conditioned compartments the selection of cold day temperatures shall be accomplished in one of three ways. The choice of method is dependent upon the amount of information available.

Table B-3 Hot Day Temperatures (°C) For Class I Equipment In Air Conditioned Compartments

ALTITUDE (K FEET)	TEMPERATURE (°C)
0	55
10	53
20	40
30	40
40	30
50	20

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Table B-4 Hot Day Ambient Temperature (°C) For Class II Equipment In Air Conditioned Compartments

ALTITUDE (K FEET) \ MACH NUMBER	0-.59	.60-.79	.80-.99	HIGH PERFORMANCE >(1.0)*
0	71	71	71	95
10	56	68	68	93
20	40	55	63	88
30	15	36	56	80
40	5	10	46	70
50	5	10	35	60
60	5	10	24	49
70	5	10	11	35

*Ambient cooled equipment must be turned off for 15 minutes after 30 minutes of operation at these temperatures to comply to the Intermittent Operation of MIL-E-5400.

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TABLE B-5 HOT DAY AMBIENT TEMPERATURES (^{o}C) FOR EQUIPMENT IN RAM COOLED COMPARTMENTS

ALTITUDE (K FEET) \ MACH NUMBER	0-.59	.60-.79	.80-.99	>1.0
0	48	60	75	95*
10	27	38	52	71
20	6	16	29	46
30	-15	-6	7	23
40	-36	-30	-16	-1
50	-30	-19	-7	8
60	-31	-23	-11	4
70	-30	-22	-10	5

*AMBIENT COOLED CLASS II EQUIPMENT MUST BE TURNED OFF FOR 15 MINUTES AFTER 30 MINUTES OF OPERATION AT THIS TEMPERATURE TO COMPLY WITH THE INTERMITTENT OPERATION REQUIREMENT OF MIL-E-5400.

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TABLE B-6 COLD DAY AMBIENT TEMPERATURES (°C) FOR EQUIPMENT IN RAM COOLED COMPARTMENTS

ALTITUDE (K FEET) \ MACH NUMBER	0-.59	.60-.79	.80-.99	>1.0
0	-44	-37	-15	-11
10	-18	-10	2	19
20	-36	-28	-16	-2
30	-58	-50	-40	-27
40	-59	-51	-41	-18
50	-82	-76	-67	-55
60	-82	-75	-66	-54
70	-65	-58	-48	-35

2759-060

1. Method I

If a limited amount of information is available, i.e., altitude and Mach No., the compartment temperature for each of the mission flight phases shall be selected from Table B-7 "cool" compartment.

2. Method II

If, in addition to altitude and Mach No., the following information is available:

- Equipment Power Dissipation (watts)
- Compartment Equipment Density

then a selection of "cool" or "warm" compartment temperatures shall be made for each of the mission flight phases, as follows:

- "Warm" Compartment Selection

  If the equipment dissipates high wattage and the compartment contains many other equipments (tending to impede cooling air flow), selection of temperatures shall be made from the "warm" compartment values.

- "Cool" Compartment Selection

  If the equipment power dissipation is minimal and the compartment is relatively uncrowded (free, unrestricted airflow), then the compartment temperature shall be selected from the "cool" compartment values.

3. Method III

In certain cases, where additional thermal and design engineering data are available, the compartment cold day temperature can be calculated for the mission flight phases, using the following expressions:

$$T_{Compartment} = \frac{3.41 \text{ X } Q_{Elect.} + 14.4\ (1.8)\ W \times T_{in} + U \times 1.8 \times A \times T_{Recov.}}{1.8 \quad [U \times A + 14.4\ W]}$$

Terms

$Q_{Elect.}$	= Electrical Load (watts)
W	= A/C Flow Rate into compartment (#/min.)
T_{in}	= Temperature of air flowing into compartment (° C)
U	= Overall heat transfer coefficient

TABLE B-7 TEMPERATURES (^{o}C) FOR CLASS I AND II EQUIPMENT IN AIR CONDITIONED COMPARTMENTS

"WARM" COMPARTMENT

ALTITUDE (K FEET) \ MACH NUMBER	0-.59	.6-.79	.8-.99	HIGH PERFORMANCE > 1.0
0	8	12	19	27
2 TO 10	24	29	36	44
20	16	20	27	35
30	7	11	17	24
40	8	12	17	24
50	6	9	14	21

"COOL" COMPARTMENT

ALTITUDE (K FEET) \ MACH NUMBER	0-.59	.6-.79	.8-.99	HIGH PERFORMANCE > 1.0
0	-26	-19	-10	2
2 TO 10	-4	3	13	27
20	-17	-10	-1	11
30	-32	-26	-17	-6
40	-33	-27	-18	-8
50	-38	-32	-24	-14

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$$U = 2 - \frac{0.67}{50,000} \times (\text{Alt. (ft.)})$$

A = Compartment area exposed to ambient (ft.^{2})

$$T_{recov.} = \left[(1 + 0.18\, M^2)(T_A + 273) - 273\right]$$

M = Mach number

T_A = Ambient Temp. @ Altitude

Alt. (ft.)	T_A (°C)
0	-51
10K	-26
20K	-43
30K	-62
40K	-65
50K	-73

For the ground conditions (non-operate and operate) a temperature of -54°C (-65°F) shall be used for both Class I and Class II equipment.

2.2.4.2 Supplementally Cooled Equipment - (a) Hot Day Temperature - The hot day compartment temperatures for the various mission flight phases and ground conditions shall be established in accordance with the requirements of paragraph 2.2.4.1(a).

b. Cold Day Temperature - The cold day compartment temperature for the various mission flight phases and ground conditions shall be established in accordance with the requirements of paragraph 2.2.4.1(b).

NOTE:

The flow rate, temperature and dewpoint temperature of the supplemental air shall be in accordance with the equipment specification values during all phases of the mission profile which require equipment operation. During the ground non-operating phases, the supplemental air flow shall be zero. During chamber air heatup, the mass flow of supplemental air shall be the minimum specified and shall be maintained until chamber air cool down. During chamber air cool down, the mass flow of supplemental air shall be the maximum specified and held until chamber air heatup.

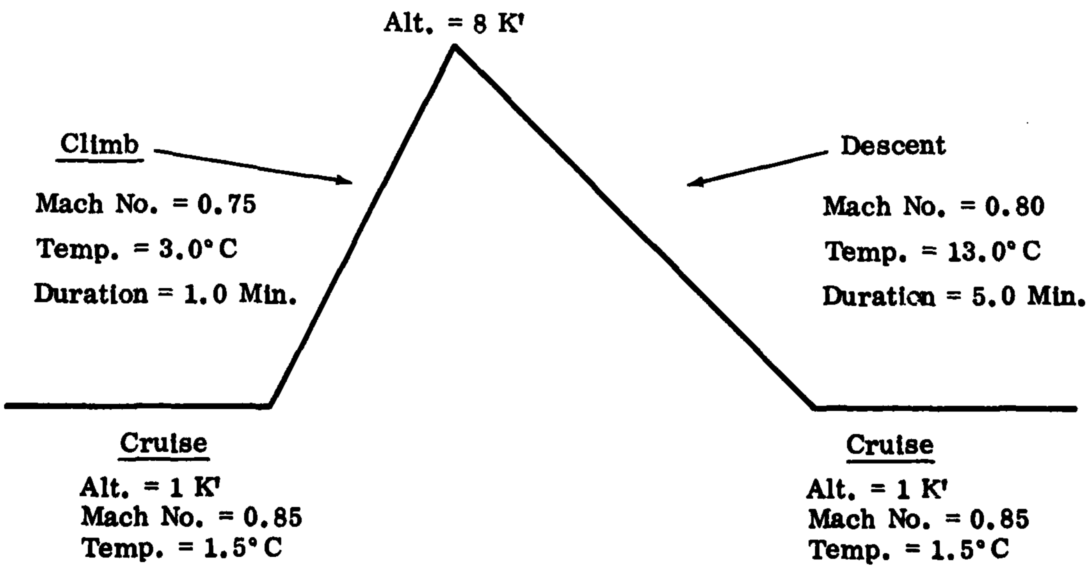
2.2.5 Temperature Rate of Change - A temperature rate of change shall be calculated for each mission phase involving a change in altitude or Mach No. This shall be accomplished by determining (in accordance with para. 2.2.4) the compartment temperatures of the steady state conditions bounding the phase in which altitude or Mach No. varied, calculating the temperature difference of the bounding phases and then dividing this value by the duration of the varying altitude or Mach No. phase. In the example presented (Table B-1), take-off and climb to altitude have been considered as a single phase from a thermal point of view.

In certain cases there may be two consecutive mission phases involving such changes e.g., a descent followed by a climb or a loiter condition followed by a dash. In these situations a temperature rate of change shall be calculated for each of the two phases. The following example illustrates the procedure:

An aircraft in a cruising mode suddenly climbs, then descends and finally resumes cruising. The following tabulation lists the phases and accompanying data.

Phase	(Min.) Duration	Mach No.	Alt. (K')	Compart. Temp. (°C)	Rate of Change (°C/Min.)
Cruise	11.3	.85	1	1.5	-
Climb	1.0	.75	1-8	3.0	1.5
Descent	5.0	.80	8-1	13.0	2.3
Cruise	10.7	.85	1	1.5	-

The sketch below presents the action pictorially:



Thermal rates of change are calculated as follows:

CLIMB (Cold Day, Cool Compartment)

Temperature at 8.0 K' and Mach. No. = 0.75 is equal to +3° C

Temperature at 1.0 K' and Mach. No. = 0.85 is equal to +1.5° C

$$\text{RATE} = \frac{3°\text{C} - 1.5°\text{C}}{1.0 \text{ Min.}} = 1.5°\text{C Min.}$$

DESCEND (Cold Day, Cool Compartment)

Temperature at 8.0 K' and Mach. No. = -.80 is equal to +13° C

Temperature at 1.0K' and Mach. No. = 0.85 is equal to +1.5° C

$$\text{RATE} = \frac{13°\text{C} - 1.5°\text{C}}{5.0 \text{ Min.}} = 2.3°\text{C/Min.}$$

2.2.6 Vibration - The random vibration level shall be determined for each of the mission phases utilizing the information presented in Table B-8 and Figs. B-1 and B-2.

As a first step, a value of dynamic pressure q shall be selected from Fig. B-1, for each steady state condition as a function of Mach No. and altitude. For transient conditions, e.g., dive, the q value shall be determined using the Mach No. (for that phase, if known) and the average altitude for that phase. If the Mach No. is not known, then the q value shall be the arithmetical average of the q at the start of a dive plus that at the termination of the dive, i.e., $\frac{(1 \text{ start} + q \text{ term.})}{2} = q \text{ avg.}$ If the altitude, Mach No. combination is such that a value of $q < 76$ will result, use $q = 76$.

The power spectral density, W_o shall then be computed in accordance with the requirements of Table B-8.

Figure B-2 shall then be employed to determine the spectrum shape (test envelope) and a W_1 calculated if required.

2.2.7 Humidity - Moisture shall be injected into the test chamber and a dewpoint temperature of +31° C (or greater) shall be attained during the initial portion of the ground, non-operate phase for a hot day. The +31° C or greater dewpoint shall be maintained and controlled until the end of the ground, operate phase for a hot day. No further injection of moisture is required for any of the other profile phases and the humidity during these phases shall be uncontrolled. The humidity shall be maintained and controlled at 31° C or greater for each subsequent cycle during the hot day ground non-operate and operate conditions. Drying of chamber air shall not be accomplished at any time during a test cycle.

TABLE B-8 JET AIRCRAFT-RANDOM VIBRATION TEST

AERODYNAMIC INDUCED VIBRATION

$W_o = K(q)^2$ q = DYNAMIC PRESSURE (WHEN q > 1200 psf USE 1200)

$W_1 = W_o - 3\,dB$

(SEE FIGURE B-2 FOR SPECTRUM SHAPE)

K	EQUIPMENT LOCATION
$.67 \times 10^{-8}$	EQUIPMENT ATTACHED TO STRUCTURE ADJACENT TO EXTERNAL SURFACES THAT ARE SMOOTH, FREE FROM DISCONTINUITIES
$.34 \times 10^{-8}$	COCKPIT EQUIPMENT AND EQUIPMENT IN COMPARTMENTS AND ON SHELVES ADJACENT TO EXTERNAL SURFACES THAT ARE SMOOTH, FREE FROM DISCONTINUITIES
3.5×10^{-8}	EQUIPMENT ATTACHED TO STRUCTURE ADJACENT TO OR IMMEDIATELY AFT OF SURFACES HAVING DISCONTINUITIES (THAT IS, CAVITIES, CHINS, BLADE ANTENNAS, AND SO FORTH)
1.75×10^{-8}	EQUIPMENT IN COMPARTMENTS ADJACENT TO OR IMMEDIATELY AFT OF SURFACES HAVING DISCONTINUITIES (THAT IS, CAVITIES, CHINS, SPEED BRAKES, AND SO FORTH)

SPECIAL CASE CONDITIONS

FIGHTER BOMBER

CONDITION/EQUIPMENT LOCATION	W_o
TAKE OFF/ATTACHED TO OR IN COMPARTMENTS ADJACENT TO STRUCTURE DIRECTLY EXPOSED TO ENGINE EXHAUST AFT OF ENGINE EXHAUST PLANE (1 MINUTE)	.7
CRUISE/(SAME AS ABOVE)	.175
TAKE OFF/IN ENGINE COMPARTMENT OR ADJACENT TO ENGINE FORWARD OF ENGINE EXHAUST PLANE (1 MINUTE)	.1
CRUISE/(SAME AS ABOVE)	.025
TAKE OFF, LANDING, MANEUVERS/WING AND FIN TIPS* DECELLERATION (SPEED BRAKE) (1 MINUTE)	.1
HIGH q (> 1000 psf)/WING AND FIN TIPS*	.02
CRUISE/WING AND FIN TIPS*	.01
TAKE OFF/ALL OTHER LOCATIONS (1 MINUTE)	.002

CARGO/TRANSPORT

CONDITION/EQUIPMENT LOCATION	W_o
TAKE OFF/FUSELAGE MOUNTED	.01
TAKE OFF/INTERNAL	.005
TAKE OFF/WING-AFT OF ENGINE EXHAUST**	.05
ALL/WING TIP AND FIN TIP***	.01

*USE WING AND FIN TIP SPECTRUM – FIGURE B-2
**EXCLUDES UPPER SURFACE BLOWN (USE) AND EXTERNALLY BLOWN FLAP (EFB)
***TAKE OFF, LANDING, PLUS 10 PERCENT OF CRUISE TIME

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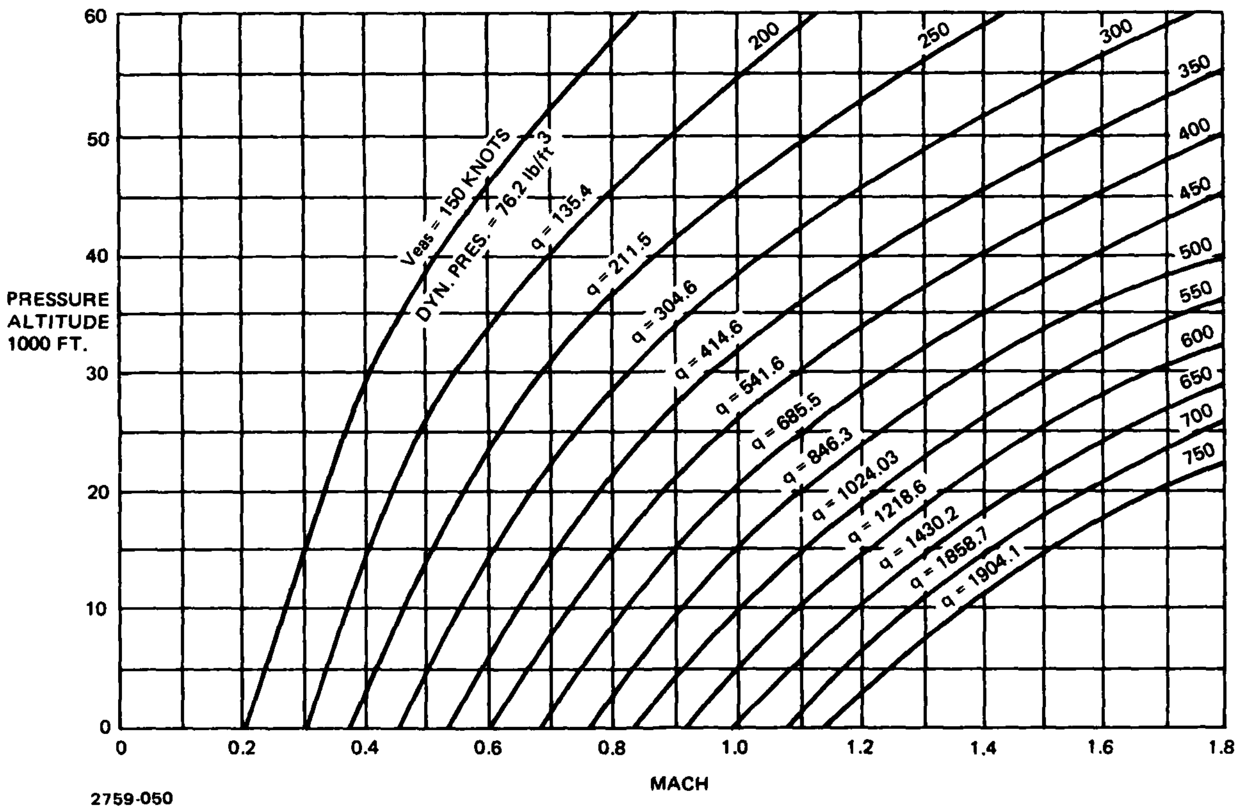
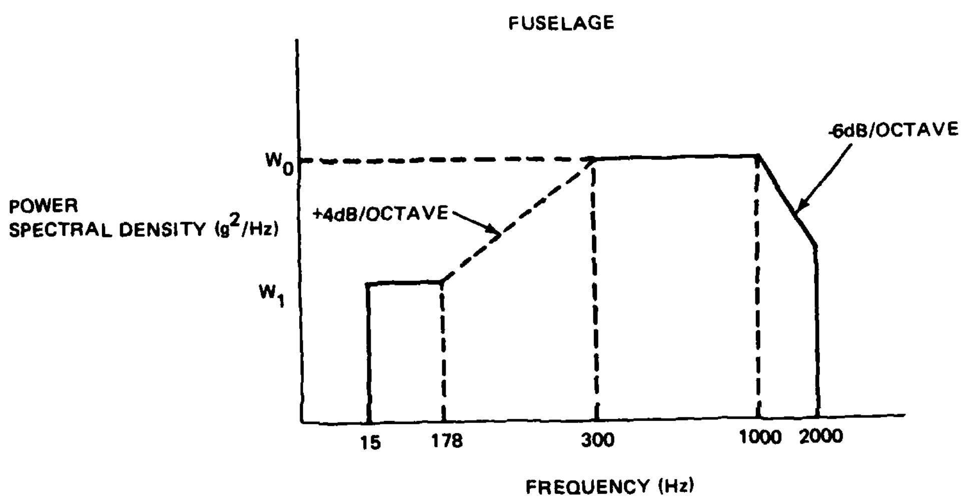


Figure B-1 Dynamic Pressure (q) as Function of Mach Number and Altitude



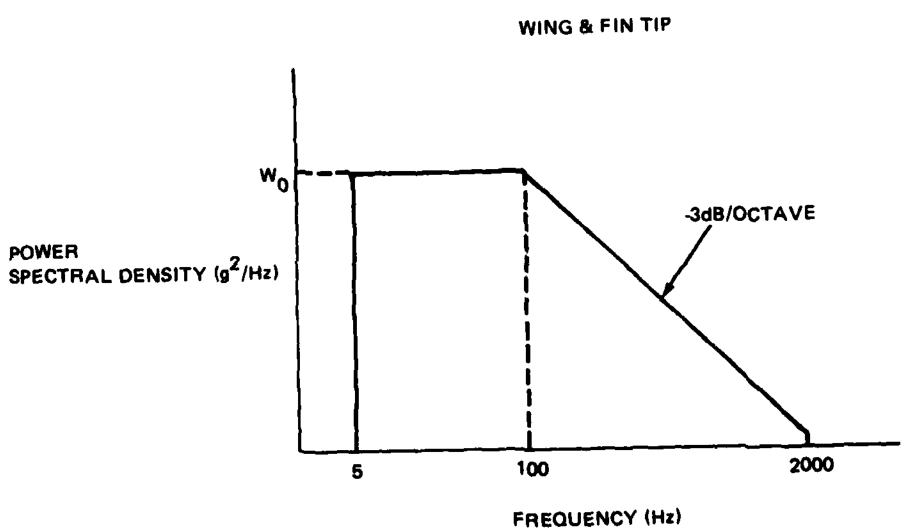


Figure B-2 Jet Aircraft Random Vibration Test Envelope

2.2.8 Equipment Operation - The equipment shall be in an operating mode during all phases of a test profile except for the ground, non-operate phases.

2.2.9 Electrical Stress - Input voltage shall be maintained at 110% of nominal for the first test cycle, at the nominal value for the second test cycle and at 90% of the nominal for the third test cycle. This sequence shall be repeated continuously during subsequent cycles throughout the test. THE EQUIPMENT SHALL BE TURNED ON AND OFF AT LEAST TWICE BEFORE CONTINUOUS POWER IS APPLIED TO DETERMINE START UP ABILITY AT THE EXTREMES OF THE THERMAL CYCLE.

2.3 Construction of Environmental Profile

An environmental profile shall be constructed using the information listed in the table generated in accordance with para. 2.2. Figure B-3 is the environmental profile resulting from the data entered in the example (Table B-1) and has been derived from the mission profile presented in Fig. B-4. It should be noted that in the example (Table B-1 combat cruise phase), a change in temperature is obtained even though no change in altitude occurs. This is due to an acceleration and then a deceleration. In this case no temperature rate of change has been defined since the acceleration and deceleration are extremely rapid (in the order of seconds).

2.4 Test Profile Developments

The environmental profile developed in para. 2.3 must now be converted into a test profile that reproduces those phases of the environmental profile which are meaningfully in terms of equipment exposure and which can be simulated in a test facility. In converting from the environmental to the test profile the ground rules and procedures discussed in the following paragraph shall be invoked.

2.4.1 Vibration - A maximum of four vibration levels (W_o values) shall be utilized in any particular test profile for each of the two missions (cold day and hot day). These levels shall be established (using the tabulated data reference table, para. 2.2), as follows:

Step One - Review the W_o values listed for each phase and delete any levels which are less than 0.001.

Step Two - Identify the W_o and duration associated with take-off and apply these values to the test profile (from Table B-8).

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DEVELOPMENT OF ENVIRONMENTAL PROFILES FOR TESTING EQUIPMENT INS--ETC(U)

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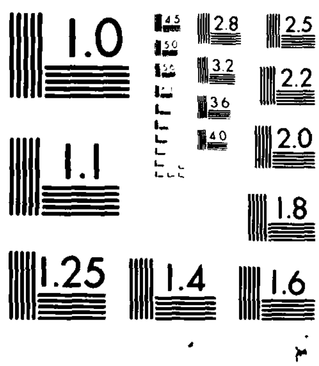

MICROCOPY RESOLUTION TEST CHART

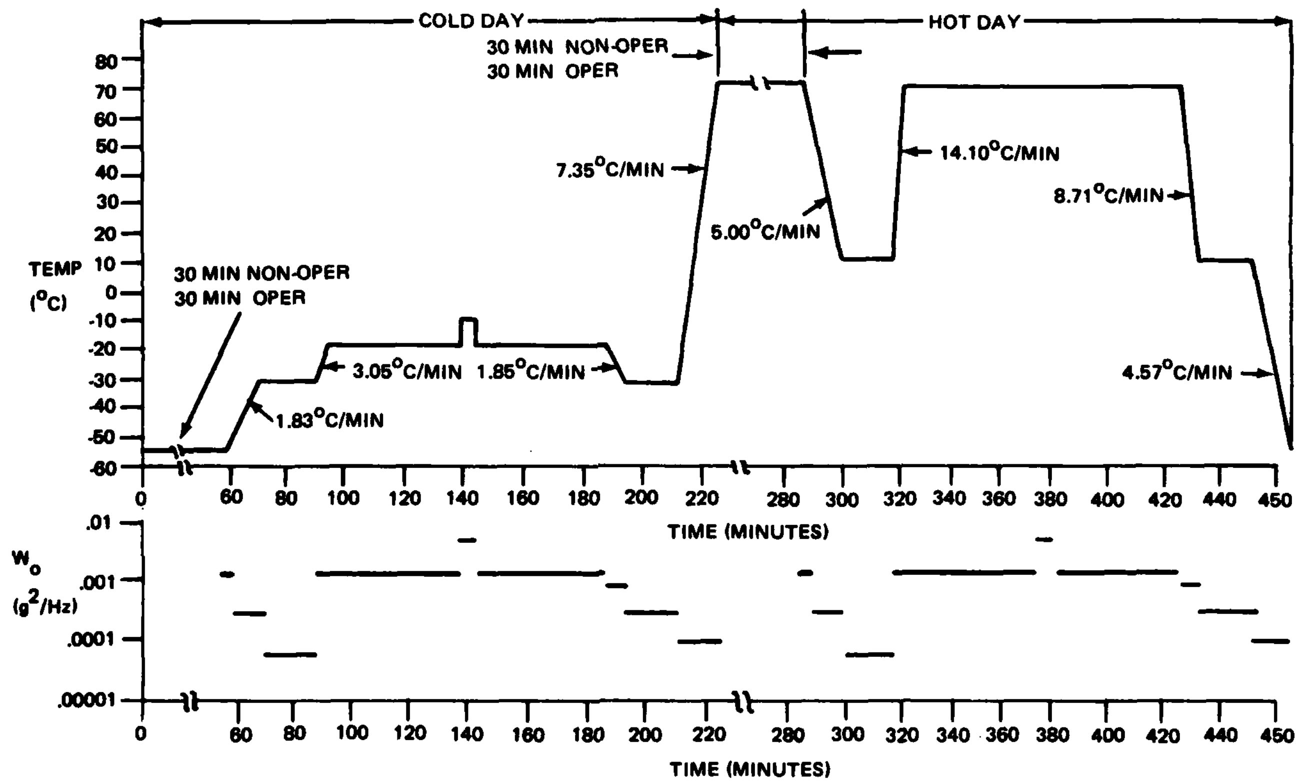

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Figure B-3 Environmental Profile (Example)

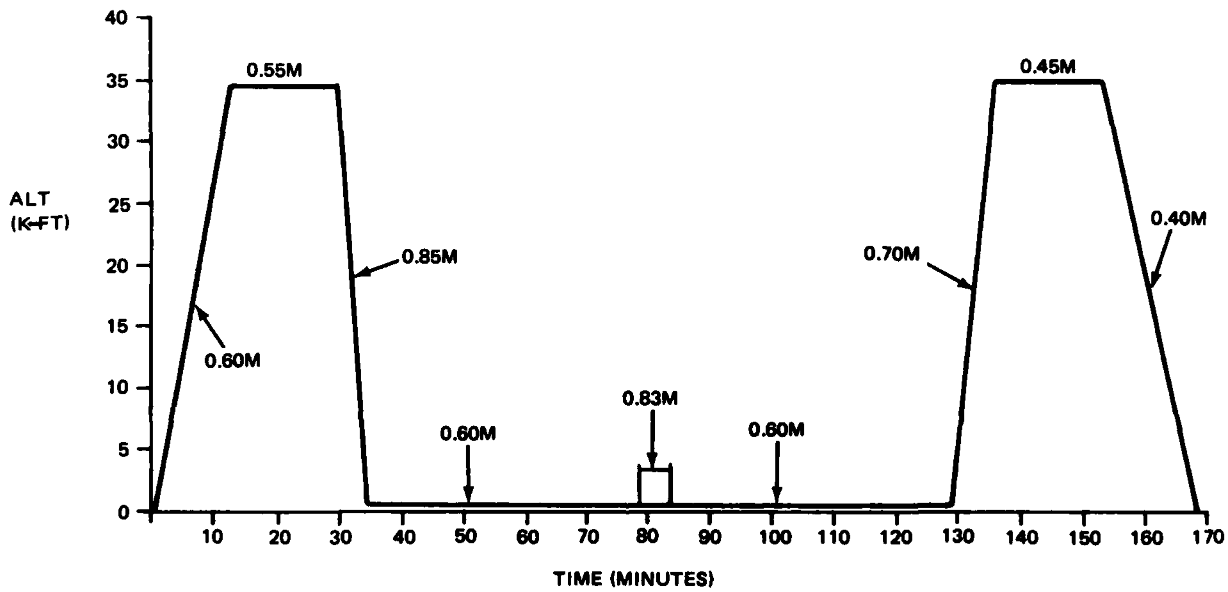

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Figure B-4 Mission Profile (Example)

Step Three - Identify the W_o's and durations associated with the highest and lowest q levels and apply these values to the test profile during the phases in which they occurred.

Step Four - The fourth level of W_o is established by calculating a time-weighted average of the W_o values remaining after identification of the take off, min and max levels. This is accomplished by multiplying each W_o by its duration, adding these products and then dividing this sum by the sum of the durations. The resulting fourth level shall be applied to those test phases associated with the environmental profile phases which were used to calculate the fourth test level. In each case the duration shall be as stipulated in the tabulation (ref. Table, para. 2.2) for that particular phase.

NOTE: For certain aircraft, flying relatively benign missions, all, or most W_o values may be less than 0.001 g^2/Hz. A value of W_o = 0.001 g^2/Hz shall be stipulated for mission flight phases not accounted for by any of the four W_o's defined in steps 1-4 above.

2.4.2 Temperature - If the temperature rate of change calculated for any transient condition, is less than 5°C/min. then a value of 5°C/min. shall be used. Any thermal condition which is less than 10°C or less than 20 min. in duration, shall be deleted from the test profile.

2.4.3 Example Test Profile - Figure B-5 is the test profile developed from the sample mission and environmental profiles after application of the aforementioned rules. Table B-2 depicts in tabular form the actual data used to construct the test profile. It should be noted that the transient thermal condition (-19 to -10°C for a period of 5 minutes) has been deleted from the test profile. Also changed were all values of temperature rate of change which were less than 5°C/min. and only the durations of those phases were reduced, all other phase durations were maintained as originally specified. Three levels of vibration remained after application of the ground rules; take-off, min and max. Take off is required at W_o selected from Table F, a max. of W_o = 0.0007 and a min. of W_o = 0.0019 were obtained from the table after all values of

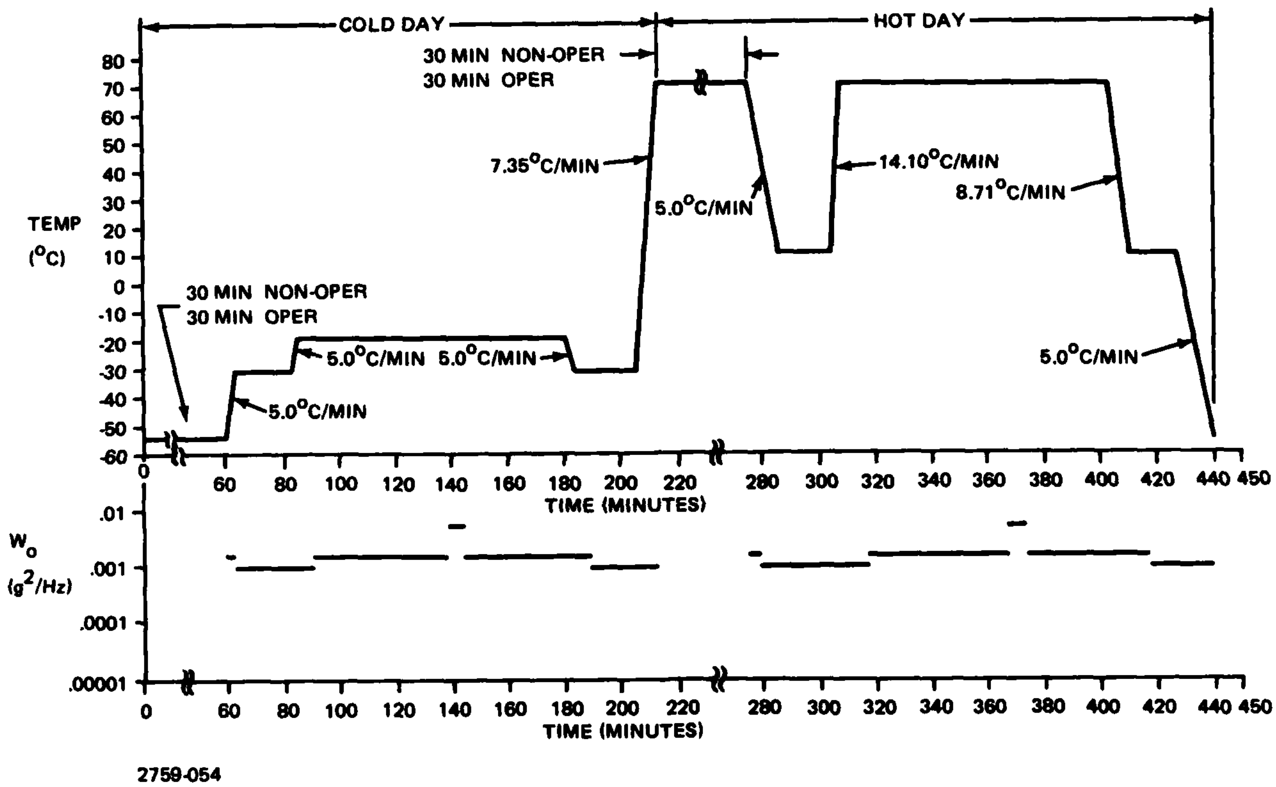


Figure B-5 Test Profile (Example)

$W_o = 0.001$ were excluded. Since these values (and their associated durations) did not account for the total mission time, a level of $W_o = 0.001\ g^2/Hz$ has been specified for the time periods not accounted for (see Table B-2).

APPENDIX C

SAMPLE TEST PROFILES

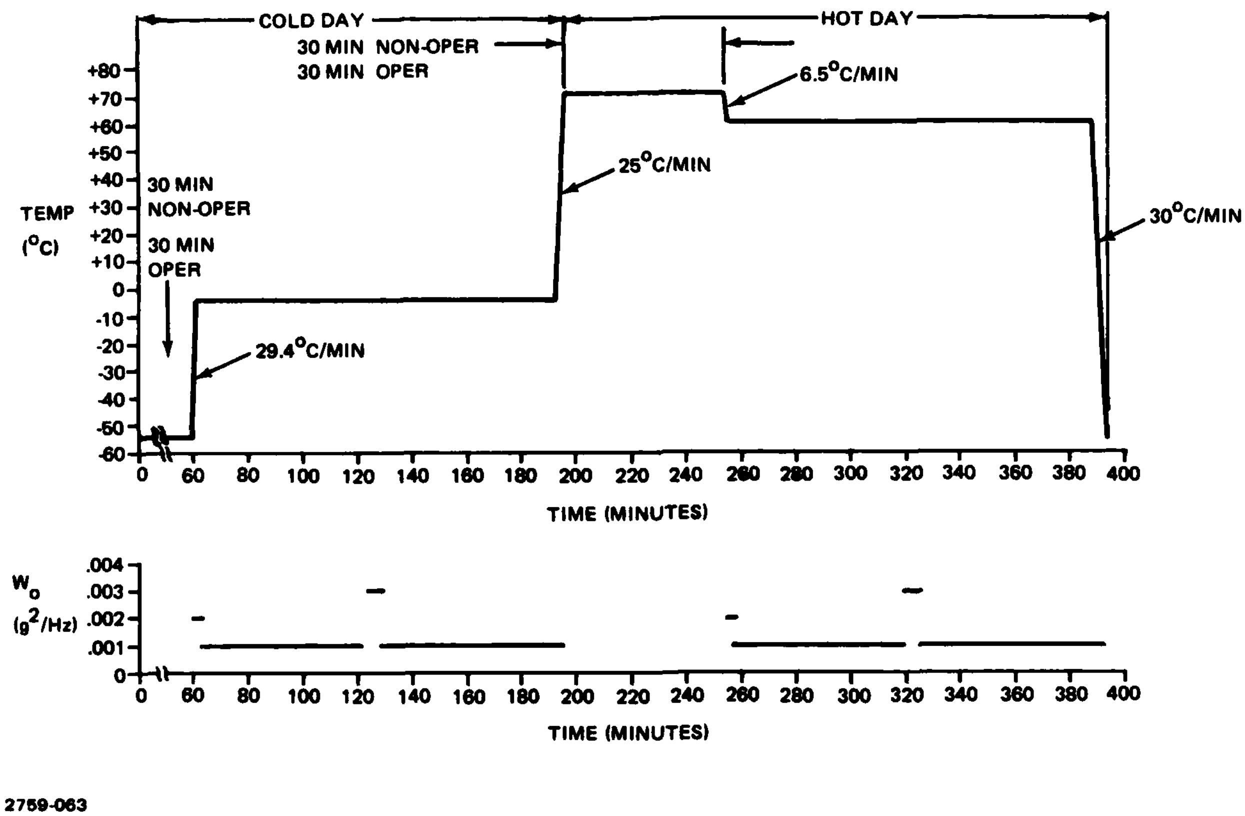
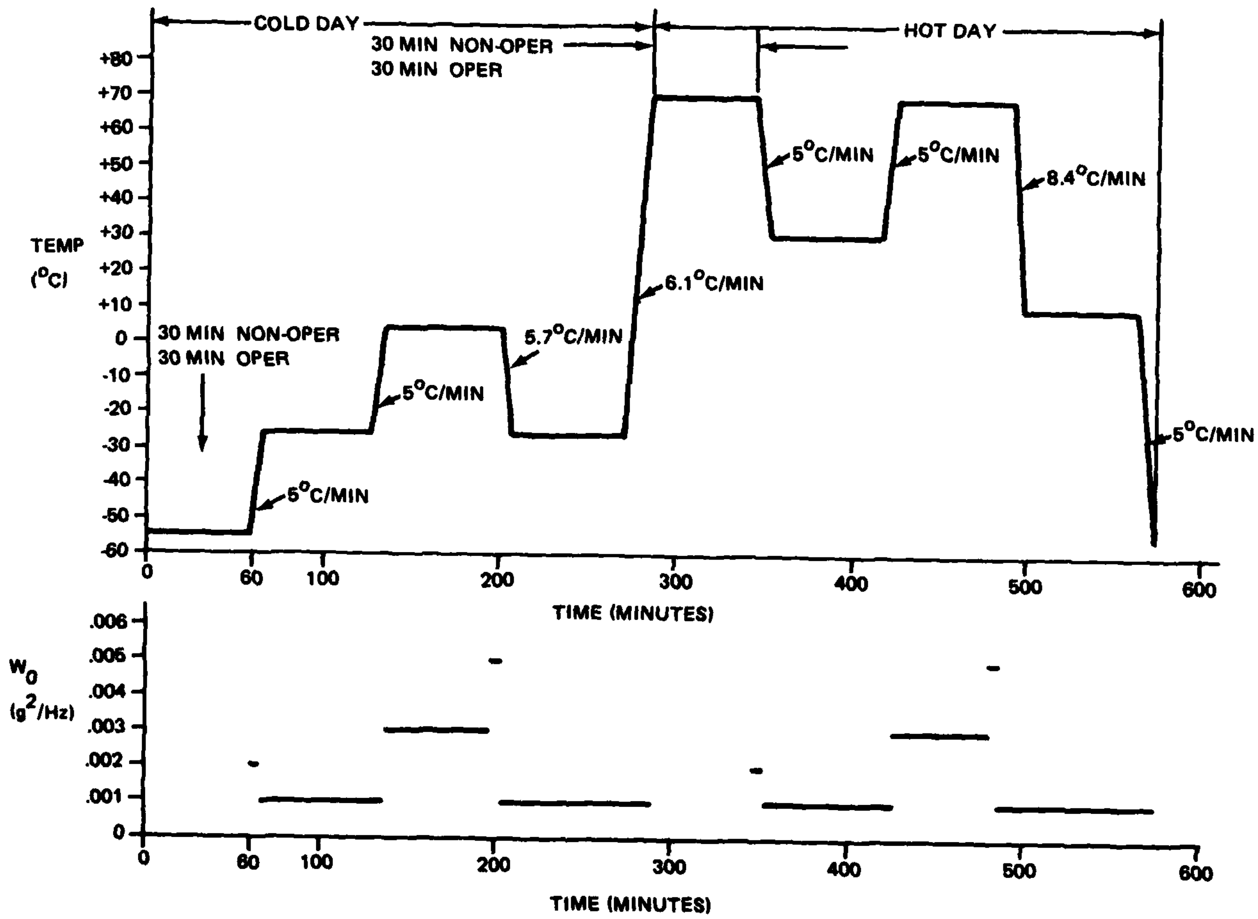
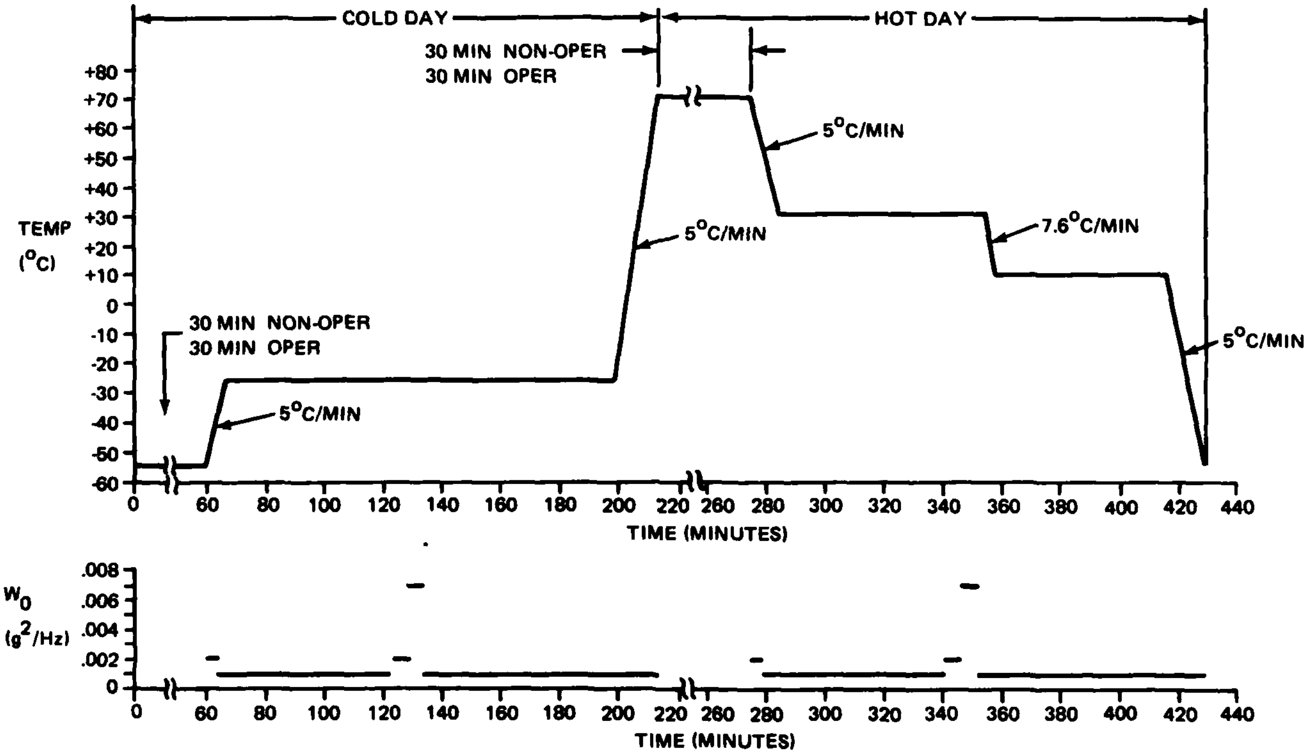


Figure C-1 Attack Aircraft Test Profile (Lo-Lo-Lo)



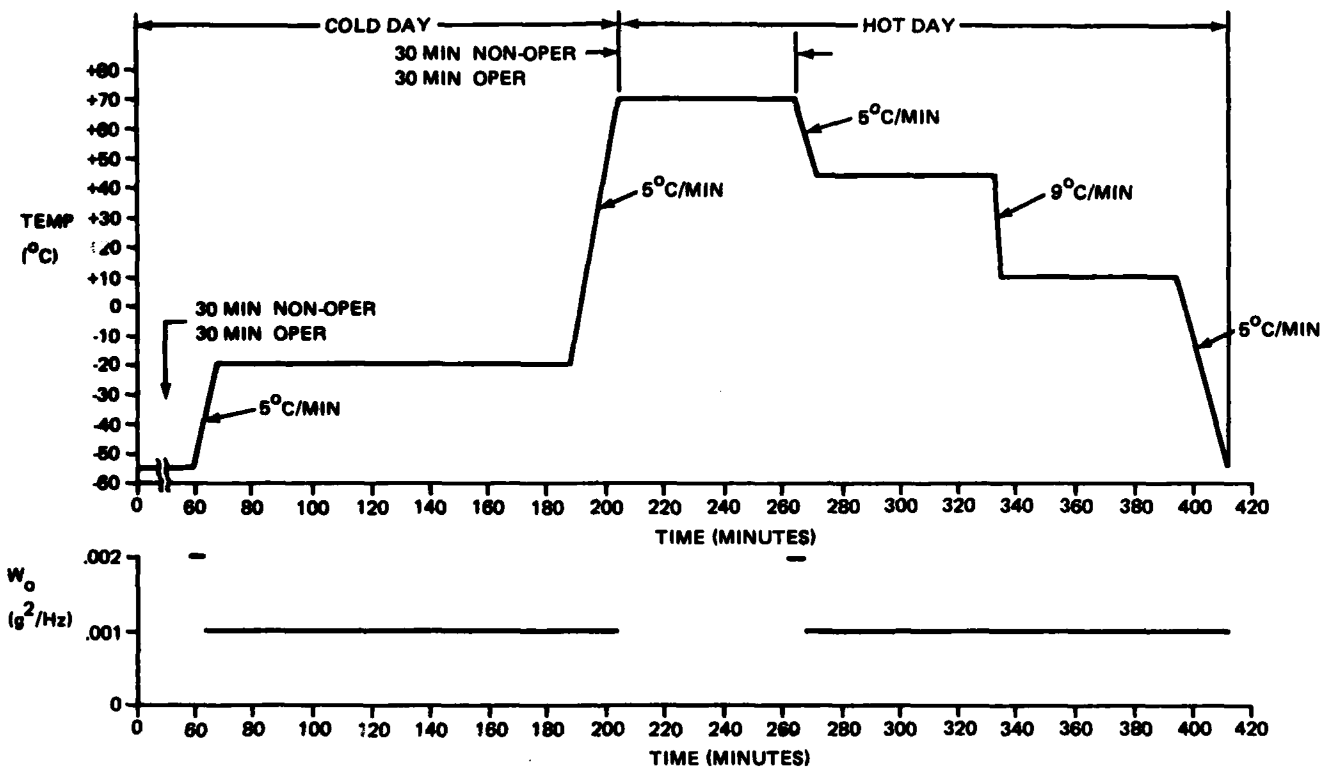
2759-064

Figure C-2 Attack Aircraft Test Profile (Close Support)



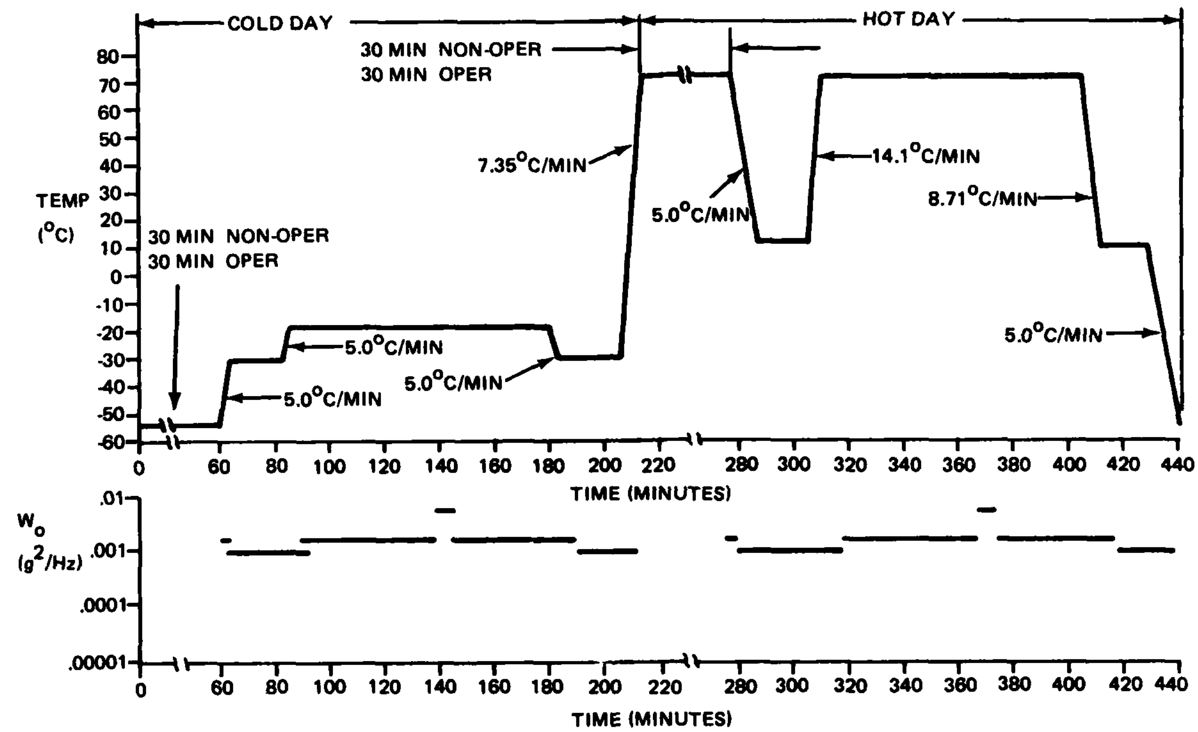
2759-065

Fig. C-3 Attack Aircraft Test Profile (Hi-Lo-Hi)



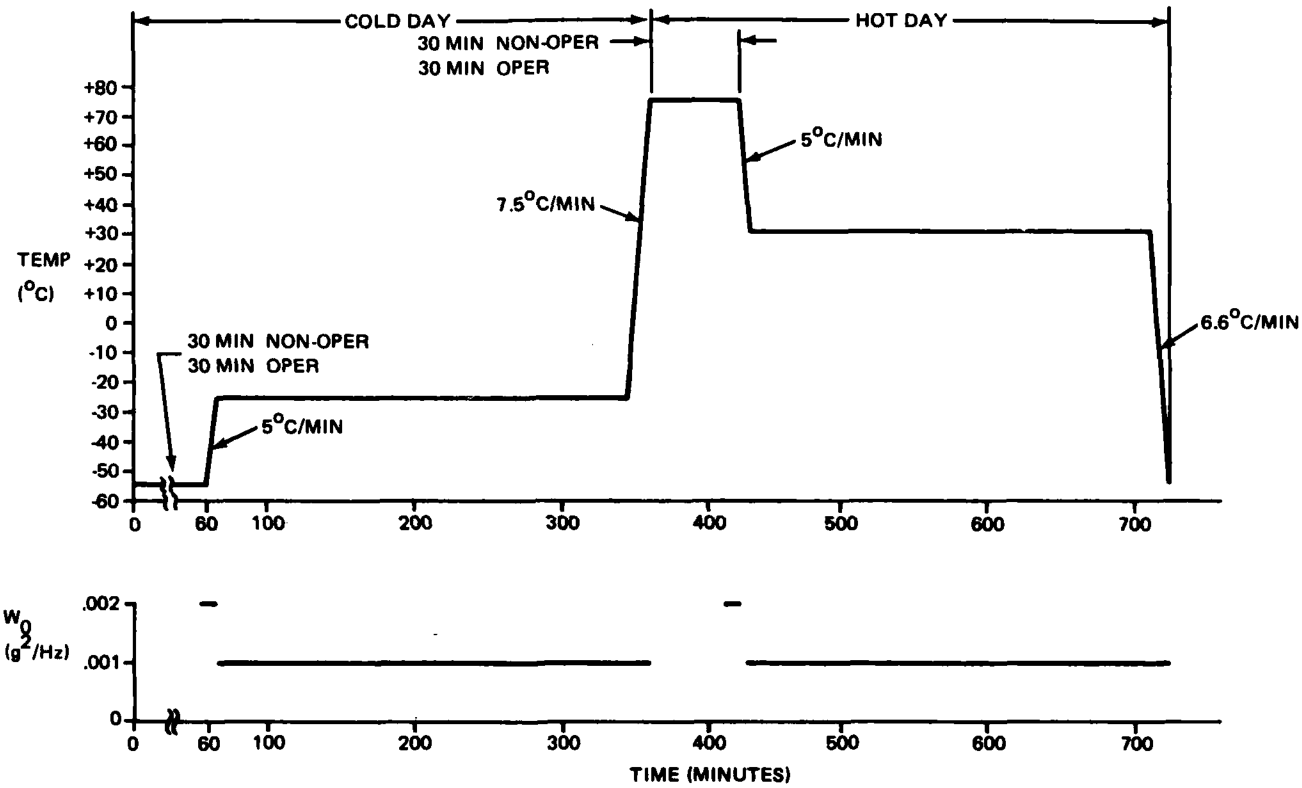
2759-066

Figure C-4 Attack Aircraft Test Profile (Hi-Hi-Hi)



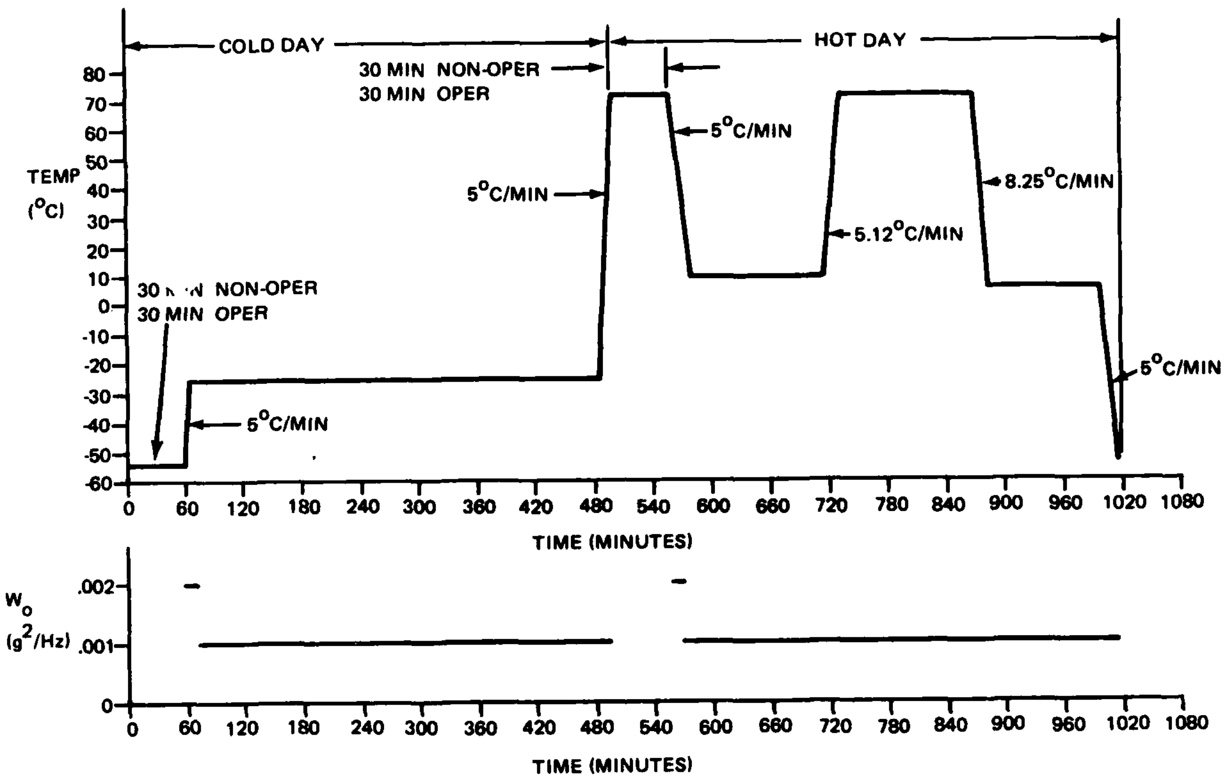
2759-067

Figure C-5 Attack Aircraft Test Profile (Hi-Lo-Lo-HI)



2759-068

Figure C-6 Attack Aircraft Test Profile (Ferry)



2759-069

Figure C-7 ASW Aircraft Test Profile (Contact Investigation — Hi)

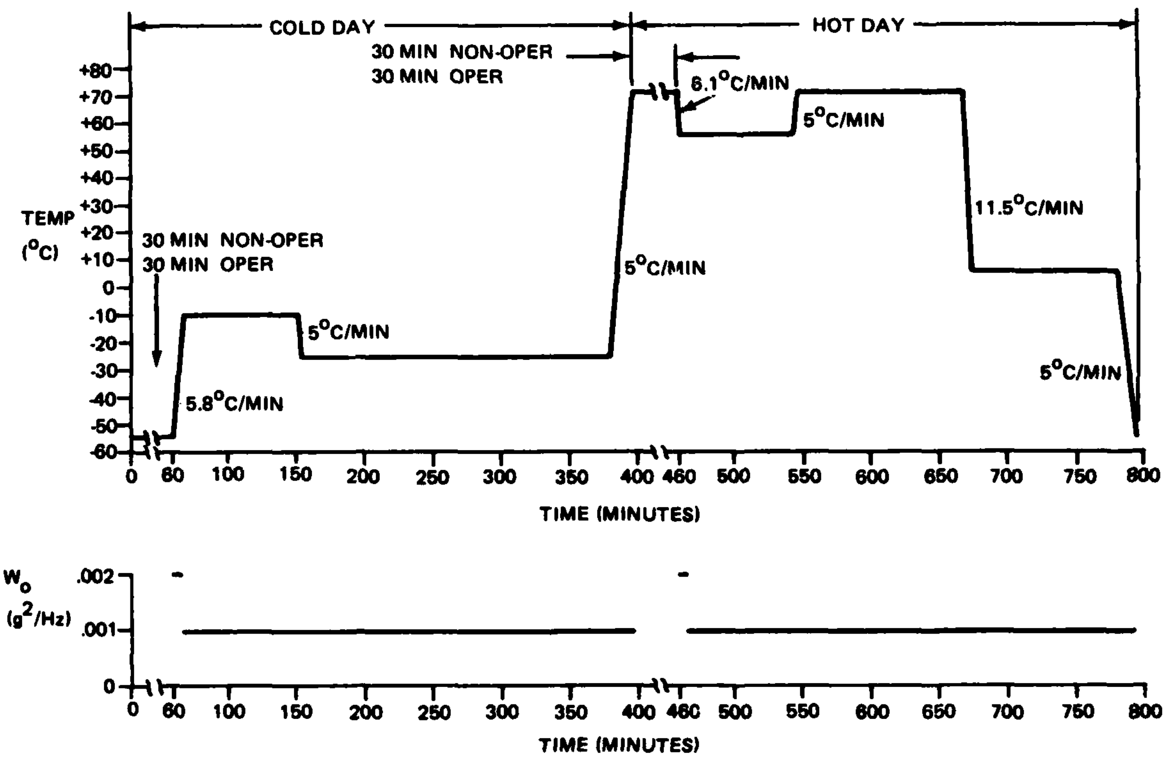


Figure C-8 ASW Aircraft Test Profile (Contact Investigation — Int.)

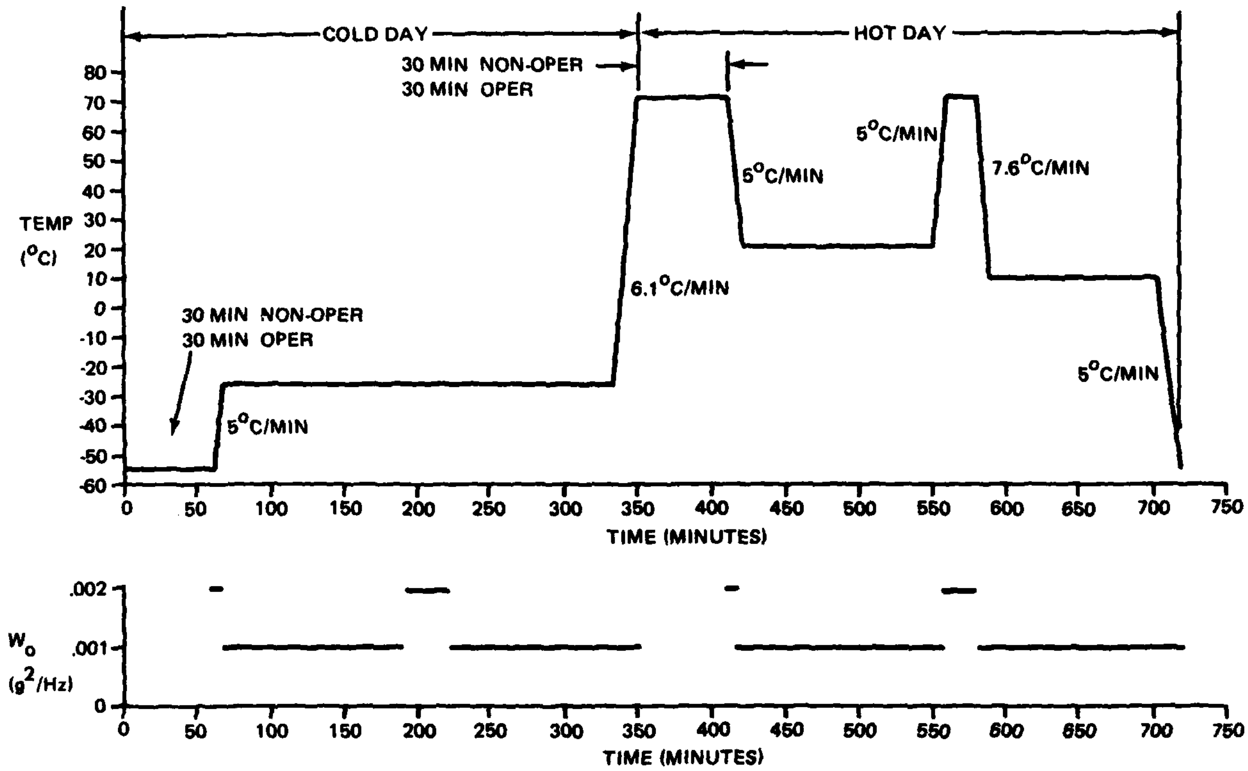


Figure C-9 AWS Aircraft Test Profile (Mine Laying)

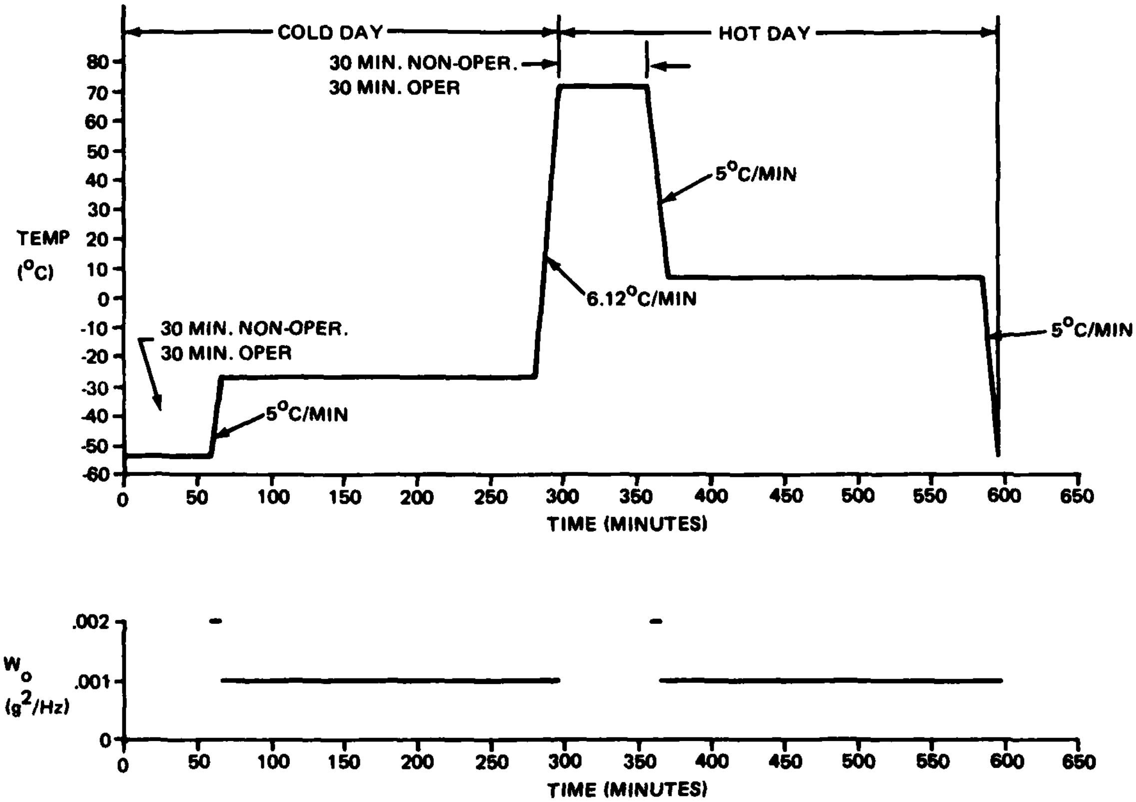


Figure C-10 ASW Aircraft Test Profile (Hi-Hi-Hi)

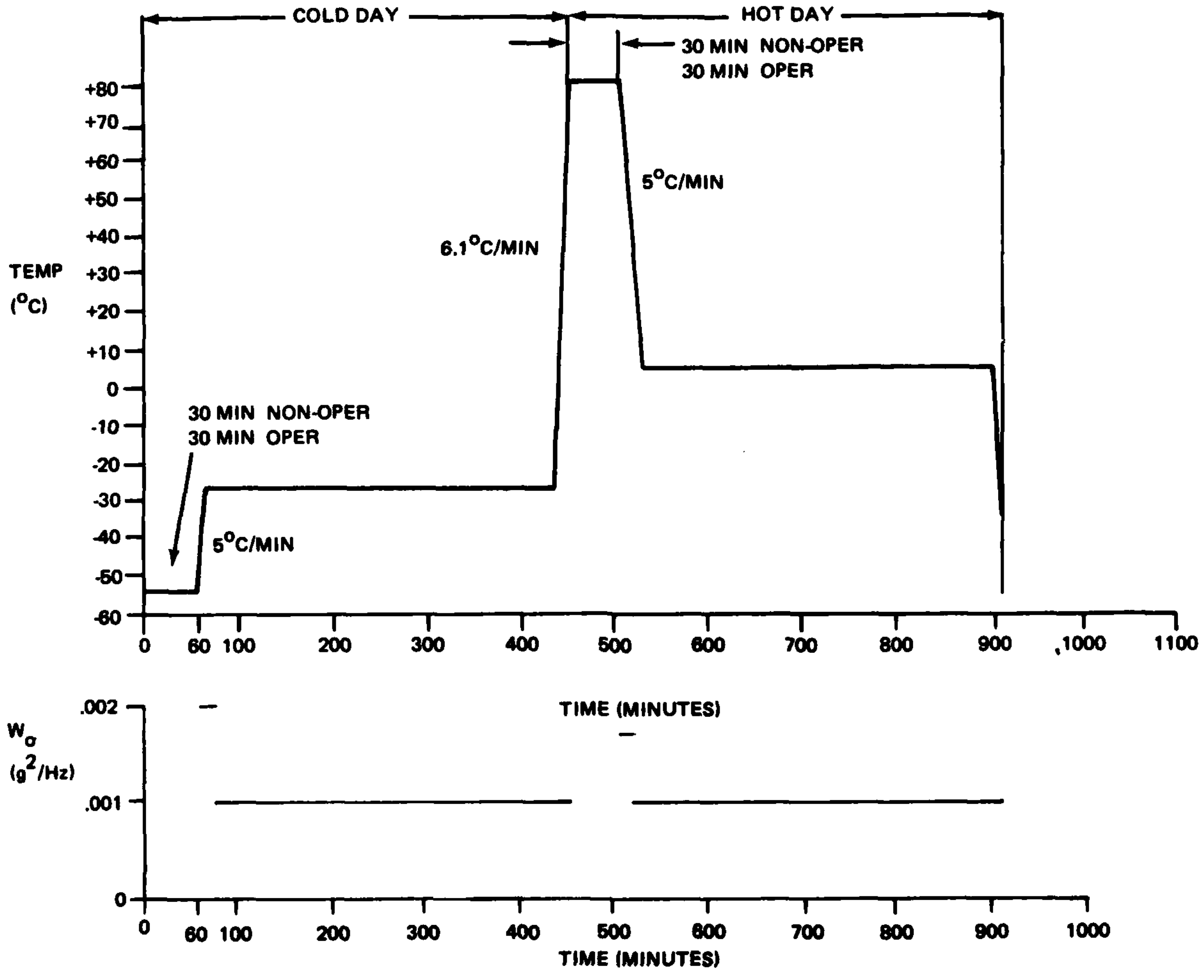


Figure C-11 ASW Aircraft Test Profile (Search & Attack)

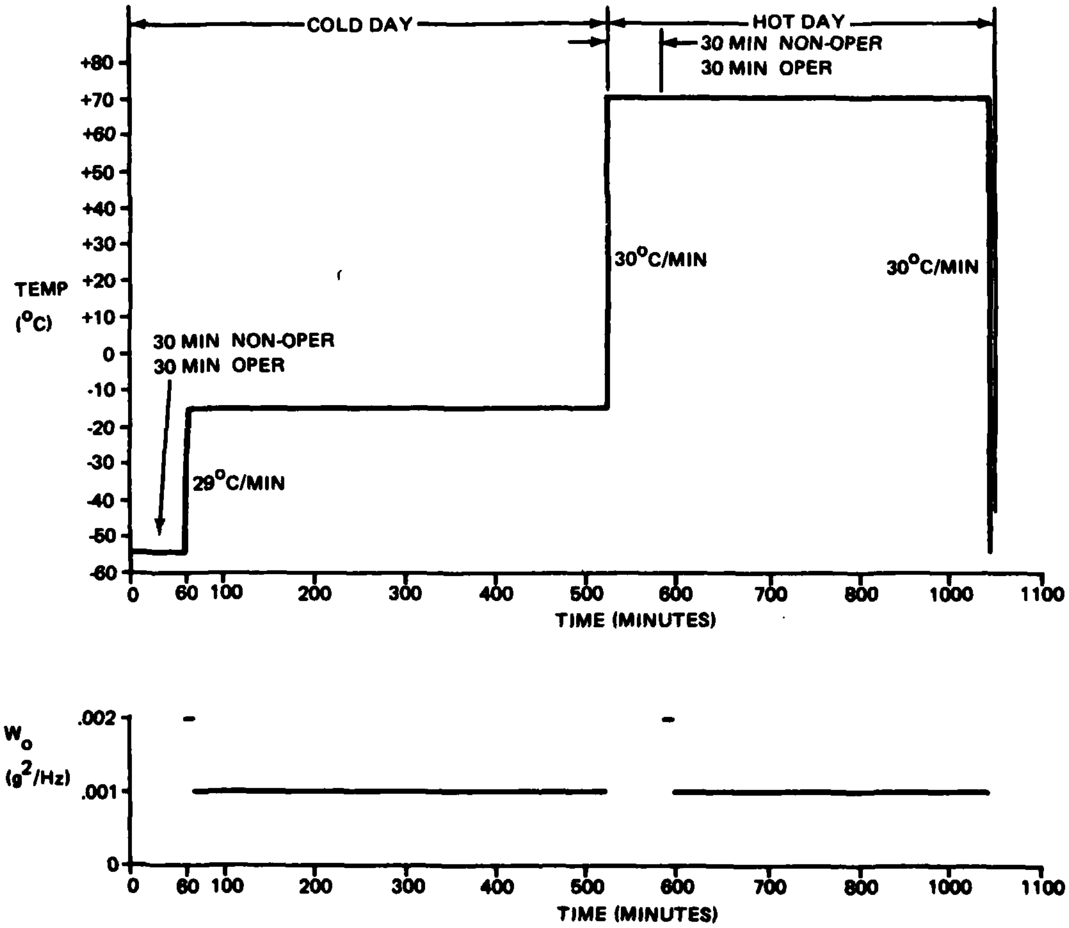


Figure C-12 ASW Aircraft Test Profile (Surface Surveillance)

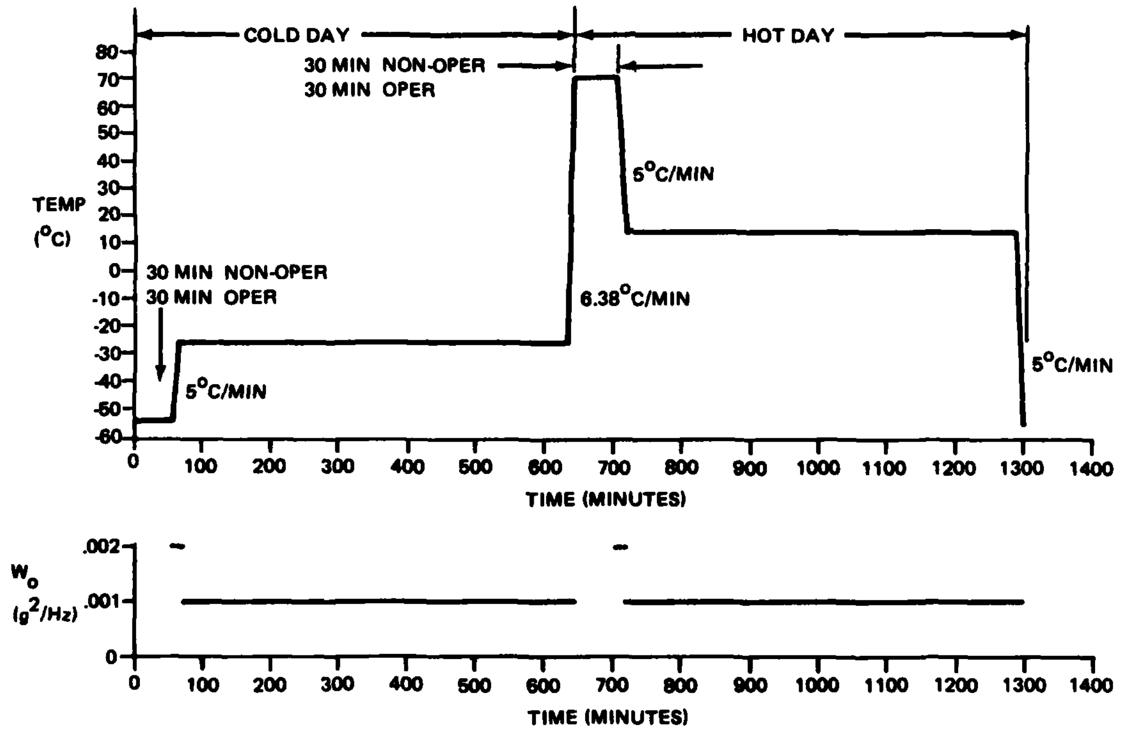


Figure C-13 ASW Aircraft Test Profile (Ferry)

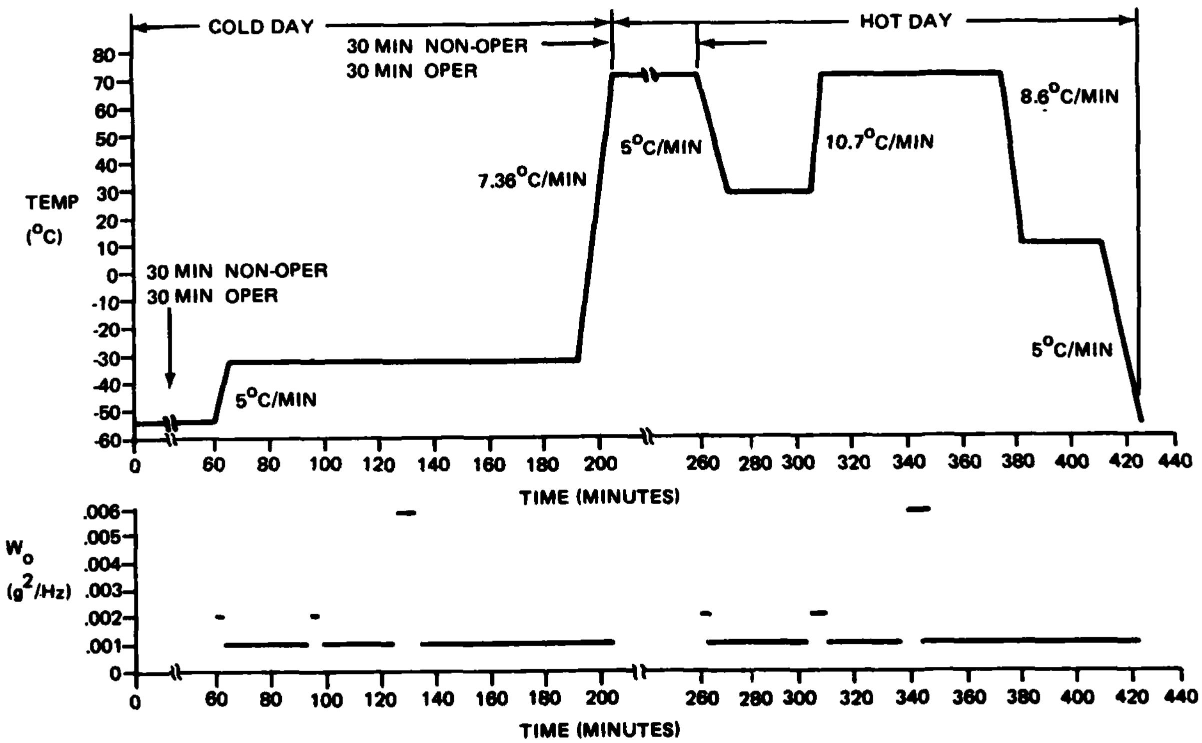


Figure C-14 ECM Aircraft Test Profile (Penetration)

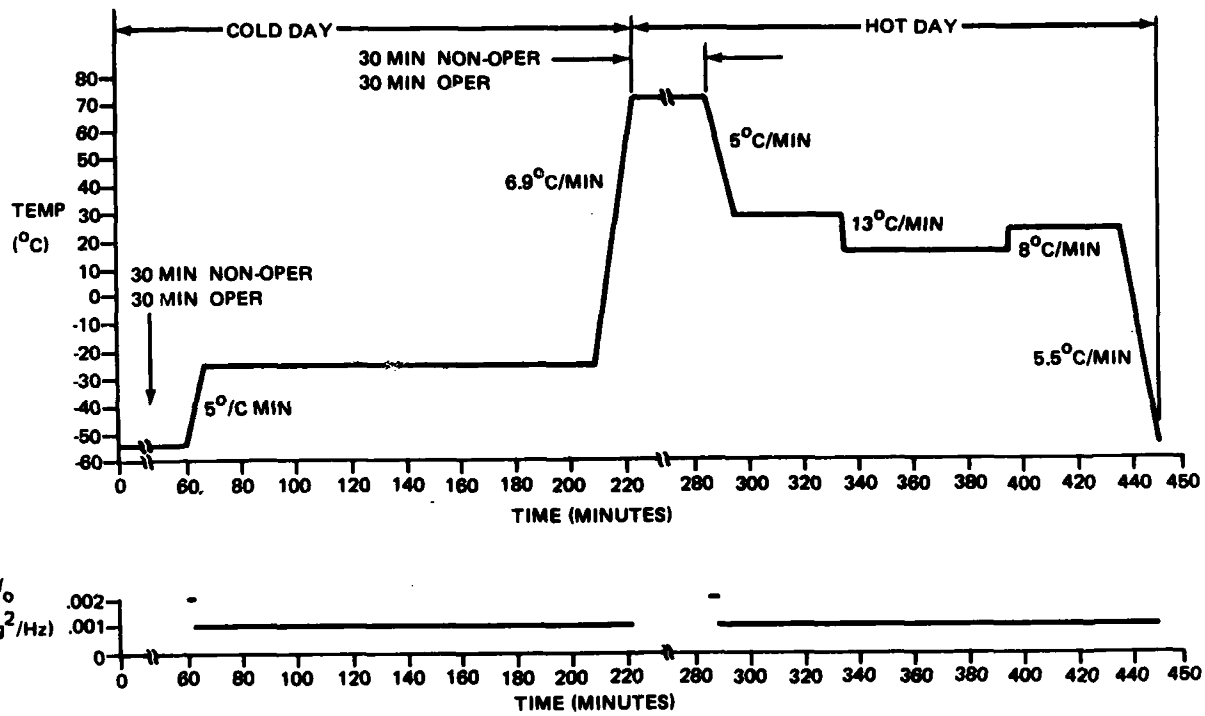


Figure C-15 ECM Aircraft Test Profile (Stand-Off)

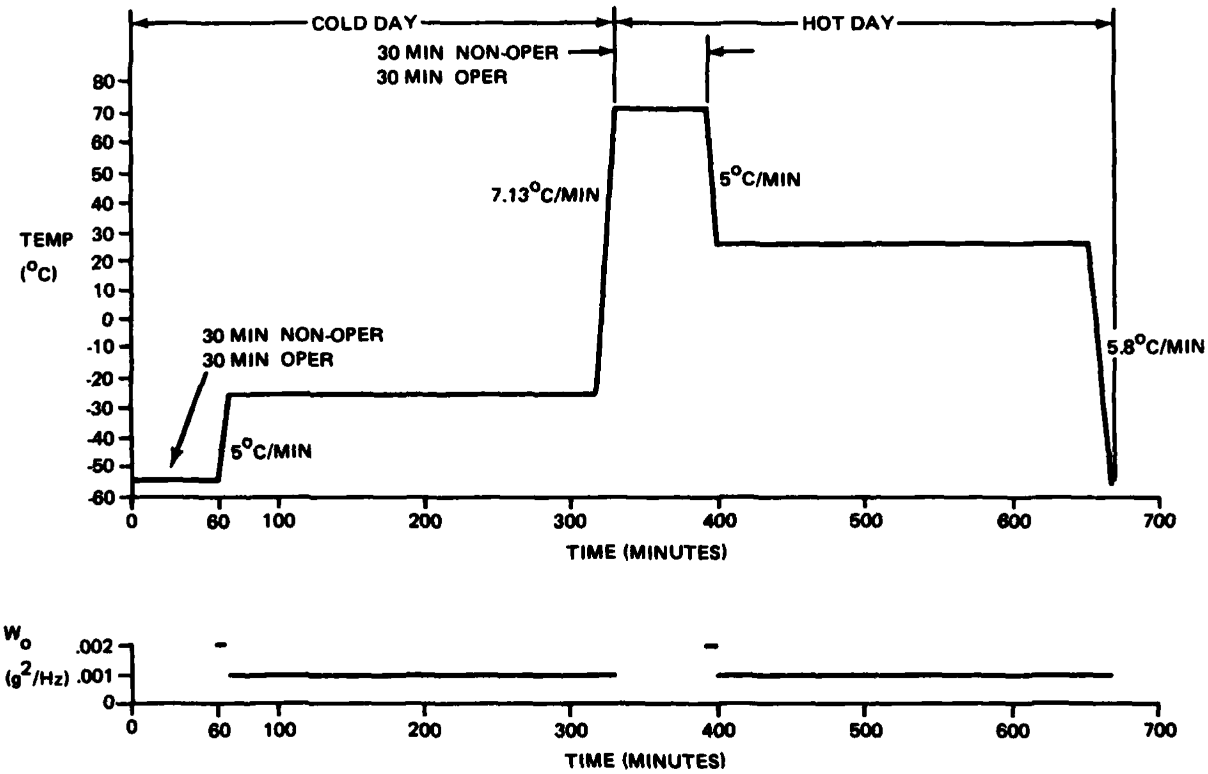


Figure C-16 ECM Aircraft Test Profile (Ferry)

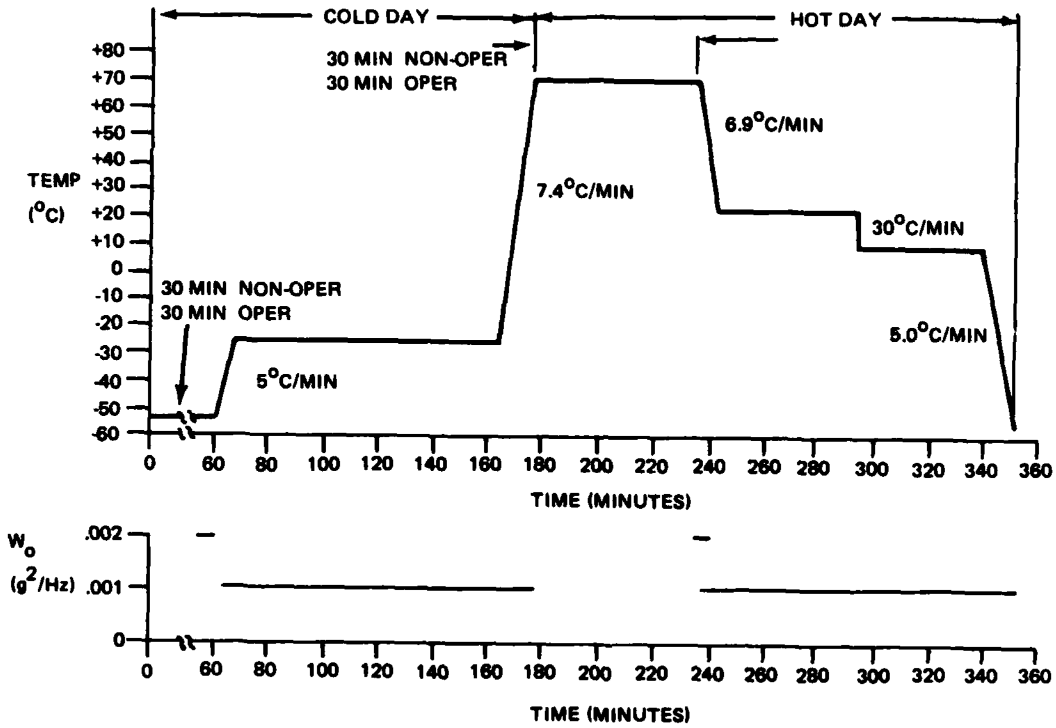


Figure C-17 Fighter Aircraft Test Profile (Hi-Hi-Hi)

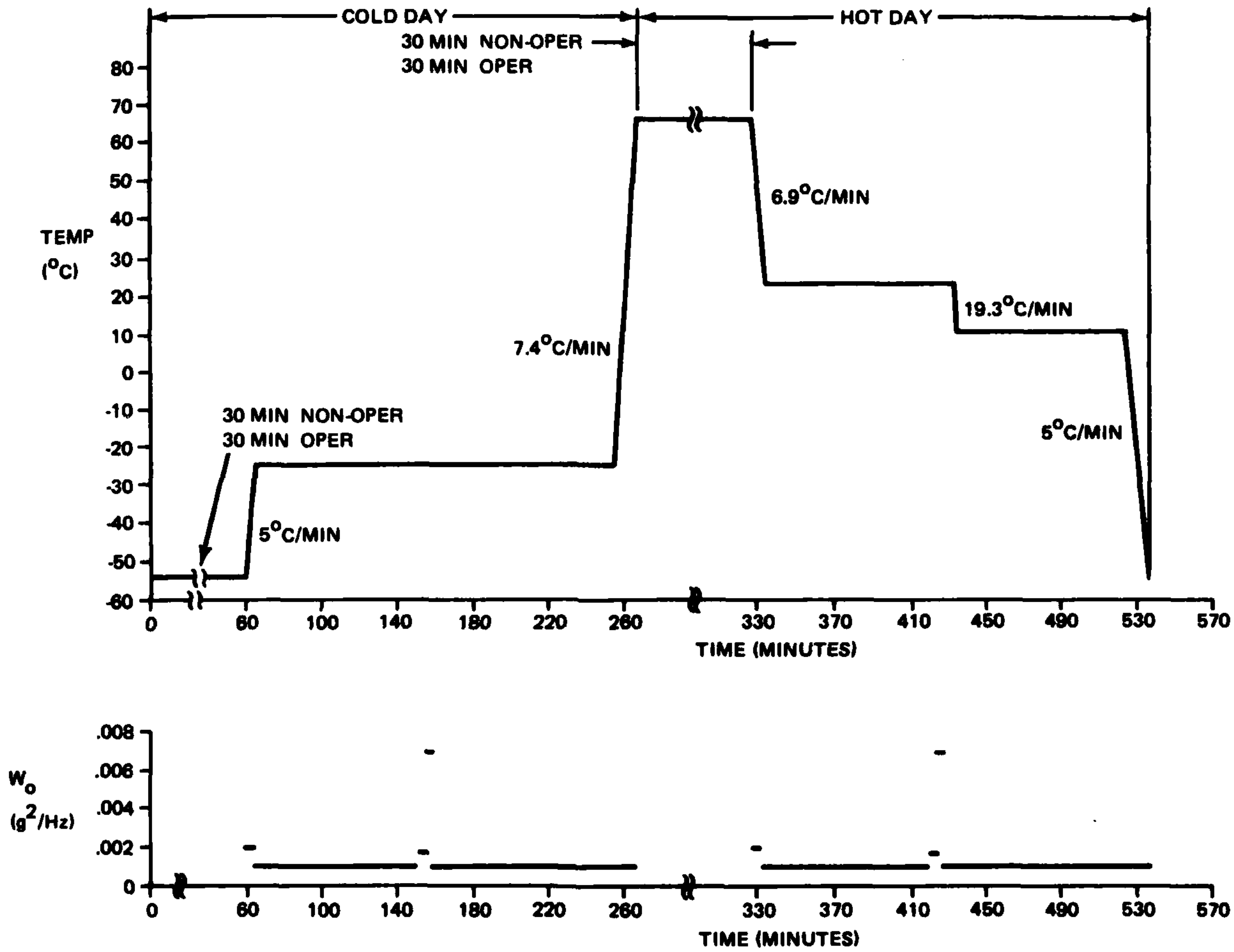


Figure C-18 Fighter Aircraft Test Profile (Escort)

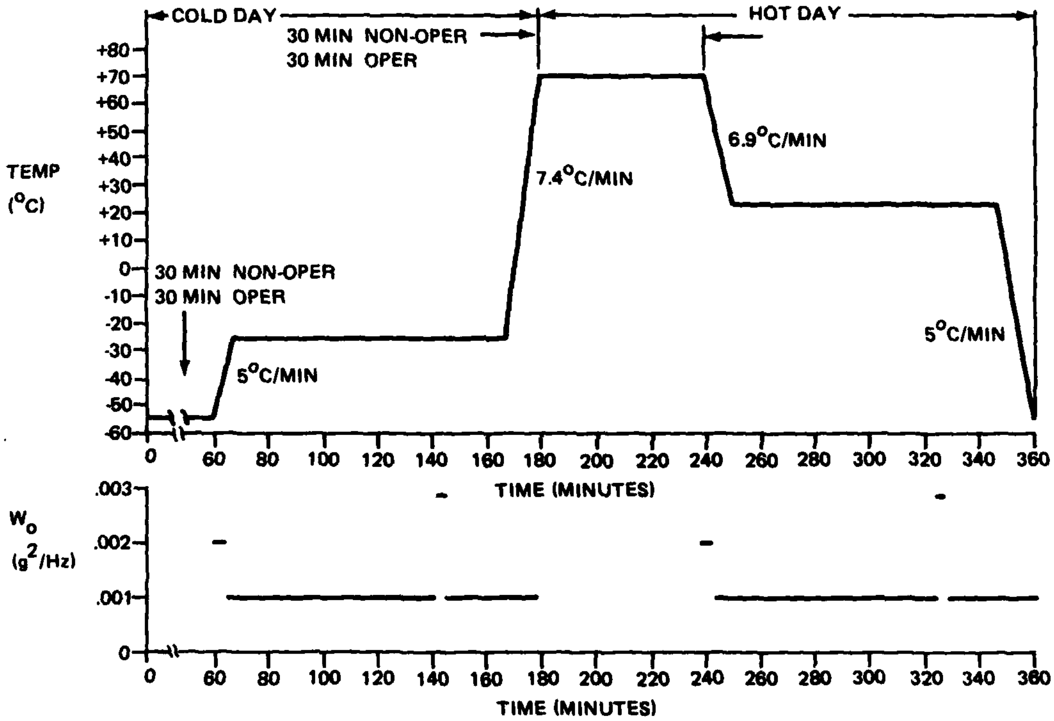


Figure C-19 Fighter Aircraft Test Profile (Air Defense/CAP)

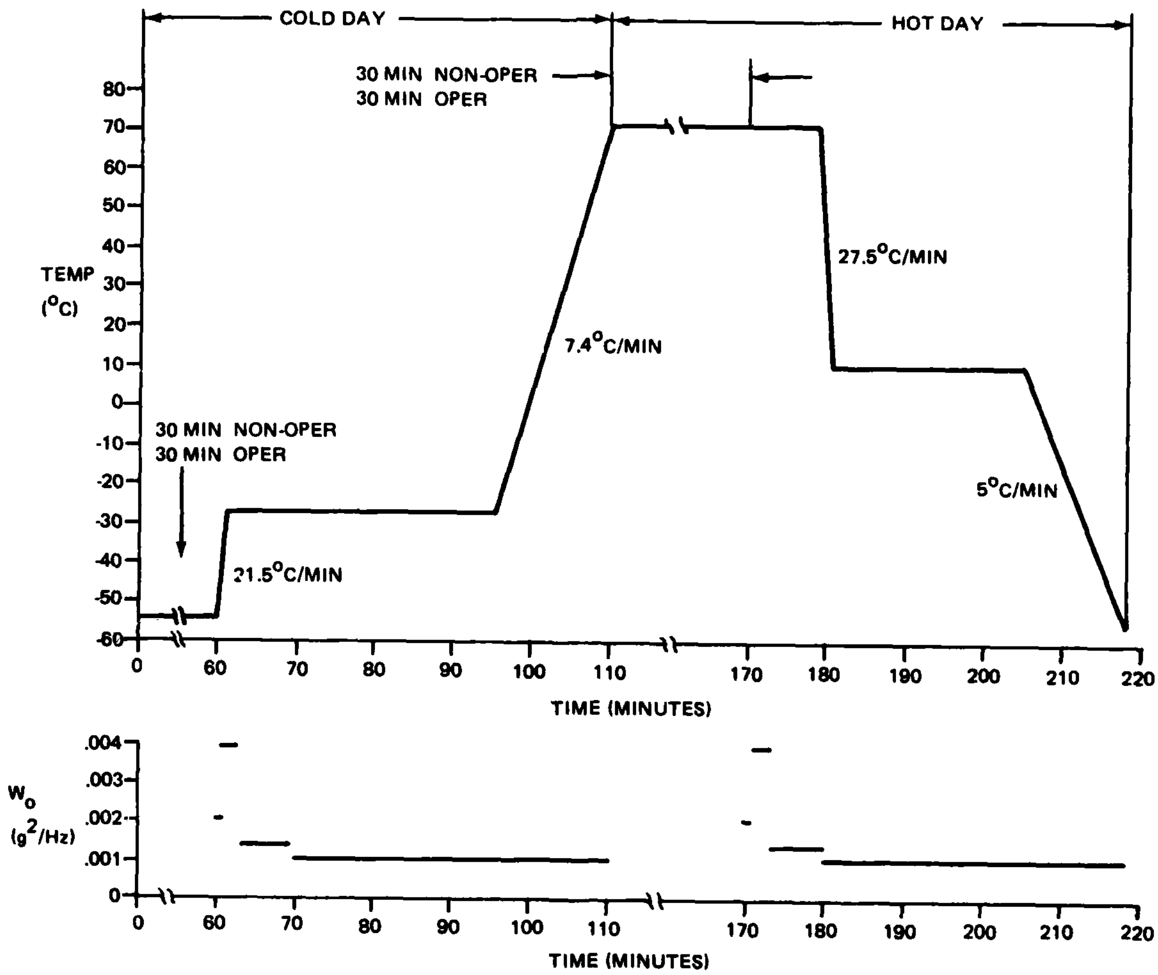


Figure C-20 Fighter Aircraft Test Profile (Intercept)

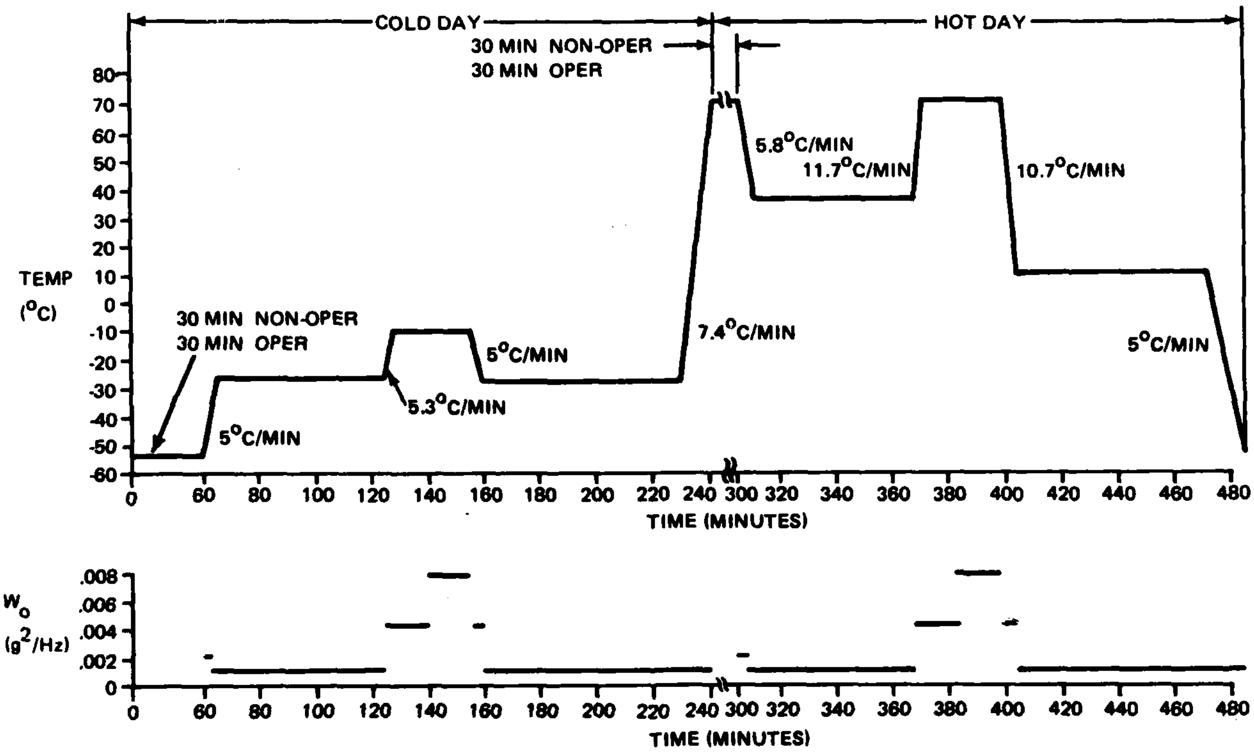


Figure C-21 Fighter Aircraft Test Profile (Hi-Lo-Lo-Hi)

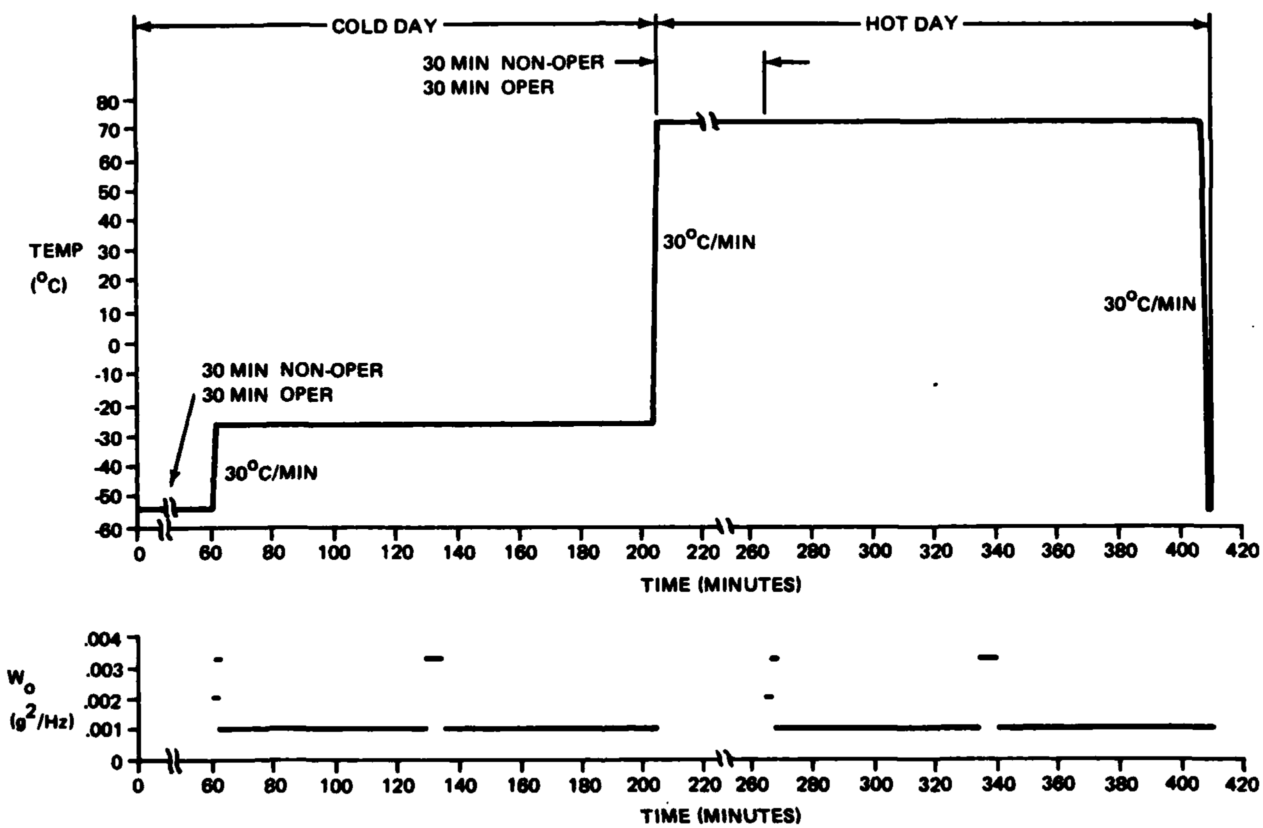


Figure C-22 Fighter Aircraft Test Profile (Lo-Lo-Lo)

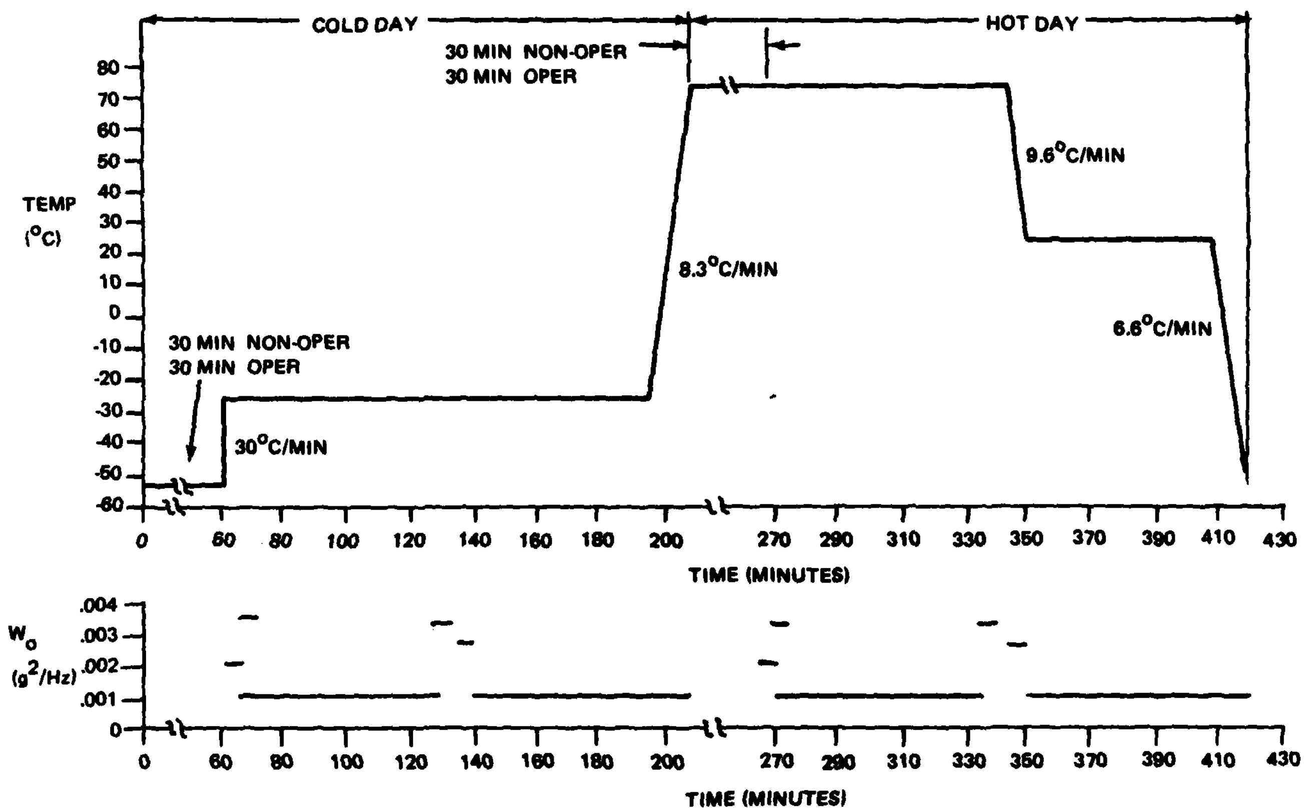


Figure C-23 Fighter Aircraft Test Profile (Lo-Lo-Hi)

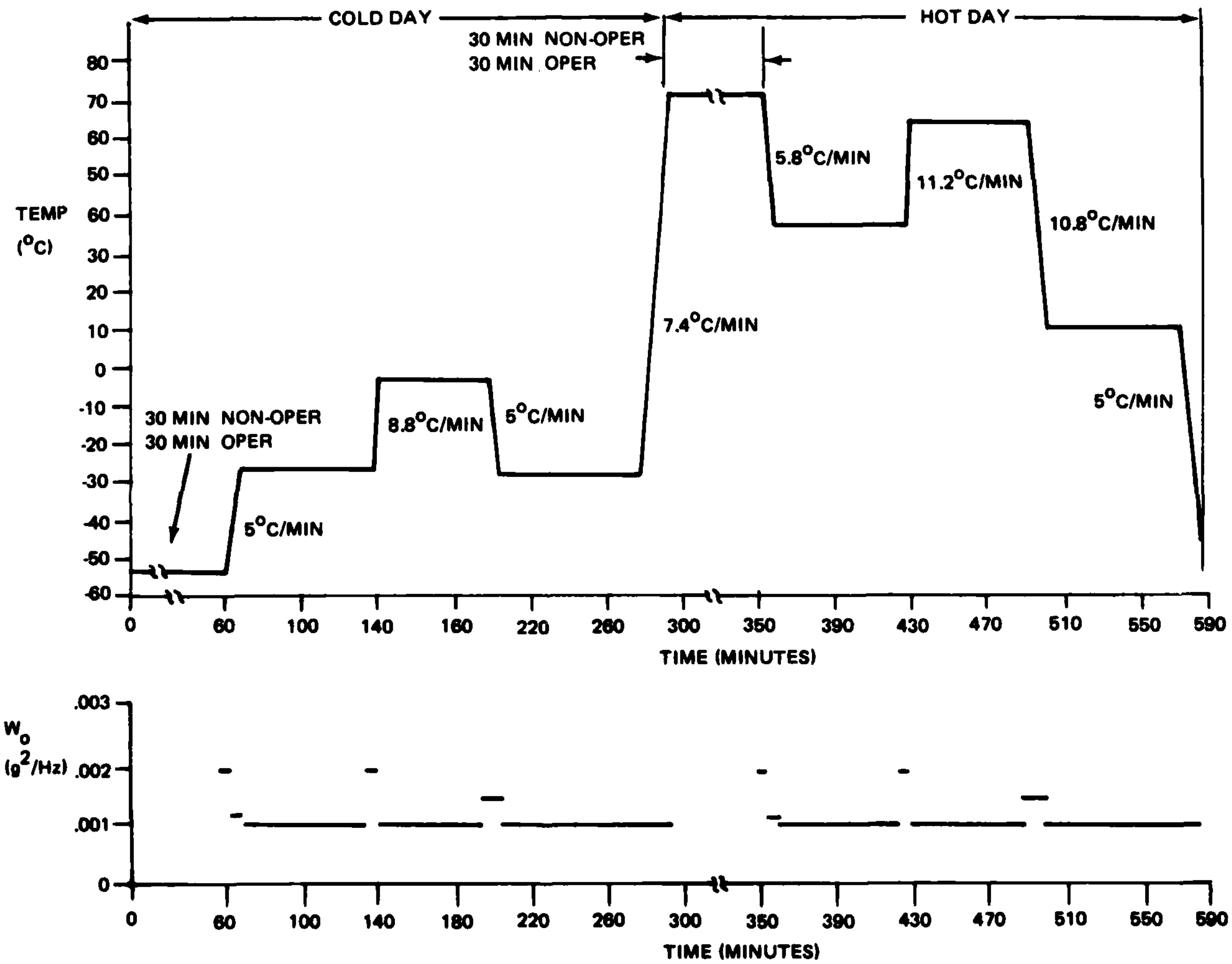


Figure C-24 Fighter Aircraft Test Profile (Close Support)

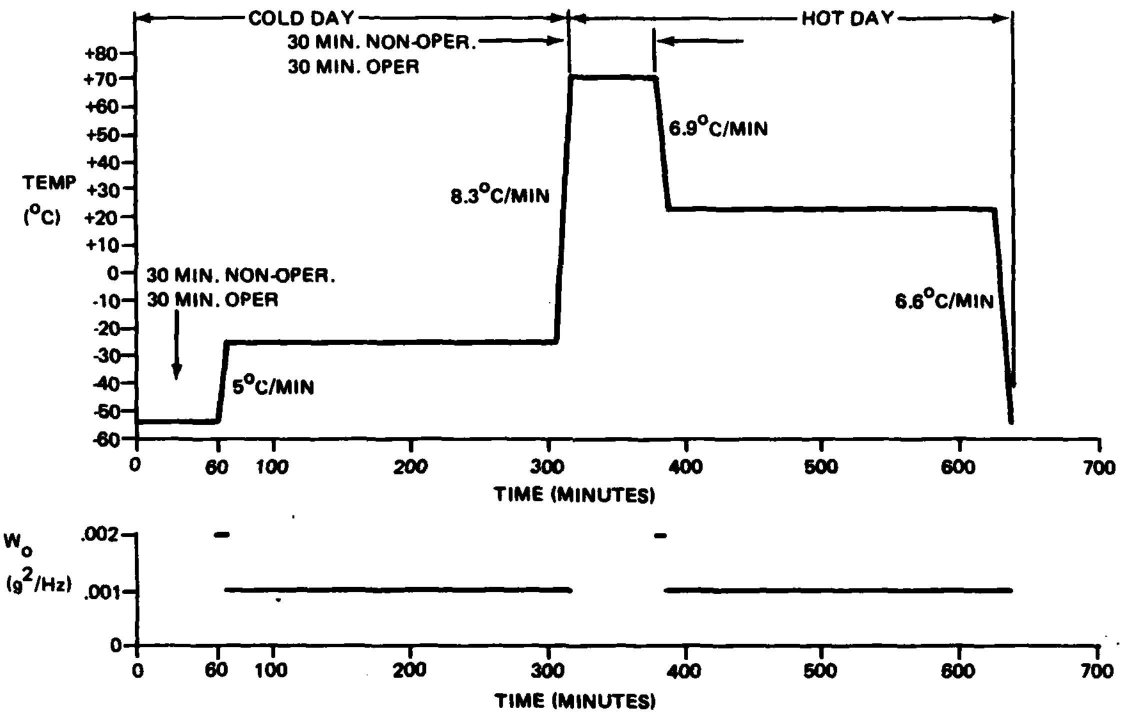


Figure C-25 Fighter Aircraft Test Profile (Ferry)

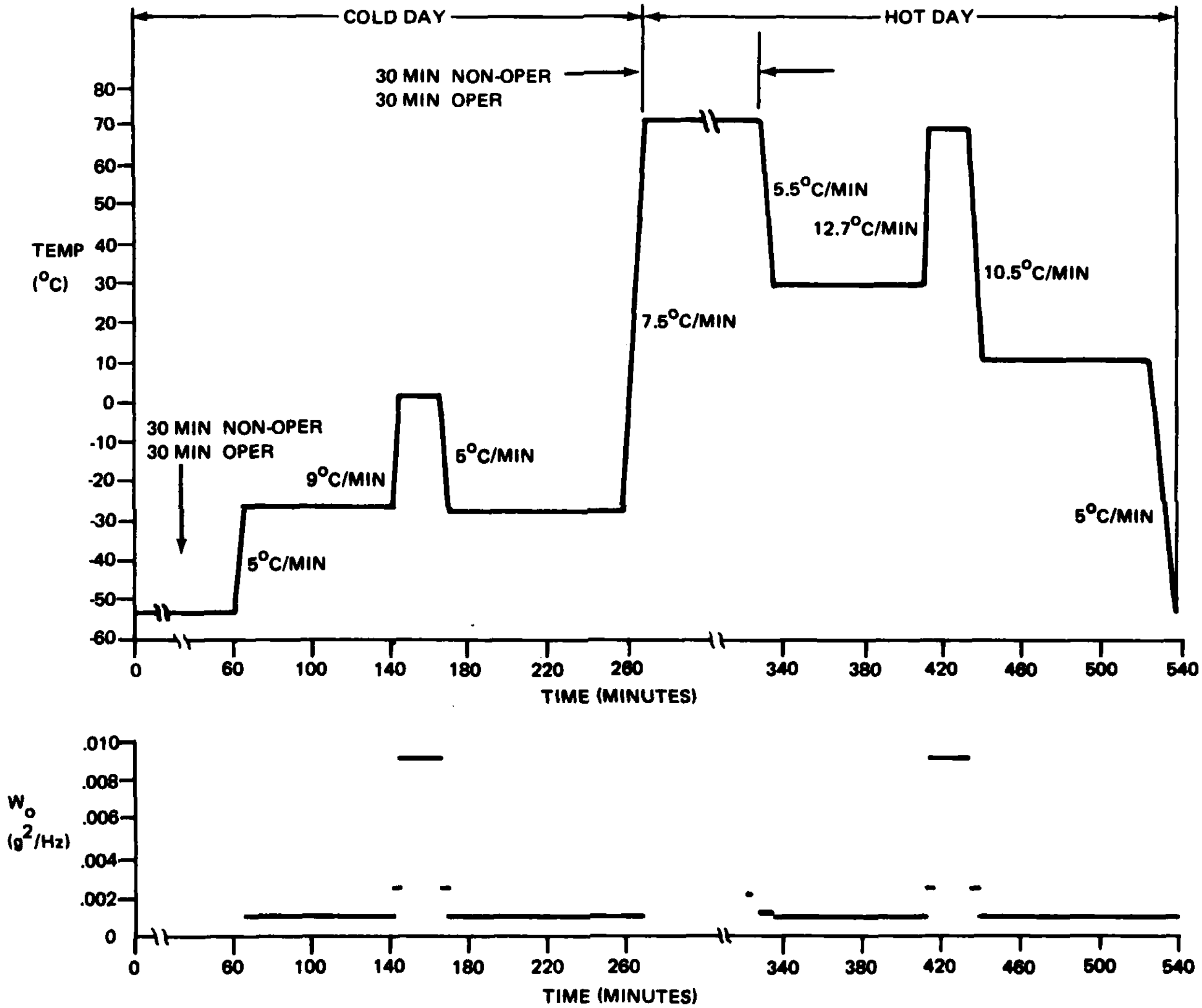


Figure C-26 Reconnaissance Aircraft Test Profile (Hi-Lo-Hi)

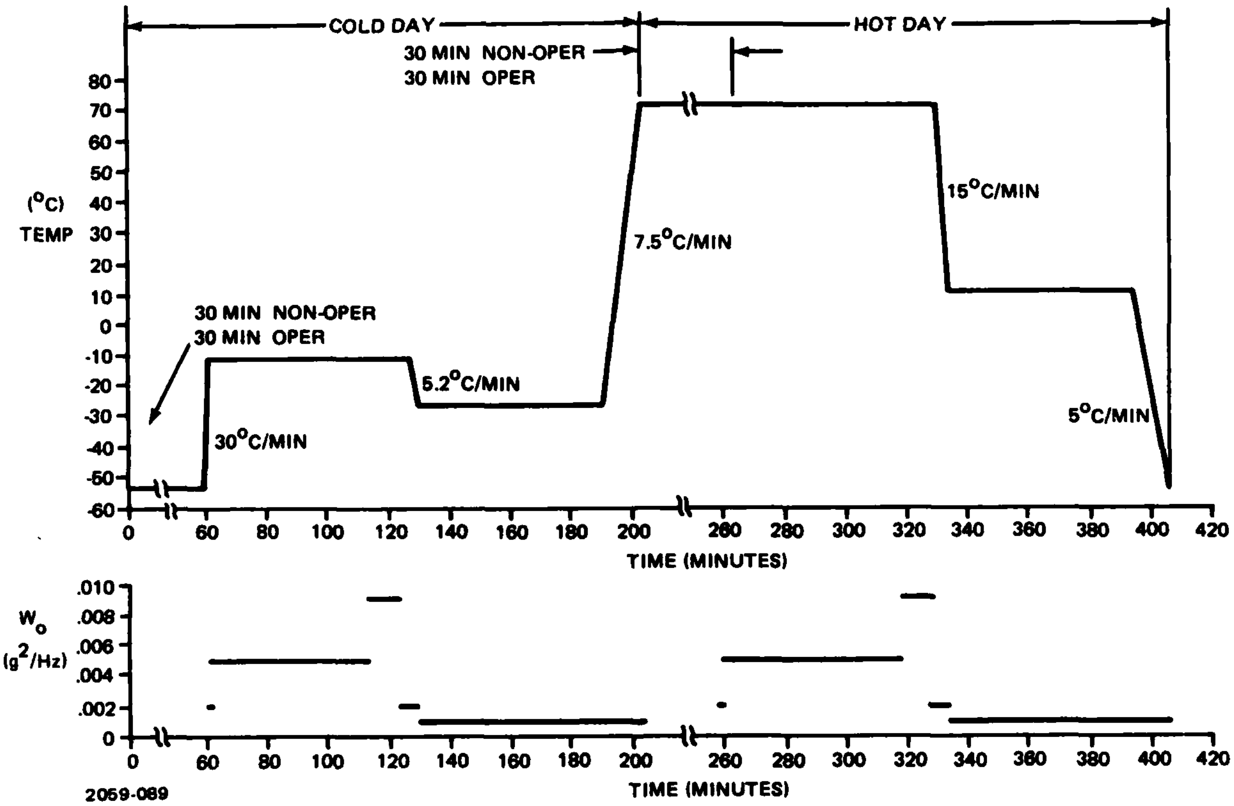


Figure C-27 Reconnaissance Aircraft Test Profile (Lo-Lo-Hi)

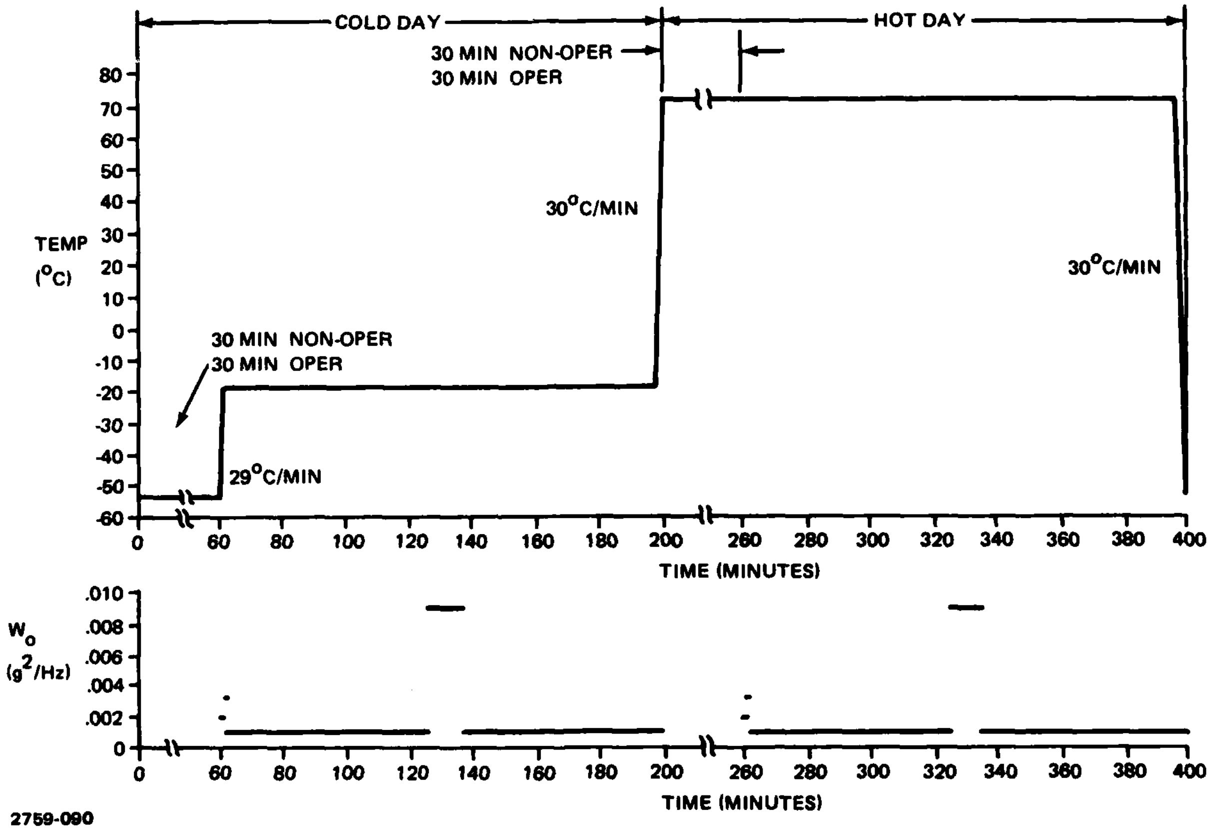


Figure C-28 Reconnaissance Aircraft Test Profile (Lo-Lo-Lo)

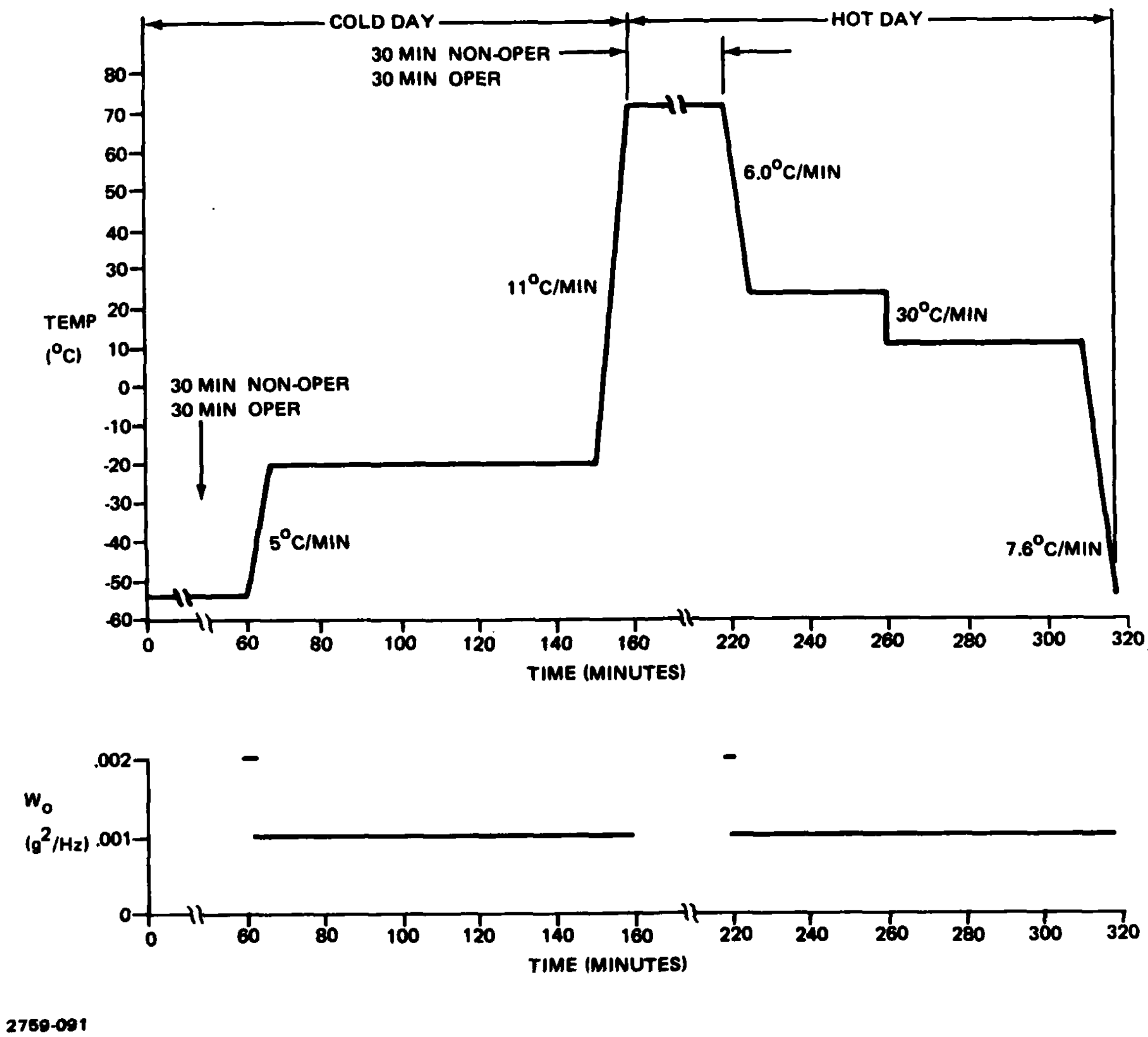


Figure C-29 Reconnaissance Aircraft Test Profile (Hi-Supersonic)

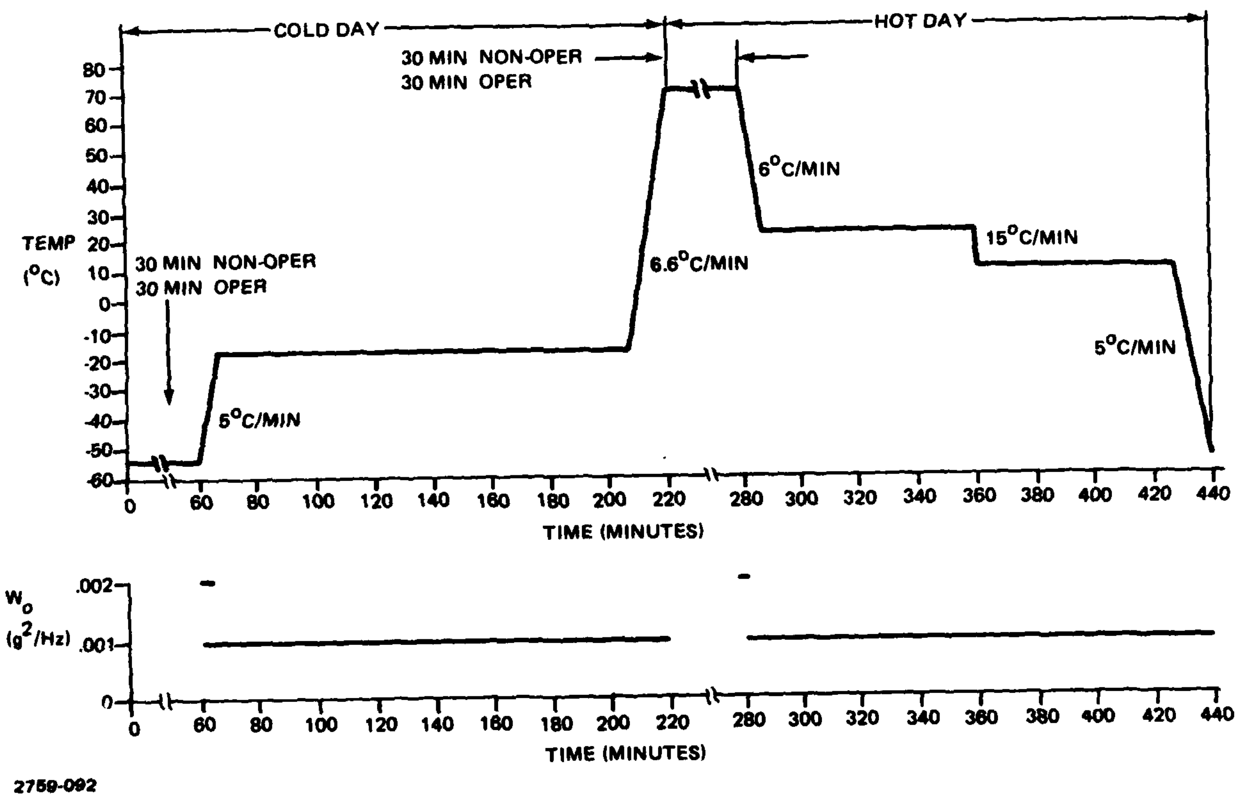


Figure C-30 Reconnaissance Aircraft Test Profile (Hi-Subsonic)

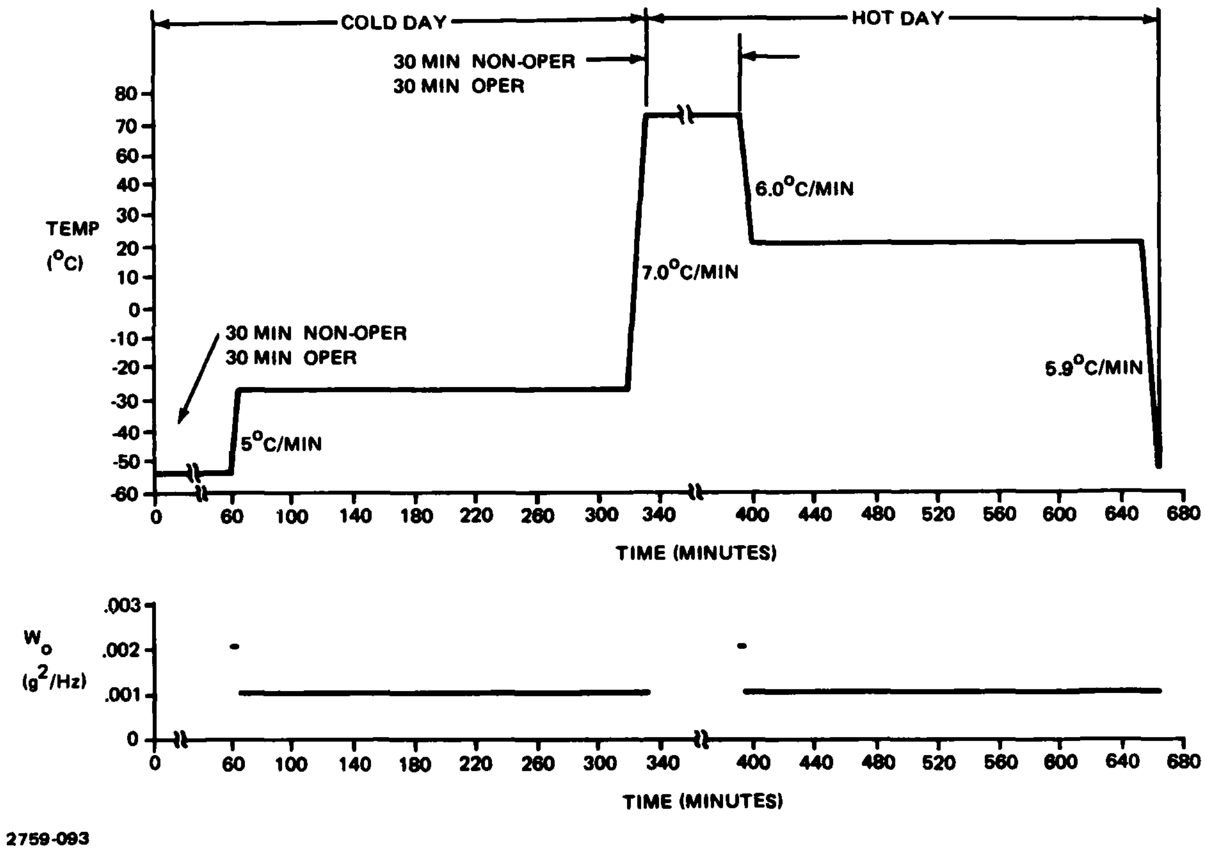


Figure C-31 Reconnaissance Aircraft Test Profile (Ferry)

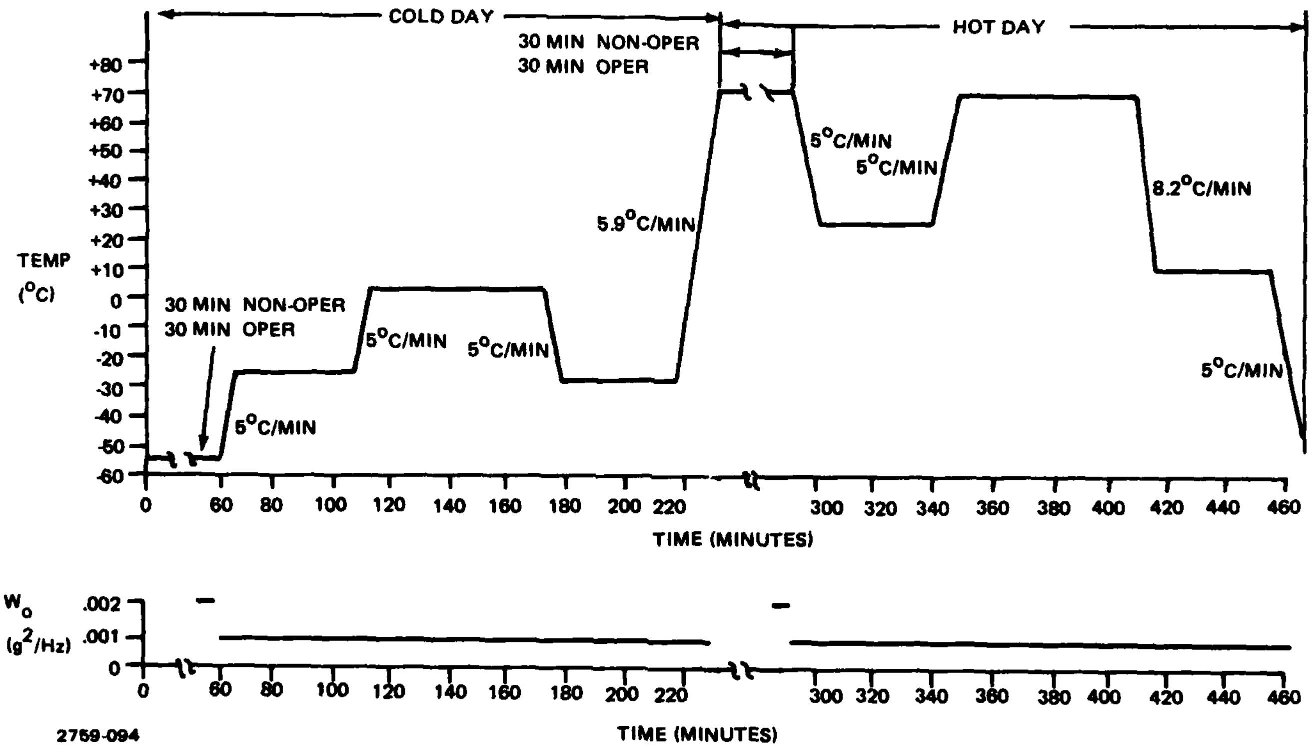


Figure C-32 Tanker Aircraft Test Profile (Hi-Lo-Hi Refuel)

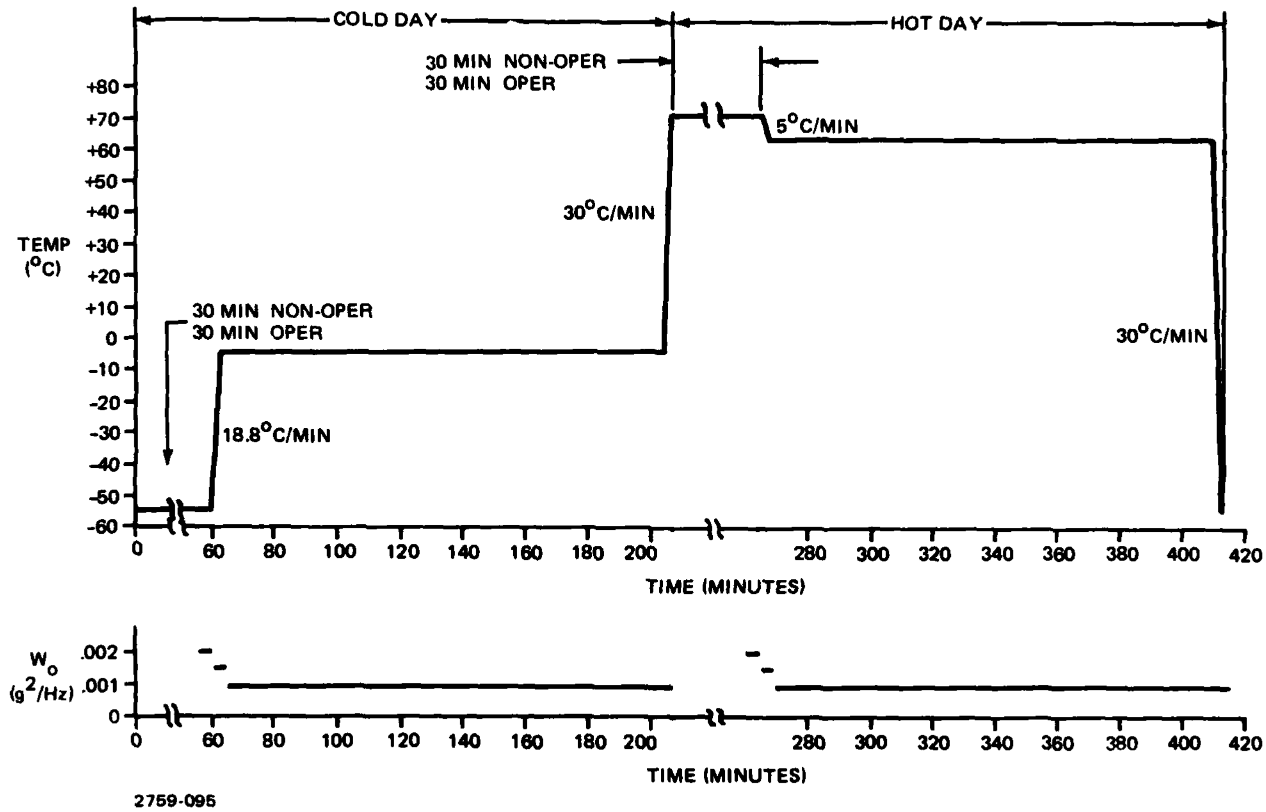


Figure C-33 Tanker Aircraft (Lo-Lo-Lo Refuel)

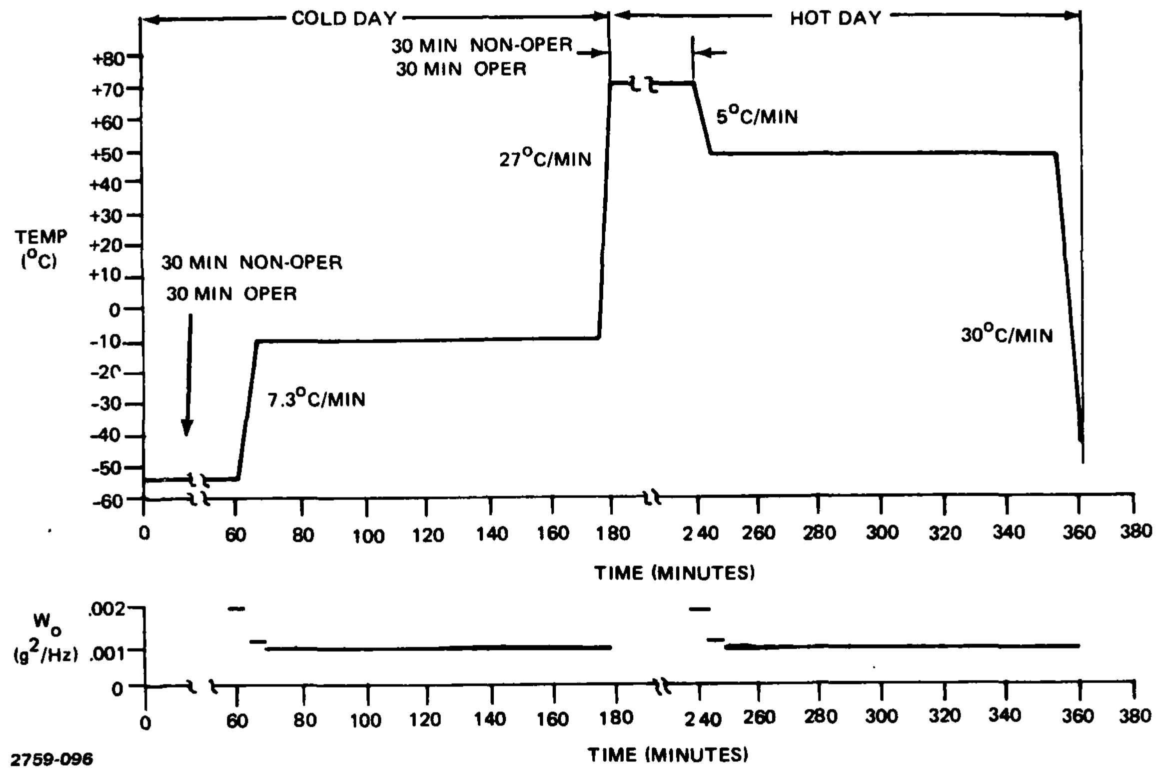


Figure C-34 Tanker Aircraft Test Profile (Strike Refuel)

APPENDIX D

COMPOSITE ENVIRONMENTAL TEST PROFILE
DEVELOPMENT PROCEDURE
(Multi-Mission Application)

COMPOSITE ENVIRONMENTAL TEST PROFILE DEVELOPMENT PROCEDURE

(Multi-Mission Application)

1. INTRODUCTION

A composite test profile shall be developed for those situations where it is anticipated that the equipment will be used during more than one type of mission. The development requires that a test profile be developed for each such identified mission (see Procedure-Appendix B) for which temperature, vibration, humidity and input voltage levels and durations have been determined. The composite test profile framework has been structured to retain the concept of two missions within each test cycle. One mission starts from a cold environment and procedes to a hot environment. The second starts from a hot environment and returns to a cold environment. Provisions have been included in the structure for exposure to three temperature levels during each mission and four vibration levels during each test cycle. This procedure requires that the following information be available to the user:

- An environmental test profile for each applicable mission (see Procedure-Appendix B for guidance in developing these test profiles)
- An estimate of the relative frequency of occurrence of each mission.

2. PROCEDURE

2.1 Required Information

2.1.1 Individual Test Profiles - A test profile for each applicable mission shall be developed using Procedure (Appendix B). Each such profile shall indicate temperature levels and rates of change and their duration for the Hot Day Mission and Cold Day Mission separately. In addition all vibration levels and corresponding durations shall be identified.

2.1.2 Mission Weighting Factors - The estimated relative frequency of occurrence of each mission shall be determined from an operations study of the application of the equipment and its intended host platform. A relative frequency of occurrence is defined as the proportion of the total missions contributed by an individual mission type.

Note: The sum of the mission weighting factors over all applicable missions shall be equal to 1.0.

2.2 Temperature

The procedure described herein is identical for the Hot Day and Cold Day missions. Separate analyses shall be performed for each.

2.2.1 Tabulation - A table, similar to that shown in Table D-1 shall be prepared. Each steady state temperature level and its corresponding duration shall be listed for each applicable mission. The mission weighting factor for each mission shall be identified. The weighted durations shall be determined by multiplying each duration by its corresponding mission weighting factor.

2.2.2 Summarization - The information presented in Table D-1 shall be summarized and a table, similar to table D-2 shall be prepared. Every unique temperature value appearing in Table D-1 shall be listed in ascending order on Table D-2. Note: Only one entry per temperature value shall be made in Table D-2 irrespective of how many times that value appears in the same or in different missions. Total weighted duration for each temperature level shall be determined by summing the weighted durations for each entry of that temperature level appearing in Table D-1.

2.2.3 Selection of Levels - Three levels of temperature (MAX, INT, MIN) and their durations shall be selected from those appearing in Table D-2. The MAX shall be the highest temperature value indicated and the MIN shall be the lowest. The test duration for each shall be the corresponding total weighted duration. The INT level shall be determined at the time weighted average of all the temperature values appearing in Table D-2 that have not been included in the determination of the MAX and MIN levels. The test duration for the INT level shall be the sum of the total weighted durations of those temperature values used in the determination of the INT value.

Notes:

1. Time Weighted Average = $\dfrac{\sum \text{(level)} \times \text{(time)}}{\sum \text{(times)}}$

For example:

☐ HOT DAY
☐ COLD DAY

TABLE D-1 TABULATION OF TEMPERATURE VALUES

MISSION A WEIGHTING FACTOR =			MISSION B WEIGHTING FACTOR =			MISSION X WEIGHTING FACTOR =		
TEMP. LEVEL	DURATION	WEIGHTED DURATION	TEMP. LEVEL	DURATION	WEIGHTED DURATION	TEMP. LEVEL	DURATION	WEIGHTED DURATION

2759-099

TABLE D-2 SUMMARY OF TEMPERATURE VALUES

TEMP. VALUE	TOTAL WEIGHTED DURATION
___	___
___	___
___	___
___	___
___	___

☐ HOT DAY
☐ COLD DAY

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Given:

Temp. level °C	Total weighted duration (min)
20	15
5	10
3	20

$$\text{INT} = \frac{(20 \times 15) + (5 \times 10) + (3 \times 20)}{15 + 10 + 20} = \frac{410}{45} = 9.1^\circ\text{C}$$

Duration $= \sum$(corresponding times)

$= 15 + 10 + 20$
$= 45$ minutes

2. When determining MAX (or MIN) level, combine all temperature values in Table D-2 within 5° C of the highest (or lowest) value by the method of time weighted average. Duration for MAX (or MIN) shall be the sum of the corresponding total weighted durations.

3. If either MAX or MIN level does not have a duration of at least 20 minutes, determine a new value of MAX or MIN by time weighting with the next most severe level(s) until at least a 20 minute duration is achieved by summing the corresponding weighted durations.

4. If INT level does not have a duration of at least 20 minutes, specify it to be 20 minutes and subtract one-half the difference between 20 and INT duration from both the MAX and MIN duration.

5. If all the temperature levels of Table D-2 have been exhausted in the determination of the MAX and MIN levels and thus the INT level cannot be determined, identify the level with the longest time. Assume that level to also be INT. Use half the duration for itself (either MAX or MIN) and the other half as the duration for INT.

2.3 Vibration

2.3.1 Tabulation - A table similar to that shown in Table D-3 shall be prepared. Each vibration level (W_o) and its corresponding duration shall be listed for each applicable mission. The take-off vibration level (TO) for one minute shall be listed separately from a W_o of the same numerical value that is derived by calculation. Similarly the W_o of $.001g^2$/Hz and its corresponding duration that has been added to require continuous

TABLE D-3 TABULATION OF VIBRATION LEVELS

MISSION A WEIGHTING FACTOR =			MISSION B WEIGHTING FACTOR =			MISSION X WEIGHTING FACTOR =		
VIBRATION LEVEL (g^2/Hz)	DURATION (MIN)	WEIGHTED DURATION	VIBRATION LEVEL	DURATION (MIN)	WEIGHTED DURATION	VIBRATION LEVEL	DURATION (MIN)	WEIGHTED DURATION
.002	1		.002	1		.002	1	
.001	–		.001	–		.001	–	
–	–		–	–		–	–	
–	–		–	–		–	–	
–	–		–	–		–	–	
–	–		–	–		–	–	

2759-101

TABLE D-4 SUMMARY OF VIBRATION LEVELS

VIBRATION LEVEL	TOTAL WEIGHTED DURATION
.002	1
.001	

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vibration (see Procedure-Appendix B para. 2.4.1.) shall be listed separately from a W_o of $.001g^2/Hz$ that was derived by calculation. These two entries shall precede any other mission vibration entries. Each mission's weighting factor shall be identified. Weighted durations shall be determined by multiplying each duration by its corresponding mission weighting factor.

2.3.2 Summarization - The information presented in Table D-3 shall be summarized and a table similar to Table D-4 shall be prepared. The TO value and the $.001g^2/Hz$ level identified in para. 2.3.1 and their total weighted duration shall be listed separately and apart from the same values determined from calculation. All other unique ation levels (W_o) appearing in Table D-3 shall be listed in Table D-4 in ascending order.

> NOTE: Only one entry per W_o shall be made in Table D-4 irrespective of how many times that value appears in the same or in different missions. The total weighted duration for each W_o value shall be determined by summing the weighted durations for each entry of that W_o in Table D-3.

2.3.3 Selection of Levels - A W_o of TO for one minute (Take-off condition) shall be required. The W_o of $.001g^2/Hz$ to permit continuous vibration during the flight phases shall be required for a period equal to its total weighted duration. In addition, three levels (MAX, INT, MIN) shall be determined for the remaining values listed in Table D-4. The MAX level shall be the highest W_o listed and the MIN level shall be the lowest W_o listed. The test duration for each shall be the corresponding total weighted duration. The INT level shall be determined as the time weighted average of the remaining W_o's. The test duration for the INT level shall be the sum of the total weighted durations of the W_o's used in determining INT.

2.4 Construction of Composite Test Profile

2.4.1 Temperature - One test cycle shall consist of the following sequence of levels:

-54°C (NonOp), -54°C(Op), INT_C, MAX_C, MIN_C, +71°C(NonOp), +71°C(Op), INT_H, MAX_H, MIN_H, return to -54°C(NonOp).

The duration of the two -54°C conditions and the two +71°C conditions shall be 30 minutes each. The duration at each of the other levels shall be as determined in paragraph 2.2.

The temperature rate of change between any two levels shall be determined from a review of comparable phases of each individual test profile and selecting that value deemed most typical. The duration of exposure to a temperature rate of change shall be determined from:

$$\text{Duration} = \frac{\text{End Temperature} - \text{Start Temperature}}{\text{Rate of Change}}$$

The entire cycle showing dwells at all levels and transitions between level shall be indicated on a table similar to Table D-5 or depicted graphically as Fig. D-1.

2.4.2 Vibration - The vibration requirements shall be integrated with the temperature time line as follows:

The MAX vibration level shall start at the same time as the MAX temperature levels anc ontinue for the time determined in para. 2.3.

The MIN vibration level shall start at the conclusion of the exposure to the MAX vibration levels and continue for the time determined in para. 2.3.

The exposure to the INT vibration level for the time as determined in para. 2.3 shall start at a time calculated to assure that its completion coincides with the start of the MAX level.

The TO level shall be applied for one minute each at the start of the transitions from -54° C to INT_C and from +71° C to INT_H.

A level of $.001g^2$/Hz shall be applied during all other periods except for the -54° C and +71° C soaks.

The vibration requirements for one complete cycle shall be indicated in a table similar to Table D-5 or depicted graphically as in Figure D-1.

2.4.3 Humidity - Moisture shall be injected into the test chamber and a dewpoint temperature of +31° C or greater shall be attained during the initial portion of the ground, non-operate phase for a hot day. The +31° C (or greater) shall be maintained and controlled until the end of the ground, operate phase for a hot day. No further injection of moisture is required for any of the other profile phases and the humidity during these phases shall be uncontrolled. The humidity shall be maintained and controlled at +31° C or greater for each subsequent cycle during the hot day ground non-operate and operate conditions. Drying of chamber air shall not be accomplished at any time during a test cycle.

TABLE D-5 COMPOSITE TEST PROFILE TIMELINE

TEMP PHASE	TEMP VALUE (°C)	DURATION (MIN.)	TEMP RATE OF CHGE (°C/MIN.)	DURATION (MIN.)	START TIME	VIB PHASE	VIB VALUE (g^2/Hz)	DURATION (MIN.)	START TIME
NON-OP SOAK						NO VIB			
OP SOAK									
TRANSITION						TO			
INT						*			
TRANSITION						INT			
MAX						MAX			
TRANSITION						MIN			
MIN						*			
TRANSITION						*			
NON-OP SOAK						NO VIB			
OP SOAK									
TRANSITION						TO			
INT						*			
TRANSITION						INT			
MAX						MAX			
TRANSITION						MIN			
MIN						*			
TRANSITION						*			
NON-OP SOAK						NO VIB			

*0.001 g^2/Hz AS REQUIRED TO ASSURE CONTINUOUS VIBRATION DURING FLIGHT PHASES

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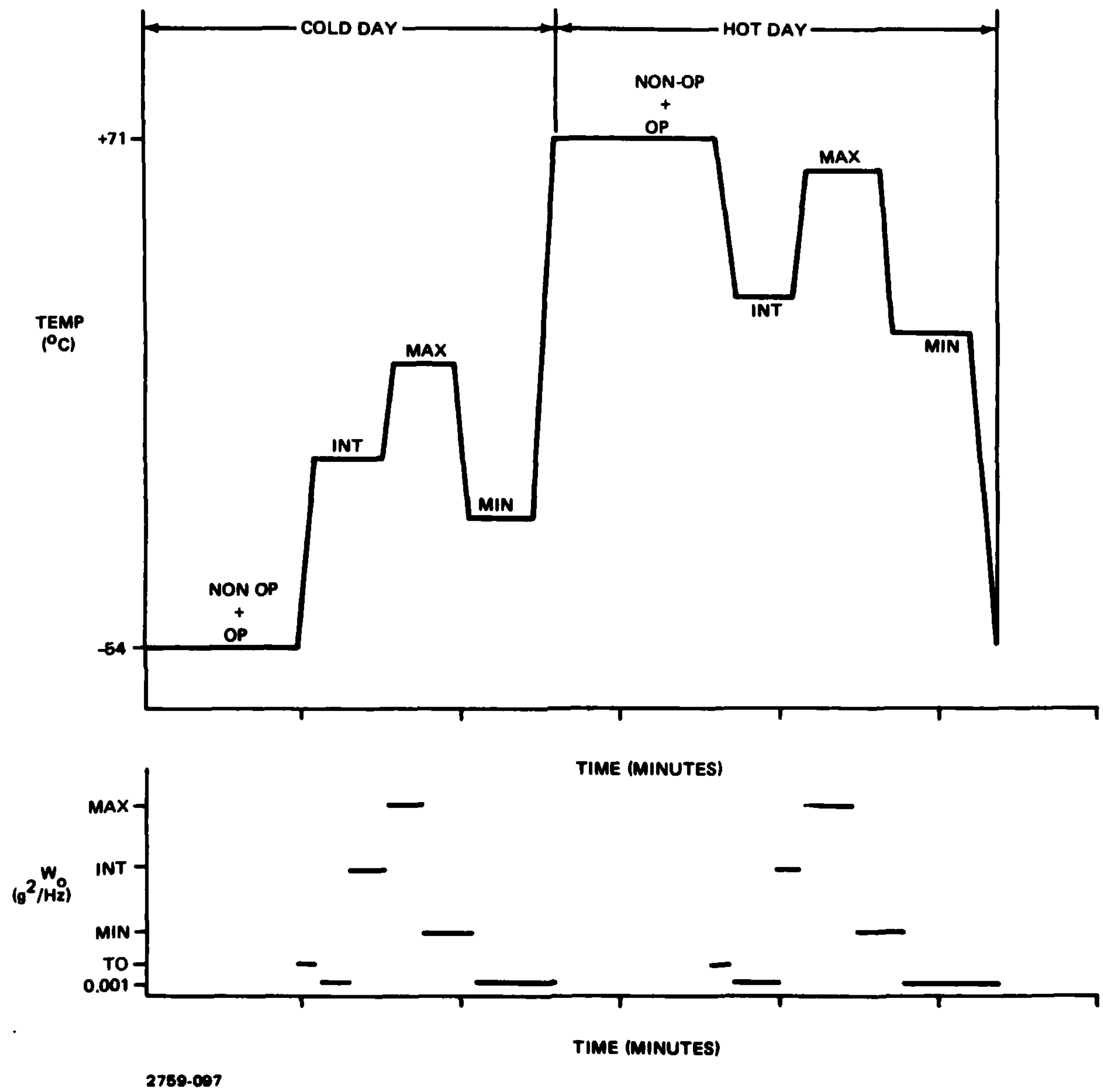

Figure D-1 Composite Test Profile (Example)

2.4.4 Equipment Operation - The equipment shall be in an operating mode during all phases of a test profile except for the ground, non-operate phases.

2.4.5 Electrical Stress - Input voltage shall be maintained at 110% of nominal for the first test cycle, at the nominal value for the second test cycle and at 90% of the nominal for the third test cycle. This sequence shall be repeated continuously during subsequent cycles through throughout the test. The equipment shall be turned ON and OFF at least twice before continuous power is applied to determine start up ability at the extremes of the thermal cycle.

3. EXAMPLE

The following example is provided to illustrate the application of the procedure.

The aim of the example is to develop a composite environmental test profile for a Class II equipment that is attached to structure adjacent to the external surface of a jet fighter aircraft. The table below indicates the missions in which the equipment is used and the relative frequency of occurrence of each mission.

MISSION TYPE	REL. FREQ. OF OCCURRENCE
Lo-Lo-Lo	.10
Hi-Lo-Lo-Hi	.40
Lo-Lo-Hi	.25
Close Support	.20
Ferry	.05
	1.0

Figures D-2 through D-6 are the corresponding test profiles for the missions enumerated above. Temperature and vibration levels and durations may be directly read from the figures. The application of the procedure is illustrated in the following tables:

Table D-6 and D-7 Hot Day Temperature
Table D-8 and D-9 Cold Day Temperature
Table D-10 and D-11 Vibration.

Temperature rates of change between levels are determined by reviewing the corresponding phases of the individual test profiles and selecting the most appropriate. The selected rates and calculated durations are presented in Table D-12.

The completed composite profile is shown in a time-line in Table D-13 and depicted graphically in Fig. D-7.

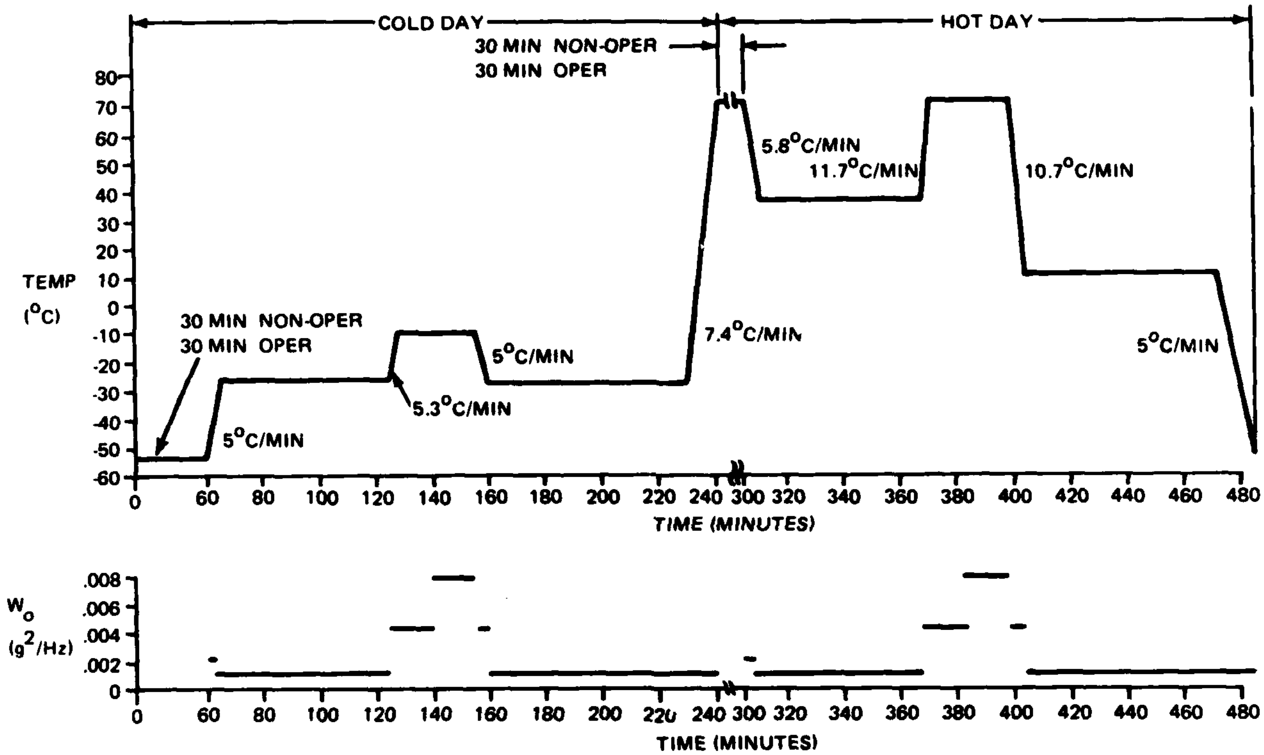

Figure D-2 Fighter Aircraft Test Profile (Hi-Lo-Lo-Hi)

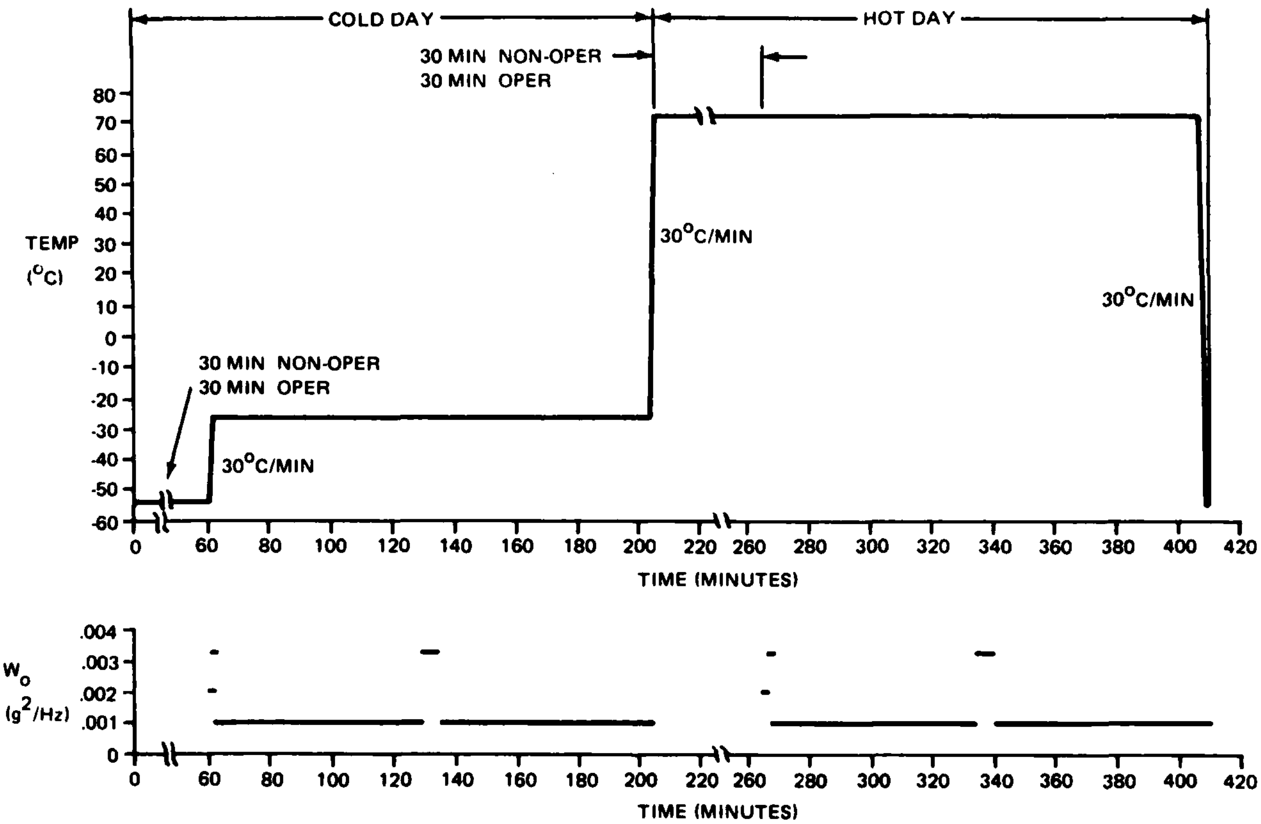

Figure D-3 Fighter Aircraft Test Profile (Lo-Lo-Lo)

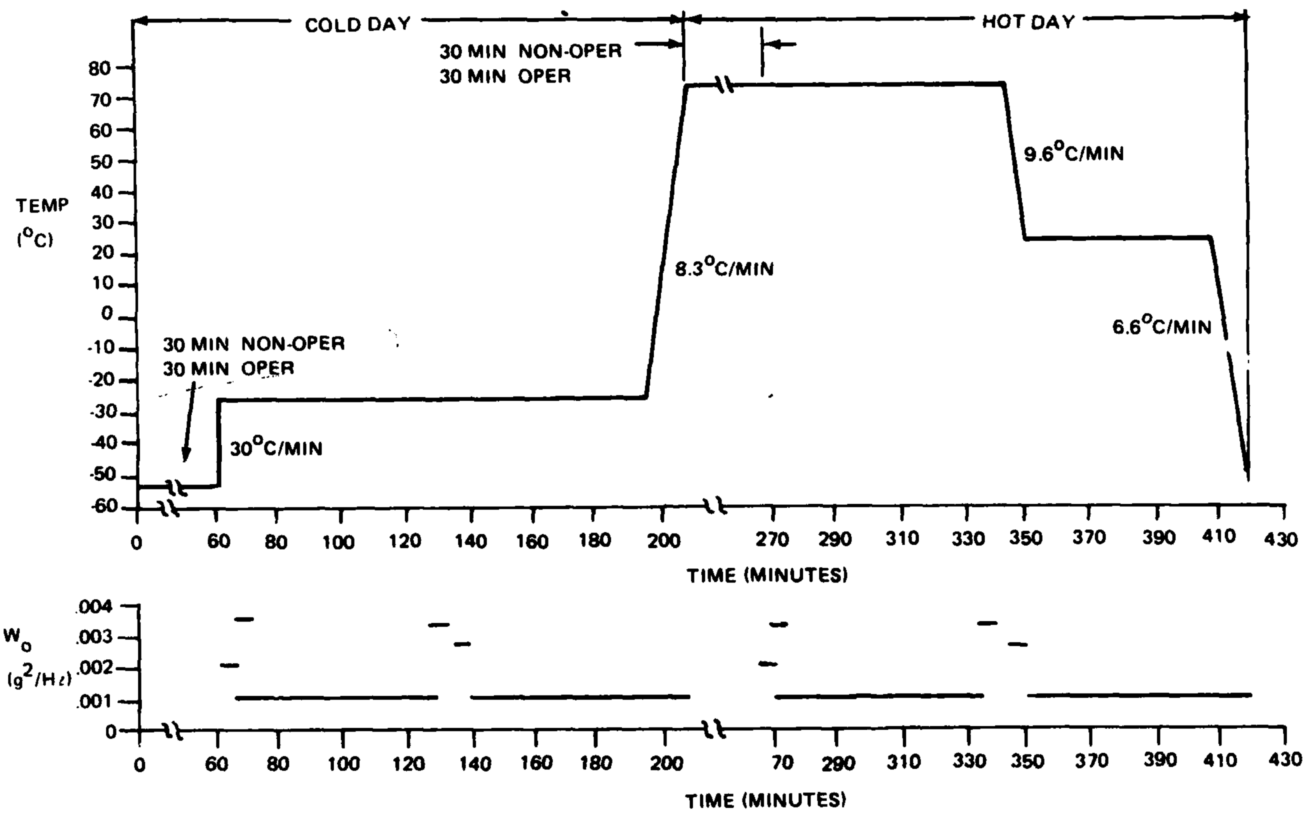

Figure D-4 Fighter Aircraft Test Profile (Lo-Lo-Hi)

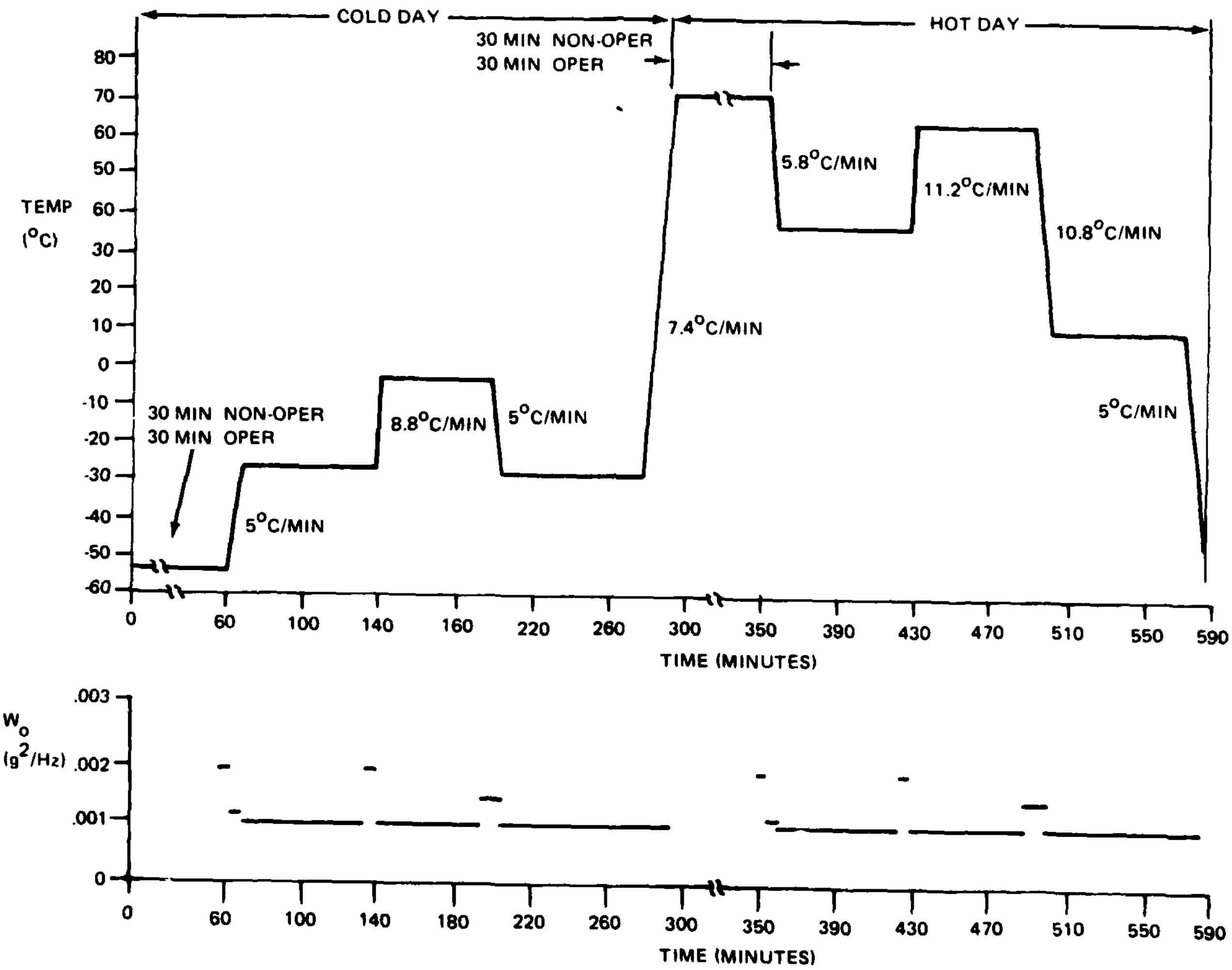

Figure D-5 Fighter Aircraft Test Profile (Close Support)

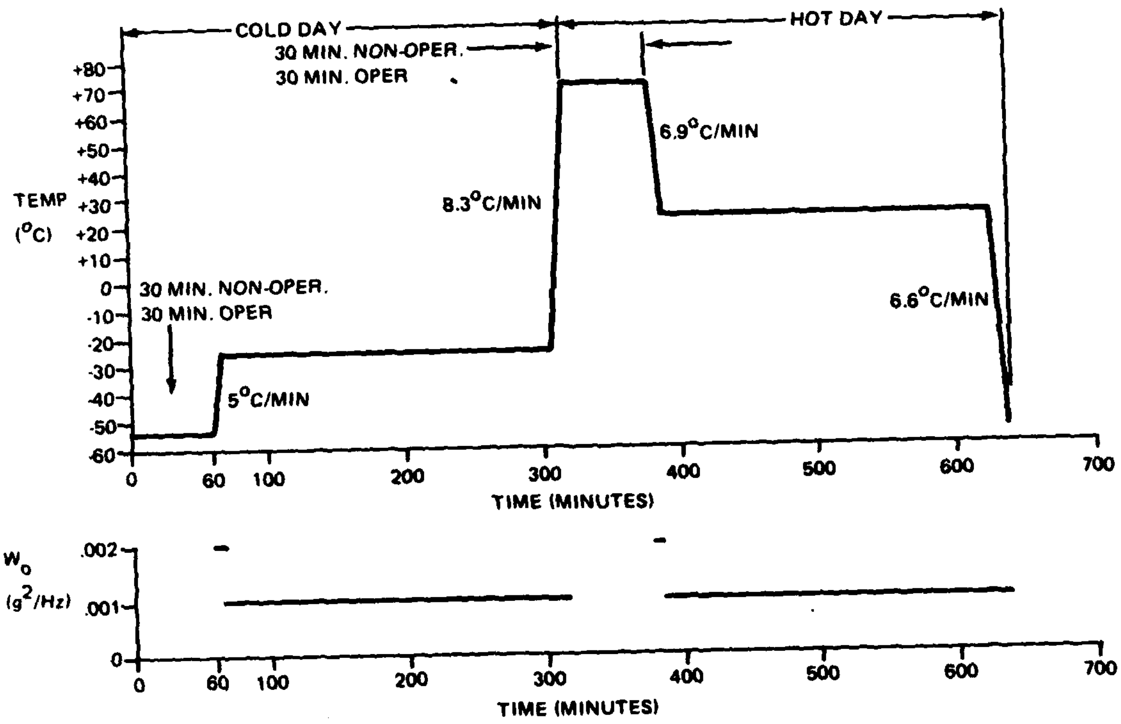

Figure D-6 Fighter Aircraft Test Profile (Ferry)

TABLE D-6 TEMPERATURE LEVEL TABULATION – HOT DAY (EXAMPLE)

LO-LO-LO WEIGHTING FACTOR = .10			HI-LO-LO-HI WEIGHTING FACTOR = .40			LO-LO-HI WEIGHTING FACTOR = .25			CLOSE SUPPORT WEIGHTING FACTOR = .20			FERRY WEIGHTING FACTOR = .05		
TEMP. LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD. DUR
71	145	14.5	36	60	24.0	71	75	18.75	36	70	14.0	23	240	12
			71	27	10.8	23	60	15.0	64	60	12.0			
			10	70	28.0				10	75	15.0			

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TABLE D-7 TEMPERATURE SUMMARY – HOT DAY (EXAMPLE)

TEMP LEVEL (°C)	TOTAL WEIGHTED DURATION (MIN)
10	43.0
23	27.0
36	38.0
64	12.0
71	44.05

2759-105

NOTE: Selected Levels and Durations are:

MIN = 10°C for 43 Minutes
MAX = 71°C for 44 Minutes
INT = 35.8°C for 77 Minutes

$$INT = \frac{(23)(27) + (36)(38) + (64)(12)}{27 + 38 + 12} = \frac{2757}{77} = 35.8$$

TABLE D-8 TEMPERATURE LEVEL TABULATION – COLD DAY (EXAMPLE)

LO-LO-LO WEIGHTING FACTOR = .10			HI-LO-LO-HI WEIGHTING FACTOR = .40			LO-LO-HI WEIGHTING FACTOR = .25			CLOSE SUPPORT WEIGHTING FACTOR = .20			FERRY WEIGHTING FACTOR = .05		
TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR	TEMP LEVEL (°C)	DURATION (MIN)	WTD DUR
-26	145	14.5	-26	130	52.0	-26	140	35.0	-26	70	14.0	-26	240	12.0
			-10	27	10.8				-4	60	12.0			
									-27	75	15.0			

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TABLE D-9 TEMPERATURE SUMMARY – COLD DAY (EXAMPLE)

TEMP. LEVEL (°C)	TOTAL WEIGHTED DURATION (MIN)
-27	15.0
-26	127.5
-10	10.8
- 4	12.0

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NOTES: Selected Levels and Durations

$$MAX^{(1)} = \frac{(-10)\ (10.8) + (-4)\ (12)}{10.8 + 12} = -6.8^{\circ}C \text{ for } 22.8 \text{ min}$$

$$MIN^{(2)} = \frac{(-27)\ (15) + (-26)\ (127.5)}{15 + 127.5} = -26.1^{\circ}C \text{ for } 142.5 \text{ min}$$

since no levels remain to select INT value(3)

MIN = $-26.1^{\circ}C$ for 71.25 minutes and

INT = $-26.1^{\circ}C$ for 71.25 minutes

(1) See procedure para. 2.2.3 – Notes 2 and 3

(2) See procedure para. 2.2.3 – Note 2

(3) See procedure para. 2.2.3 – Note 5

TABLE D-10 VIBRATION LEVEL TABULATION (EXAMPLE)

LO-LO-LO WEIGHTING FACTOR = .10			HI-LO-LO-HI WEIGHTING FACTOR = .40			LO-LO-HI WEIGHTING FACTOR = .25			CLOSE SUPPORT WEIGHTING FACTOR = .20			FERRY WEIGHTING FACTOR = .05		
VIB LEVEL (g^2/Hz)	DURATION (MIN)	WTD DUR	VIB LEVEL (g^2/Hz)	DURATION (MIN)	WTD DUR	VIB LEVEL (g^2/Hz)	DURATION (MIN)	WTD DUR	VIB LEVEL (g^2/Hz)	DURATION (MIN)	WTD DUR	VIB LEVEL (g^2/Hz)	DURATION (MIN)	WTD DUR
002	1	0 1	002	1	0 4	002	1	0 25	.002	1	0 2	.002	1	0 5
(take off)			(take-off)		(take-off)	(take off)		(take-off)				(take-off)		
001	140 3	14 03	001	143	57 2	001	142	35 5	001	218	43 6	001	259	12 95
0032	5 2	0 52	0041	20 7	8 28	0032	5 2	1.3	.0012	6.0	1 2			
			.0077	15 0	6.0	.0026	5.0	1 25	002	2 5	0 5			
			0012	6 0	2 4				0015	5.0	1 0			

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TABLE D-11 VIBRATION LEVEL SUMMARY (EXAMPLE)

VIBRATION LEVEL (g^2/Hz)	TOTAL WEIGHTED DURATION (MIN)
.002	1.0
.001	163.28
.0012	3.6
.0015	1.0
.002	0.5
.0026	1.25
.0032	1.82
.0041	8.28
.0077	6.0

Notes: Selected Levels and Durations

T/O = .002g^2/Hz for 1 minute

MAX = .0077g^2/Hz for 6 minutes

MIN = .0012g^2/Hz for 3.6 minutes

INT$^{(1)}$ = .0035g^2/Hz for 12.85 minutes

.001g^2/Hz for 163.28 minutes to assure continuous vibration

(1) INT =

$$\frac{(.0015)(1.0)+(.002)(0.5)+(.0026)(1.25)+(.0032)(1.82)+(.0041)(8.28)}{1.0 + 0.5 + 1.25 + 1.82 + 8.28} =$$

$$\frac{.045522}{12.95} = .0035$$

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TABLE D-12 TEMPERATURE RATE OF CHANGE (EXAMPLE)

FROM LEVEL	TO LEVEL	TEMP RATE OF CHANGE (°C)	DURATION (MIN)
-54°C	INT_C	5	[(-26.1) – (-54)] ÷ 5 = 5.6
INT_C	MAX_C	7	[(-6.8) – (-26.1)] ÷ 7 = 2.8
MAX_C	MIN_C	5	[(-26.1) – (-6.8)] ÷ 5 = 3.9
MIN_C	+71°C	8	[(+71) – (-26.1)] ÷ 8 = 12.1
+71°C	INT_H	6	[(35.8) – (71)] ÷ 6 = 5.9
INT_H	MAX_H	11.5	[(71) – (35.8)] ÷ 11.5 = 3.1
MAX_H	MIN_H	10.5	[(10) – (71)] ÷ 10.5 = 5.8
MIN_H	-54°C	6	[(-54) – (10)] ÷ 6 = 10.7

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TABLE D-13 COMPOSITE TEST PROFILE TIMELINE (EXAMPLE)

TEMP PHASE	TEMP LEVEL (°C)	DURATION (MIN)	TEMP RATE OF CHANGE (°C/MIN)	DURATION (MIN)	START TIME	VIBRATION PHASE	VIBR LEVEL (g^2/Hz)	DURATION (MIN)	START TIME
NON-OP SOAK	-54	30			0				
OP SOAK	-54	30			30	NO VIB	–		0
TRANSITION			5	5.6	60	TO	.002	1.0	60
INT_C	-26.1	71.25			65.6	.001	.001	NOTE (1)	61
TRANSITION			7	2.8	136.85	INT	.0035	12.85	126.8
MAX_C	-6.8	22.8			139.65	MAX	.0077	6.0	139.65
TRANSITION			5	3.9	162.45	MIN	.0012	3.6	145.65
MIN_C	-26.1	71.25			166.35	.001	.001	NOTE (1)	149.25
TRANSITION			8	12.1	237.6				
NON-OP SOAK	+71	30			249.7	NO VIB	–		249.7
OP SOAK	+71	30			279.7				
TRANSITION			6	5.9	309.7	TO	.002	1.0	309.7
INT_H	+35.8	77			315.6	.001	.001	NOTE (1)	310.7
TRANSITION			11.5	3.1	392.6	INT	.0035	12.85	382.85
MAX_H	+71	44			395.7	MAX	.0077	6.0	395.7
TRANSITION			10.5	5.8	439.7	MIN	.0012	3.6	401.7
MIN_H	+10	43			445.5	.001	.001	NOTE (1)	405.3
TRANSITION			6	10.7	488.5				
NON-OP SOAK	-54				499.2	NO VIB	–		499.2

NOTE: A LEVEL OF .001g^2/Hz INSERTED AS REQUIRED TO ASSURE CONTINUOUS VIBRATION DURING FLIGHT PHASES.

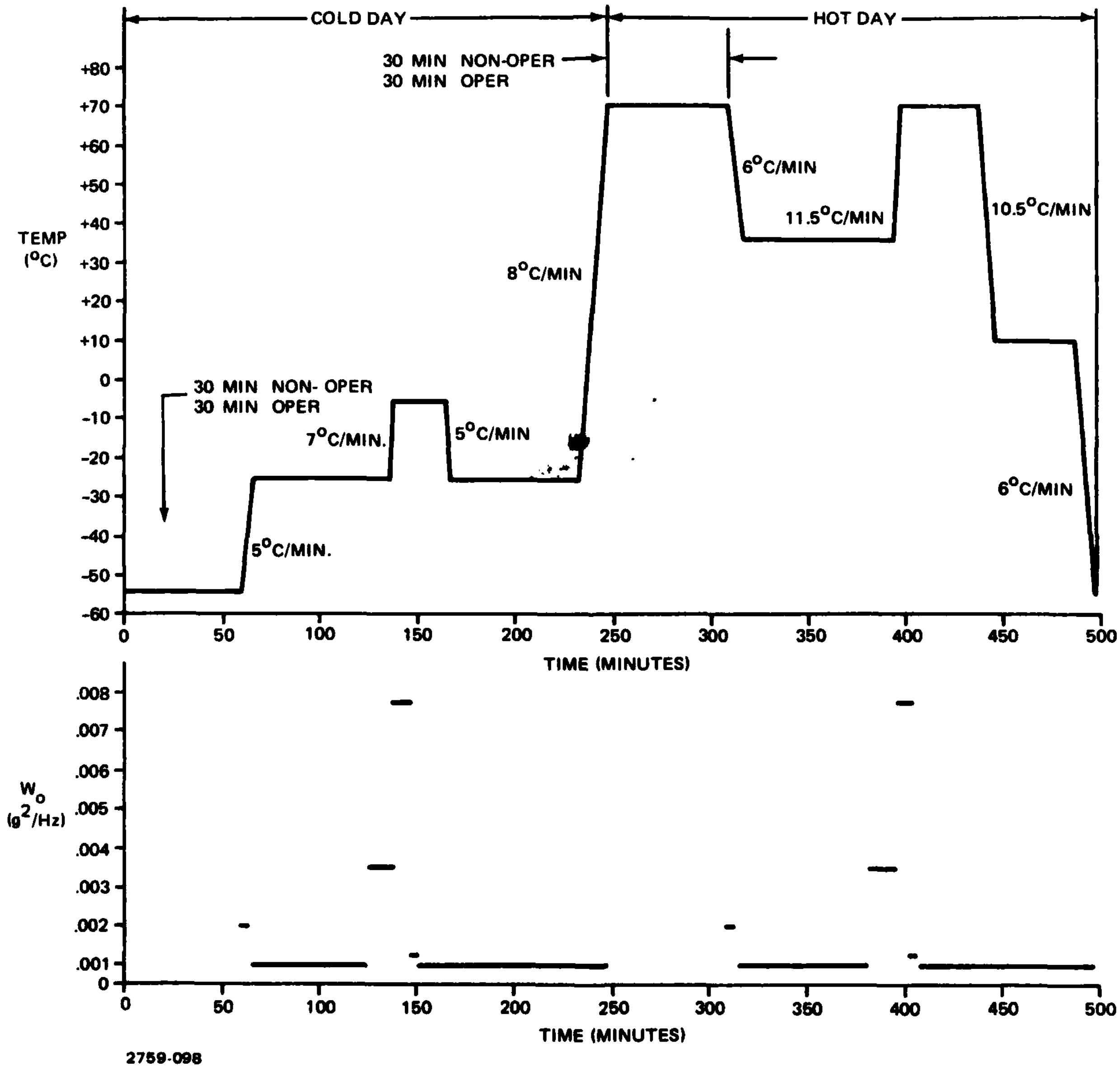

Figure D-7 Composite Test Profile (Examples)

DATE
ILME