NATO STANDARD

AECTP-230

CLIMATIC CONDITIONS

Edition B, Version 1

JUNE 2025

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED ENVIRONMENTAL CONDITIONS AND TEST PUBLICATIONS

Published by the
NATO STANDARDIZATION OFFICE (NSO)

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

3 June 2025

1. The enclosed Allied Environmental Conditions and Test Publication AECTP-230, Edition B, Version 1, CLIMATIC CONDITIONS, which has been approved by the nations in the LIFE CYCLE MANAGEMENT GROUP (AC/327 LCMG), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4866.

2. AECTP-230, Edition B, Version 1, is effective upon receipt and supersedes AECTP-230, Edition 1, which shall be destroyed in accordance with the local procedure for the destruction of documents.

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4. This publication shall be handled in accordance with C-M(2002)60.

Thierry POULETTE
Major General, FRA (A)
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Documents Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
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ALLIED ENVIRONMENTAL CONDITIONS AND TEST PUBLICATIONS (AECTP)

AECTP 230 – CLIMATIC CONDITIONS

AECTP-230 is one of two documents included in STANAG 4866. It provides characteristics and data on climatic conditions for operational service environments and scenarios that influence the design of defence materiel.

The Allied Environmental Conditions and Test Publications (AECTP) series 230 and 300 were formerly covered by STANAG 4370. The Allied Environmental Conditions and Test Publications (AECTP) are now organised as follows:

The AECTP series 230 and 300 were formerly covered by STANAG 4370. The AECTP are now organised as follows:

- STANAG 4370 – Environmental Testing
  - AECTP-100 – Environmental Guidelines for Defence Materiel
  - AECTP-600 – The Ten Step Method for Evaluating the Ability of Materiel to Meet Extended Life Requirements and Role and Deployment Changes

- STANAG 4866 – Climatic Environmental Conditions and Test Methods
  - AECTP-230 – Climatic Conditions
  - AECTP-300 – Climatic Environmental Tests

- STANAG 4867 – Mechanical Environmental Conditions and Test Methods
  - AECTP-240 – Mechanical Conditions
  - AECTP-400 – Mechanical Environmental Tests

- STANAG 4868 – Electrical & Electromagnetic Environmental Conditions and Test Methods
  - AECTP-250 – Electrical & Electromagnetic Environmental Conditions
  - AECTP-500 – Electromagnetic Environmental Effects Tests and Verification

AECTP-230 should be used in conjunction with STANAG 4370.

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LIST OF SECTIONS AND LEAFLETS

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RECORD OF SIGNIFICANT CHANGES

LOCATION	DESCRIPTION OF CHANGE
Preliminary and Introductory Pages. Section 231	The only changes from AECTP-230 Edition 1 to AECTP-230 Edition B Version 1 are the inclusion of content from the now cancelled AECTP-200 within the introductory paragraphs. There are also typographical / formatting improvements throughout, consistent with AEP-32. There is also reference to the new STANAGs of 4866, 4867, and 4868. No technical content within the AECTP-230 leaflets of Edition B Version 1 has been modified or changed.
Section 2310 Leaflet 2310/1 Table 3	Formatting error caused two values in the M3 cycle to show at the incorrect time. This has been corrected.
Section 2311 Leaflet 2311/1	The climatic category maps have been updated to include current national borders. The formatting has been changed to provide improved resolution and colouring of the climatic categories. The climatic categories themselves have not been altered.

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INTRODUCTION

1. PURPOSE

1.1. The purpose of AECTP-230 is to provide characteristics and data on climatic environments and also guidance on the application of the data.

2. SCOPE

2.1. AECTP-230 describes climatic environmental conditions and data that have been compiled from established sources within NATO countries. Where possible the potential damaging effects of these conditions on defence materiel are also identified. Advice is given on the selection of suitable test methods.

2.2. AECTP-230 does not address environments arising from accident or hostile conditions, or nuclear effects.

2.3. The purpose of the AECTP-230 series of leaflets is to present characteristics and data samples of natural and induced climatic conditions that influence the design of materiel. For the purpose of this document, induced climatic conditions are the ambient environmental conditions resulting from the modification of the natural climatic conditions due to the structure in which, or on which, the materiel is used.

3. APPLICATION

3.1. The characteristics and data contained in AECTP-230 should be used, where possible, in the preparation of national requirement documents for defence materiel to be procured for NATO forces. It should be used in conjunction with measured data for deriving the appropriate conditions for specific defence materiel and as the basis for determining environmental design and test criteria.

3.2. The data presented in AECTP-230 is intended for use during the specification process but also is to be considered when extended life is under focus. Refer to STANAG 4370 AECTP-600 for guidance.

3.3. AECTP-230 “Climatic Conditions” remains a relevant and current description of the global environment applicable to the test and evaluation of NATO materiel. Future updates of ACETP-230 “Climatic Conditions” will take into account the impact of current and future changes in environmental conditions as it relates to evaluating the resilience of NATO materiel.

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SECTION 231
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GENERAL

1. GENERAL

1.1. Purpose

a. The purpose of the AECTP-230 series of leaflets is to present characteristics and data samples of natural and induced climatic conditions that influence the design of materiel. For the purpose of this document, induced climatic conditions are the ambient environmental conditions resulting from the modification of the natural climatic conditions due to the structure in which, or on which, the materiel is used.

b. Leaflet 231 gives general guidance on the types and causes of natural and induced climatic environments, and gives information that is applicable to a variety of materiel types and platforms. Induced environments included are as follows:

- Temperature (including solar radiation).
- Humidity.
- Air Pressure.
- Hydrostatic Pressure.
- Icing.
- Dust and Sand.
- Wetting.
- Erosion by Impact.

c. Section 231 should be consulted before any other leaflets in AECTP-230 are consulted.

d. Sections 232–239 cover different situations in which materiel may be found, and follow a standardised format. For each situation, the characteristics of relevant induced environments are described for each set of circumstances that may apply. The potential damaging effects of those environments are described, and advice is given on the selection of test methods and severities.

1.2. Scope

a. AECTP-230 was previously contained in STANAG 4370. It identifies potential damaging effects that climatic environmental conditions (including induced environments) have on materiel, and by providing guidance on the selection of suitable test methods.

b. AECTP-230 series of leaflets are organised around classes of materiel items. The leaflets focus on the effects of the natural environment, or on the act or process by which environments experienced by materiel items are altered by environmental factors inherent in circumstantial conditions, platforms, or other materiel items that surround them. These leaflets are not intended to be comprehensive. When used in conjunction with STANAG 4370 AECTP-100 and STANAG 4866 AECTP-300 (and other sources of relevant information), these leaflets provide information on climatic conditions that should enable a comprehensive and cost-effective set of environmental tests (type approval or qualification) to be selected, formulated, and conducted in response to project environmental and related requirements.

2. APPLICATIONS

The information contained in the AECTP-230 series of leaflets is intended for use in the following applications:

a. To permit customers or potential customers to ask intelligent questions to confirm that key environmental characteristics and issues have been, or will be addressed by suppliers or potential suppliers.

b. To assist project engineers to compile Environmental Requirement (or Life Cycle Environmental Profile) specifications by identifying all major environments and by illustrating and quantifying key environmental characteristics and parameters that may influence specifications.

c. To assist project engineers to prepare Environmental Design Specifications by providing improved environmental characteristics data that will help them to select more valid initial design values.

d. To assist design engineers by indicating potential failure modes that specific environmental characteristics could induce, and thereby providing pointers to monitor during design and testing.

e. To assist test engineers in preparing test specifications by indicating which test methods are preferred when considering how to test for specific climatic environmental effects. The test methods contained in AECTP-300 are recommended where relevant.

f. To assist test engineers to compile programmes to acquire good quality field data. This aspect is covered extensively in these leaflets. Such data are used primarily to formulate test levels for qualification trials.

3. TYPES AND CAUSES OF INDUCED CLIMATIC ENVIRONMENTS

Materiel, components, and stores may experience wide ranging induced climatic environmental conditions in excess of outdoor ambient levels depending on their design or their location on or in a platform. Induced levels of climatic elements, either singly or in combination, (such as temperature, humidity, air pressure, etc.) may degrade materiel's performance and reliability. Materiel may be required to survive or to continue to operate when subjected to these induced environments, and therefore, must be designed to do so up to acceptable levels of risk.

3.1. Temperature

Solar radiation, heat dissipation from nearby materiel, air conditioning in compartments, and thermal shock, in addition to other factors, contributes to increased and decreased induced temperatures.

3.1.1. Effects of Solar Radiation and Dissipated Heat on Temperature

a. Depending on their locations on platforms, materiel items or components may experience wide-ranging direct or indirect induced temperatures in excess of outdoor ambient levels during transportation, storage, handling and use. Solar radiation has a direct temperature elevating effect on outer surfaces of materiel. Roofs and walls of shelters and temporary covers, exposed to direct sunlight can elevate temperatures on outside surfaces and in living/operating areas far above external ambient conditions. Temperatures in the enclosed areas may be alleviated by ventilation or forced-air cooling, or alternatively, aggravated by heat from operational equipment.

b. High temperatures experienced by materiel installed within the frames of their platforms are likely to exceed the local ambient conditions because of indirect effects of solar heating of the platform structure or by absorption of heat emitted by the platform power units. Temperatures of equipment installed in racks and instrument panels are likely to be influenced by self-dissipated heat and heat from adjacent electronic units and electrical power supplies.

c. Conversely when materiel is operating in cold regions, non-heat-dissipating materiel installed in enclosed compartments, stored under cover on external platform areas, may experience temperatures lower than the external ambient conditions, because the skin surfaces or enclosures are often better radiators to the night sky than the ambient air.

3.1.2. Temperatures in Fully Air-Conditioned Compartments

Temperatures in fully air-conditioned compartments on or within platforms are controlled to provide a comparatively benign environment. Each compartment should be assessed to determine if individual items of materiel are located in semi-stagnant areas where the temperature could fall outside the range of the controlled conditions. Temperatures experienced by individual units and components in electronic cabinets, racks, and consoles will depend on localised levels of dissipated heat and the provision of dedicated supplies of cooling air.

3.1.3. Temperatures in Partially and Non-Conditioned Compartments

In partially and non-conditioned compartments, temperatures may be moderated by fresh air ventilation, by a supply of warm air (e.g., when a ship is operating in low temperature regions), or by air extraction system (e.g., to alleviate the effects of temperatures in the warmer geographical regions and of heat generated by operational machinery). Some items of materiel may be located in refrigerated areas.

3.1.4. Thermal Shock

During transportation, storage, or phases of service life, materiel may experience wide ranging induced temperatures in excess of local ambient conditions. Some materiel may be subjected to fast transient temperatures (or thermal shocks). Such transient temperatures may be generated when materiel is handled from inside a shelter to out of doors, or conversely. The magnitude of such a thermal shock is determined by both inside and outside temperatures and heat absorption/dissipation capacities of materiel. Examples are materiel that is moved into cold outdoor ambient environments from a comparatively hot storage area. A converse example is materiel that is exposed to direct solar radiation before immersion into water.

3.2. Humidity

Temperature, air conditioning in compartments, and atmospheric pressure differentials are factors contributing to induced levels of humidity and moisture accumulation.

3.2.1. Effects of Heat on Humidity

The factors responsible for induced high temperatures inside shelters or under temporary covers exposed to direct solar radiation are likely to raise the moisture content of the enclosed atmosphere above external ambient conditions.

3.2.2. Humidity in Fully Air-Conditioned Compartments

The moisture content of the atmosphere in air-conditioned compartments is normally controlled to provide comfortable and optimum working conditions for crew and installed equipment. In the event of a breakdown of the supply of conditioned air, the introduction of external ambient air at a higher temperature and relative humidity can result in condensation and accumulations of moisture on the surfaces of installed materiel (e.g., when deployed in hot wet tropic regions).

3.2.3. Humidity in Partially and Non-Conditioned Compartments

The ambient conditions in partially and non-conditioned compartments can range from a dry heat to a damp heat environment. Factors influencing conditions include the level of ventilation and operational machinery contained in the compartment. Heat generated by engines and electrical power generators is likely to reduce levels of relative humidity, while condensation and steam in air conditioning plants, galleys, and laundries are likely to elevate relative humidity.

3.2.4. Moisture Accumulation

a. Without adequate ventilation, the diurnal variations in solar heating and ambient temperature, plus the self-induced heating and cooling that occurs during operation and following switch-off, can induce differential pressures causing materiel to breathe in and entrap moisture from the external atmosphere. This phenomenon is evident particularly in humid tropic regions and applies to materiel under covers, to shelters, and even to otherwise sealed electronic units.

b. Conversely, extremely low levels of relative humidity may exist in localised areas of equipment when dissipated heat adds to the drying effects prevailing in hot, dry regions of the world.

c. Condensation may occur on materiel when moved from a cold area to a hot area because of the difference of temperature. Similarly, moisture may enter and condense within compartments and individual materiel during descent from altitude to ground level.

d. Under certain conditions of temperature and humidity, hygroscopic materials in an enclosure may release moisture to the air and this moisture can subsequently condense on the internal surface of the enclosure causing accumulation of water.

3.3. Air Pressure

Altitude, compartment differential pressure, blast, and rapid decompression are factors contributing to induced levels of air pressure.

3.3.1. Altitude

3.3.1.1. Elevated Land Areas

Materiel including hand-carried or mounted materiel may experience low air pressure levels that alter materiel effectiveness at high altitudes. Pressure tight components or pressure relief mechanisms may be of value to maintain materiel performance and reliability.

3.3.1.2. Altitude Above Sea Level

a. Materiel transported in aircraft is required to survive or function at air pressures above and below normal ground ambient determined by the location of the materiel on the flight platform and by the flight profile. Aircraft compartments may be pressurised to limit and maintain compartment atmosphere at acceptable pressures equivalent to a nominal altitude above sea level. Such compartments include cockpit or cabins that are occupied by the crew or passengers and cargo bays or areas that house avionics or other items specific to the operation of the aircraft or air carried stores. Materiel carried in un-pressurised regions will be subject to prevailing ambient pressures at flight altitudes. Also, during take-off and landing or as a result of flight manoeuvres, rates of change of pressure far in excess of those arising from meteorological conditions may occur.

b. Frontal areas and leading edges of externally carried stores on aircraft will be subject to dynamic pressure during flight. Air pressure transients above normal ground ambient will be experienced by externally fitted materiel subject to blast from battlefield explosions. Internally fitted materiel located in pressurised compartments will be subject to steady values of overpressure during ground pressurisation tests.

c. Materiel deployed on fixed-wing aircraft is required to survive or function at air pressures above and below normal ground ambient determined by its location on the flight platform and the operational scenario. Aircraft compartments may be pressurised to limit and maintain the atmosphere at an acceptable pressure equivalent to a nominal altitude above sea level (e.g., cockpit or cabins occupied by the crew or passengers, cargo bays, or areas housing avionics or other items specific to the operation of the aircraft or air-carried stores). Materiel carried in un-pressurised areas will be subject to the prevailing ambient pressure at the flight altitude. Also, during take-off and landing or as a result of flight manoeuvres, rates of change of pressure far in excess of those arising from meteorological conditions may occur

3.3.2. Pressurised Compartments

a. Compartments of vehicles may be pressurised. Therefore, levels of pressure may be different from those arising from meteorological conditions.

b. During storage, compartments of shelters may be pressurised above outdoor ambient levels. The compartment level is then maintained above that of the external ambient pressure by an amount known as the differential pressure. Handling may require compartments to be depressurised or may result in unexpected depressurisation. When handled, rates of change of pressure far in excess of those arising from meteorological conditions are likely to occur.

c. Normally during flight, materiel installed in pressurised compartments will experience air pressures ranging between local ground ambient and some lower value equivalent to that at a predetermined altitude, say 3000 m. Alternatively, materiel installed in un-pressurised areas will be subject to the ambient air pressure at the flight altitude.

3.3.3. Rates of Change of Air Pressure

3.3.3.1. Normal Operational Transient Changes

a. It may be necessary for some items of materiel to remain installed during routine high-pressure testing of submarine compartments. Air pressure within the hull may rise above standard ambient while submerged, especially when firing a salvo of weapons. Materiel installed or carried inside the pressure hull is likely to be subjected to cyclic variation in air pressure below standard ambient during snorting.

b. Positive and negative rates of change of pressure during flight sorties vary from those resulting from normal take-off and landing. Rates of change experienced by carried materiel depend on aircraft performance, the flight or mission profile and whether the materiel is carried in a pressurised or non-pressurised area.

c. Operational roles of rotary winged aircraft preclude the need for pressurised compartments. Pressure levels experienced by deployed materiel are the prevailing ambient conditions at all stages of operation. However, rates of change of pressure will invariably exceed those resulting from meteorological conditions and will be determined by rates of climb and descent of the flight platform.

3.3.3.2. Blast

a. Externally deployed materiel may experience overpressure caused by blast from explosions, gunfire and efflux from weapons fired or launched from the aircraft.

b. Materiel on ships deployed above deck or in magazine areas may be required to survive, remain safe or continue to operate when subjected to blast from gunfire and motors of ship-launched weapons.

3.3.3.3. Rapid Decompression

a. Abnormal rates of change of pressure may occur in normally pressurised compartments during emergency situations. The rate of depressurisation following failure of the pressurisation system will depend on the volume of the compartment and the initial pressure differential. In the absence of specific information regarding the size of compartments, a maximum duration of one minute should be assumed for the pressure to fall to its minimum value.

b. Emergency flight conditions caused by failure of the pressurisation system or failure of the aircraft structure induce rapid or explosive decompression during which deployed materiel may be required to remain safe, survive, or continue operating.

3.4. Hydrostatic Pressure

Materiel deployed underwater or carried on the external surfaces of ships hulls, particularly on submarines, will be subjected to induced hydrostatic pressure dependent on the depth of immersion.

3.5. Icing

In addition to naturally occurring and combinations of low temperature and dew point, factors contributing to icing include ships manoeuvres in cold temperature, aircraft impact with super-cooled water droplets, moisture accumulations within materiel subsequently exposed to cold temperatures, and materiel stored adjacent to refrigerated units.

3.5.1. Low Temperature and Dew Point

Icing may occur during any stage of materiel service life when combinations of temperature and dew point combine at critical levels. Wet surfaces exposed to sufficiently cold atmospheric temperatures will freeze, particularly those surfaces not warmed by ground temperatures.

3.5.2. Ships Manoeuvres

When operating in low temperature regions ships manoeuvres (e.g., speed and orientation with respect to the prevailing wind) may contribute to the level of icing experienced by the superstructure and by materiel carried on deck. When submarines operate on the surface in low temperature regions, spray created by manoeuvres of the submarine in the prevailing sea and wind may contribute to the level of icing experienced by materiel on the hull and superstructure.

3.5.3. Aircraft Impact with Super-Cooled Water Droplets

Induced icing of externally carried stores may occur during the various stages of a flight sortie caused by impact with super cooled water droplets (e.g., clouds and mist).

3.5.4. Accumulated Moisture

Materiel installed in compartments of the aircraft or air carried stores that are susceptible to breathing and retaining moisture, may experience frosting and icing due either to sub-zero temperatures at flight altitude or when cold surfaces meet warmer damp air during descent to ground level. Localised drainage may help to alleviate moisture retention and freezing problems. Icing may be counteracted by on-board de-icing systems.

3.5.5. Proximity to Refrigerated Units

Certain types of materiel carried on materiel platforms may have built-in refrigeration systems that function during operations. Surfaces of other materiel stored next to such refrigerated systems may experience induced condensation that will freeze in low temperatures unless influenced by exhaust portions of refrigerated systems.

3.6. Dust and Sand

a. Materiel deployed or stored on aircraft required to operate from airfields or landing areas in dry desert regions may be exposed to dust and sand-laden atmospheres caused by aircraft operations and movement of land-based vehicles. While parked, aircraft may become enveloped in clouds of dust created during ground operations of other aircraft and land-based support vehicles. Busy airfields are likely to incur many traffic movements producing significant accumulations of dust and sand.

b. Servicing procedures will, from time to time, require that panels be removed for access to plug in points on aircraft and air carried stores. Such servicing may allow dust to enter. The dust remains in that internal atmosphere indefinitely.

c. When ground running or hovering at low level over desert areas (or areas covered in other types of small particles), rotary winged aircraft are noted for self-inducing dust and sand environments.

3.7. Wetting

Precipitation, spray, drip, splash, and immersion are factors contributing to induced levels of wetting caused by dripping condensation from overhead surfaces, fire sprinklers, fractured pipes, leaking joints, cleaning operations, and exposure to splashing or immersion directly from operations in or near open waters.

3.7.1. Condensation and Drip

a. When cold surfaces meet warmer damp air, condensation forms on colder surfaces and drips or runs onto crevices where it may accumulate and cause other problems such as corrosion or electrical short circuits in the materiel itself or in other materiel or stores.

b. This phenomenon can occur during aircraft descent from flight altitude to ground level or during vehicle operations in hot humid exterior conditions when interiors of air-conditioned vehicles are opened to hot and humid outdoor ambient conditions.

3.7.2. Spray and Splash

a. For ships manoeuvres in prevailing sea conditions, containers or stores placed above deck, and movement of vehicles or other types of service platforms that use the ship as an operational base, can result in levels of wetting ranging from mild spray or splashing to rough seas.

b. Materiel installed or stored in workshops or other areas where vehicles or machinery are maintained or repaired is likely to remain in situ while the platform is washed down during cleaning procedures. Such materiel may be subject to occasional splashing or spraying by other types of fluids such as fuels, lubricants and cleaning fluids. Surfaces of externally deployed materiel may be sprayed with other types of wetting agents such as de-icing fluids.

3.7.3. Immersion

a. Clearly materiel on the outer surface of the hull will be subjected to total immersion while operating underwater. While on the surface, submarine manoeuvres in the prevailing sea conditions or washing and hosing down operations can result in levels of exposure ranging from mild spray or splashing to green seas.

b. Materiel not intended for operation mainly on the ground (e.g., aircraft, stores may be subjected to splashing, spray, or fording during movement on the ground).

c. Rotary-winged aircraft and materiel and stores on those aircraft are subject to spray generated by the downwash of the rotor of the host aircraft when hovering at low level over water.

3.8. Erosion by Impact

Leading edges and forward-facing surfaces of externally carried materiel may be susceptible to erosion by impact with rain, hail, dust and sand or other forms of particulate, especially during flight.

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SECTION 232
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TRANSPORTATION

1. GENERAL

a. This leaflet addresses the climatic environments that may be experienced by materiel during road, rail, air, or sea transportation among manufacturing sites, storage bases, forward areas, and in tactical situations. Characteristics of climatic environments induced under these transportation conditions are presented, discussed, and supplemented by data sheets. Advice is given on potential damaging effects, treatment options and, where relevant, the selection of the appropriate AECTP-300 test method.

b. For the purpose of this sub-section, materiel exposed to transportation environments may be unprotected or carried within some form of protection, package, or container. The platform may be in different configurations (e.g., uncovered, covered, open, or closed vehicle).

c. All of the natural environments may be encountered during this transportation in open sky and induced climatic environments. Natural environments (open sky) are addressed in Section 2311; the only difference is perhaps the ventilation produced by the speed of the vehicle in transit.

d. Typical types and causes of induced climatic environments (applying to transportation, handling and storage, and to deployment on aircraft and ships) are presented in Section 231, “General”.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS[1]

2.1. Temperature

2.1.1. Road and Rail Transportation

2.1.1.1. Materiel Carried in Covered Vehicles

a. The platform environment for materiel carried in covered vehicles is characterised primarily by ambient air temperature within the enclosed area, influenced by solar radiation falling directly on the covering surface. Covered, solar-loaded platforms can elevate interior temperature to the limit allowed by the cooling effects of ventilation induced by the speed of the vehicle when the enclosure is not airtight.

[1] General types and causes of induced climatic environments are described in Section 231 of this document. Characteristics of open sky ambient climatic environments (e.g., for vehicles on the ground not under cover) are described in Section 2311.

b. An example of internal vs. external temperature and humidity (by time of day) in the covered cargo area of a common carrier at rest (storage condition) and while moving at speeds of up to 90 kph (transportation condition) is presented in Annex A. Note that the air movement during transportation tends to moderate swings in temperature and humidity throughout daylight hours.

2.1.2. Air Transportation

2.1.2.1. Aircraft Parked

High temperatures inside unventilated compartments may exceed local ambient temperatures due to the indirect effects of solar radiation. Therefore, systems and components contained within such compartments will be affected similarly. To determine the highest temperatures that carried stores may be expected to withstand, data should be obtained at specific locations within platforms where stores are to be carried. Examples of such data obtained at two locations within an aircraft are in Annex A. Note that temperature at one location is fairly steady throughout the diurnal cycle while temperature at the other location varies widely.

2.1.2.2. Ground Operating

a. When power is applied either directly from the engine or from external supplies, onboard environmental control systems will distribute conditioned air to some compartments of the aircraft or to aircraft carried stores to alleviate the effects of induced conditions.

b. At initial switch-on, external ambient air is drawn in and distributed around the aircraft before the environmental control system has had time to become effective. External ambient air in cold regions may chill materiel in conditioned compartments at a higher rate than would be expected from the ambient air in temperate regions. As ground running continues, the environmental control system becomes more effective. In cold regions, materiel begins to benefit from any self-generated heat and from heat given off by other materiel.

c. During normal ground running, temperatures inside aircraft compartments depend on external ambient air temperatures, on materiel packing densities, on heat radiated from adjacent structures and operational materiel, on the level of any conditioning, and on the period of operation. In contrast, during long-term ground running in hot regions, the combined effect of heat radiated from adjacent structures and operational materiel may tend to counteract the effects of the conditioned air. Long-term ground running without forced-air cooling should be avoided in hot, dry regions, otherwise permanent damage or degraded reliability may occur.

d. Data on induced temperatures should be derived from measurements made at the intended location of materiel on the flight platform during representative worst-case conditions. Historically, where specifically measured data have not been available, maximum switch-on temperatures for materiel carried in both conditioned and non-conditioned areas of aircraft deployed in hot, dry regions have been taken as equivalent to the maximum induced temperatures for ground conditions. For long-term ground running in hot, dry regions and where characteristics of cooling air are unknown, ambient temperatures in conditioned compartments are assumed to stabilise at 15 °C lower than at switch-on. Temperatures at switch-on should be assumed to prevail in non-conditioned areas.

e. Temperature levels may be influenced by the packing density of stores, heat dissipation of components, the number of thermal paths to external surfaces, and the incorporation of cooling systems. Where internal ambient temperatures or temperature levels of individual components are of concern, expected temperature levels should be estimated using thermal analysis programs incorporating the influences given above supported by specific measurements made in representative conditions.

f. For deployment in low temperature regions, and in the absence of measured data, the severities in Table 1 may be assumed to represent worst-case conditions at switch-on for materiel in enclosed compartments of which the skin surfaces are better radiators of heat to the night sky than the ambient air.

Table 1: Worst-Case Conditions for Materiel in Enclosed Compartments

Area of Deployment (Climatic Category)	Induced Temperature (°C)
C0	-21
C1	-33
C2	-46
C3	-51
C4	-57

2.1.2.3. Flight Sorties

a. Materiel installed inside aircraft compartments may be subjected to high induced temperatures from heat given off by engines and auxiliary power units, engine exhaust systems, avionics and electrical materiel, or from being located in a stagnant area such as a materiel rack or behind an instrument panel. The cooling capability of materiel operating in partially or non-conditioned compartments may be affected by lower density air at flight altitude and cause the operating temperature of that materiel to rise to unacceptable levels.

b. Materiel aboard operating aircraft may be subjected to thermal shock. Transition times between ambient temperatures at ground level and flight altitude, and vice-versa, during take-off and landing are likely to induce thermal shock in materiel in non-conditioned areas. Such shock may stress materiel beyond design limits unless taken into account during design and manufacture. In the absence of measured data, severities may be derived from knowledge of maximum rates of climb and descent for the host aircraft. Rates of change should be determined from data measured during representative flight trials.

2.1.3. Sea Transportation

2.1.3.1. Above Deck on Surface Ships

a. Where no ventilation or assisted cooling is provided, high temperatures inside unventilated shelters or under temporary covers exposed to solar radiation are likely to exceed those outside of the enclosed area. One of the most severe conditions will occur when ship-borne materiel is installed or carried above deck in hot regions of the world. The relative angle of elevation between the sun and the exposed surface, the prevailing cloud cover, the surface finish, the colour and heat capacity of the radiated surface, and the duration of exposure will determine the amount of heat absorbed. The induced ambient temperature of the enclosed atmosphere will depend on the level of any ventilation or forced air cooling.

b. Information on temperatures induced on surface ships inside sheltered areas or under temporary covers above deck is not readily available. Expected induced levels should be determined from specific measurements for particular applications. In the absence of measured data, the temperatures determined for general Transportation and Storage in Leaflet 2311 (marine category M1) should be assumed to apply to materiel in shelters or under cover above deck aboard ship. The severities for high temperature areas on open seas (marine category M1) tend to be around 2 °C lower than those for overland (climatic category A1), implying the latter should be taken into account if the ship is to operate in and out of ports in those geographic regions. A similar consideration is more appropriate with regard to temperature severities for Transport and Storage in the colder regions of the seas, (marine category M3), where temperatures may be up to 12 °C higher than those over land in the same geographical areas (climatic category C2).

c. Materiel may experience thermal shock. When the ship is operating in low-temperature regions, materiel brought on deck from a hold may experience changes in temperature in the order of 45 °C over a period of a few minutes or less. Conversely, materiel immersed in the sea immediately after a solar temperature soak could experience a change in temperature in the order of 50 °C in a few seconds.

2.1.3.2. Air-Conditioned Compartments

Temperatures in air-conditioned compartments on surface ships may range from 15 °C–30 °C and relative humidity of 30–70 percent. Variations within those limits will depend on external ambient conditions and the amount of heat given off by operational materiel and personnel occupying the compartment but may be considered constant once established in the climatic area of operation. In the event of an interruption in the supply of conditioned air, in the absence of measured data, a temperature of 40 °C with relative humidity of 70 percent should be assumed to occur for periods of up to 20 minutes.

2.1.3.3. Partial and Non-Conditioned Compartments

a. The influence of external ambient conditions on the levels of temperature and humidity in partial and non-conditioned compartments will depend on the location of the compartment within the vessel. The further the compartment is below the main deck and towards the centre of the hull, the more likely the influence of external ambient conditions will be diminished. In some cases the heat and moisture dissipated by operational machinery will be the dominant factor such that when the vessel is operational, constant ambient conditions ranging from dry to damp heat can occur.

b. Some conditions may be localised to particular areas of a compartment. The closer an unconditioned compartment above the water line is to the outside walls of the hull or the main deck, then the greater will be the indirect effects of solar heating of the ships structure on the ambient temperature in the compartment, particularly when operating in category A climatic areas. In the absence of measured data, conditions in fresh air ventilated compartments range from 15 °C–45 °C with relative humidity of 30–85 percent, but for the reasons given above, severities for particular installations should be determined from specifically measured data.

c. Steady-state conditions in unconditioned compartments may range from 0 °C–880 °C with 30–80 percent relative humidity. Abnormal excursions may rise to 100 °C. Higher temperatures are more likely to be experienced as a result of being attached, or in close proximity, to operational machinery that has high surface temperatures or that is located in stagnant areas not served by any form of ventilation.

d. Some materiel may be located in refrigerated areas or close to external hatches. Unless otherwise specified, operational materiel near external hatches should maintain correct operation to -10 °C, with degraded performance to -30 °C.

2.2. Humidity

2.2.1. Road and Rail Transportation

2.2.1.1. Materiel Carried in a Covered Platform

Absolute humidity experienced by materiel during transportation is quite the same as external ambient or meteorological humidity.

2.2.1.2. Materiel Carried in an Enclosed Platform

The magnitude of the diurnal cycle of relative humidity experienced by materiel is normally more than the meteorological conditions for most kinds of warm/hot climatic conditions because temperature variations are increased.

2.2.2. Air Transportation

2.2.2.1. Aircraft Parked

Dependent on its location on the flight platform, levels of humidity experienced by materiel may exceed those of local meteorological conditions. Unventilated compartments of flight platforms deployed in wet tropical regions may breathe in moisture as a result of pressure changes induced by the diurnal temperature cycle. Similarly, condensation and ingress of moisture occur inside compartments and individual materiel during descent from altitude to ground level.

2.2.2.2. Ground Running

a. It may be assumed that when engines are running or aircraft systems are operating from external power supplies, hatches will be open and air conditioning systems will be operating, providing ventilation and a reduction in the level of moisture of the atmosphere in the previously closed compartments. The relative humidity inside installed materiel within semi-sealed, unventilated enclosures will be reduced gradually by self-dissipated heat, although moisture content is unlikely to be reduced. When power is switched off and the materiel cools, the differential air pressure on either side of the walls of an enclosure may cause the enclosure to breathe in external air and increase the level of retained moisture.

b. Materiel transported in aircraft operating in hot, dry regions of the world may experience extremely low levels of humidity when subjected to the indirect effects of solar heating or when located close to sources of dissipated heat during ground running. Electrical/electronic systems with high packing densities and on-board air-carried armaments subject to ground running may be similarly affected. No recorded data are readily available for such induced dry atmospheres.

Relative humidity levels of less than 30 percent are common for naturally occurring conditions in hot, dry regions of the world. Therefore, equivalent or lower levels of relative humidity (RH) may be assumed to occur inside nominally dry aircraft compartments or similar areas of individual materiel subjected to induced high temperatures.

2.2.2.3. Flight Sorties

Moisture may be formed on external and internal surfaces of materiel during flight sorties as a result of the transfer between prevailing temperatures at ground level and flight altitude and vice-versa, especially when flying into and out of airfields in tropic regions. Warm air in the compartments and individual items of materiel mixes with lower temperature ambient air during the climb to altitude. When cold aircraft surfaces meet warm damp air during descent and landing, moisture condenses out as the air temperatures are reduced below their respective dew points. In the latter case, conditioning is aggravated by the change in air pressure forcing in warm, damp air. It should be assumed that RH levels in conditioned compartments will reach 90–95 percent, while in unconditioned compartments saturation will occur.

2.2.3. Sea Transportation

2.2.3.1. Above Deck on Surface Ships

a. Materiel stored on deck in unventilated shelters or under temporary covers is likely to be subjected to high levels of induced humidity, especially when deployed in hot, wet tropic regions. Worst cases occur where the diurnal cycle is characterised by high temperatures during the day and low temperatures at night, producing corresponding variations of pressure in the covered areas, causing them to breathe in moisture, some of which is retained when the external ambient temperature rises again. Solar radiation on the external surfaces of shelters or temporary covers during the hotter part of the diurnal cycle can result in enclosed materiel being subjected to a damp heat environment more severe than the external ambient conditions. The accumulation of moisture can lead to a higher dew-point temperature and, therefore, the possibility of saturation occurring during the cooler part of the cycle.

b. Preferably, conditions for particular applications should be determined from specifically measured data. Levels of relative humidity may be reduced by heat from operational materiel, but in the absence of measured data, the Leaflet 2310/1 induced conditions should be selected.

2.2.3.2. Air-Conditioned Compartments

See paragraph 2.1.3.2.

2.2.3.3. Partial and Non-Conditioned Compartments

See paragraph 2.1.3.3.

2.3. Air Pressure

2.3.1. Road and Rail Transportation

Pressure inside a vehicle is generally the same as for open-sky conditions.

2.3.2. Air Transportation

2.3.2.1. Aircraft Parked and Ground Running

Materiel transported in aircraft will normally experience air pressures equal to those of local ground ambient with the exceptions given in paragraphs below. While subject to routine ground pressurisation tests, materiel fitted in aircraft compartments pressurised during flight may be required to remain in-situ to determine the integrity of seals. Where applicable, the value of overpressure likely to be experienced should be agreed between the aircraft manufacturer or operator and the Design Authority for the installed materiel.

2.3.2.2. Flight Sorties

a. Normally during flight, materiel installed in pressurised compartments will experience air pressures ranging between local ground ambient and some lower value equivalent to that at a predetermined altitude (for example, 3000 m). The internal pressure is then maintained by onboard systems above that of the external ambient pressure by an amount known as the differential pressure. Alternatively, materiel installed in un-pressurised areas will be subject to the ambient air pressure at the flight altitude.

b. Rates of change of pressure vary during flight sorties from those resulting from normal take-off and landing. Rates of change experienced by carried materiel depend on aircraft performance, the flight, or mission profile and whether the materiel is carried in a pressurised or non-pressurised area or container.

c. Rapid decompression (i.e., abnormal rates of change of pressure) may occur in normally pressurised compartments during emergency situations. The rate of depressurisation following failure of the pressurisation system will depend on the volume of the compartment and the initial pressure differential. In the absence of specific information regarding the size of compartments, a maximum decompression duration of one minute should be assumed.

2.3.3. Sea Transportation

2.3.3.1. Above Deck on Surface Ships

Materiel installed above deck normally will experience pressures equivalent to the local ambient air pressure at sea level.

2.3.3.2. Air-Conditioned Compartments

Air pressure inside compartments of a ship may be raised above the local ambient air pressure to provide a gas tight seal against the ingress of external contamination. The absolute pressure experienced by materiel contained within the compartment should be assumed to be the maximum value of ambient pressure likely to occur at sea, (in the order of 1060 mbar), plus some specified level of overpressure determined to be appropriate. In the absence of a specified value, a level of 8 kPa (80 mbar) over pressure should be assumed.

2.4. Icing

2.4.1. Road and Rail Transportation

For materiel carried in covered and in enclosed vehicles, icing of materiel during transportation normally arises entirely from the prevailing meteorological conditions.

2.4.2. Air Transportation

2.4.2.1. Aircraft Parked

Materiel icing on aircraft that are static on the airfield normally arises entirely from the prevailing meteorological conditions at ground level.

2.4.2.2. Ground Running

Icing of materiel may be counteracted by on-board de-icing systems during ground running.

2.4.2.3. Flight Sorties

Freezing of induced moisture depends on the provision or otherwise of localised drainage, accumulations of water are likely to be frozen by low temperatures at flight altitude.

2.4.3. Sea Transportation

Materiel on open decks is likely to be subjected to accumulations of ice formed from freezing spray. Ship manoeuvres in prevailing sea conditions can increase the amount of spray thrown over the vessel. Rates of ice accretion of up to 40 mm/h have been reported for ships operating in the Arctic region.

2.5. Dust and Sand

2.5.1. Road and Rail Transportation

2.5.1.1. Materiel Carried in Covered Vehicles

Operation and movement of common carriers are likely to generate clouds of dust and sand that intrude into the interior vehicles because they are not dust-proof. Severities of concentration and distribution of particulates are generally less than those experienced in open-sky situations.

2.5.2. Air Transportation

2.5.2.1. Aircraft Parked

Operation and ground movement of an aircraft in the vicinity of a parked aircraft (e.g., vertical take-off and landing, hovering, and normal helicopter activity) are likely to generate considerable accumulations of turbulent, driven dust particularly when deployed in hot, dry desert regions. To a lesser extent, the wheels and tracks of land-based vehicles also generate clouds of dust and sand. Severities of concentration and distribution of particulates above ground level depend on the same parameters as for naturally occurring dust and sand clouds.

2.5.2.2. Ground Running

When the host aircraft is ground running on airfields in hot, dry desert regions or on temporary landing strips, the backwash from propellers or the efflux from jet engines can produce considerable concentrations of airborne dust and sand and other types of small particulates. Areas forward of jet tailpipes are also vulnerable if reverse thrust mechanisms are exercised during engine runs.

2.6. Immersion, Precipitation, and Spray

2.6.1. Sea Transportation

2.6.1.1. Above Deck on Surface Ships

No measured data indicating severities of induced forms of wetting experienced by materiel installed or carried above deck are readily available. Subjective observations indicate that materiel can be subjected to short periods of precipitation equivalent to heavy rain and accumulations of water up to 250 mm deep. This depth is associated with the maximum height of shipboard coamings/doorways.

2.6.1.2. Air-Conditioned Compartments

The levels of precipitation associated with condensation on overhead surfaces and emergencies such as fractured and leaking joints in water pipes are unpredictable. Historically, a minimum rate of 280 $l/m^2/h$ is used when testing materiel for compatibility with this type of conditioning (dripping and pooling).

2.6.1.3. Partial and Non-Conditioned Compartments

When materiel is installed or stored in unconditioned compartments (e.g., as cargo bays, aircraft hangers, garages for deck vehicles, engine and generator rooms, workshops, laundries, and galleys) there is a greater probability of materiel being subjected to some form of wetting including, in some cases, the possibility of partial immersion. Severities of up to 280 $l/m^2/hr$ should be assumed for precipitation, dripping, and pooling, and depths of up to 150mm for immersion.

2.7. Hydrostatic Pressure

During sea transportation, materiel carried on board for subsequent immersion in the sea, will be subjected to hydrostatic pressure dependent on the depth of immersion defined in the design requirement for the individual materiel. Pressure is related to the depth of immersion by the following formula:

$$p = 9.8d$$

Where p is the hydrostatic pressure in kPa, and d is the depth of immersion in meters.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

3.1.1. General

a. Induced temperatures experienced by materiel during transportation can affect the physical and chemical properties of materials used in their manufacture. Expansion and contraction of structural components accompanied by reductions in mechanical strength and changes in ductility result in interference and separation between adjacent parts and impose unacceptable levels of stress and strain leading to deformation or mechanical failure. Induced variations in the characteristics of electrical/electronic components and changes in viscosity of lubricants reduce accuracy, reliability, and operating efficiency.

b. Thermal shock induces high rates of expansion and contraction, resulting in stress and fracture of materials, failure of bonded joints, and degraded performance of seals.

3.1.2. High-Altitude Aircraft and Missiles

High and low temperatures affect the physical and chemical characteristics of rocket fuels which may result in malfunction of motors of guided weapons.

3.2. Humidity

3.2.1. General

a. Induced damp heat conditions, resulting from a combination of inadequate ventilation and enforced breathing of moisture, created inside vehicles accelerate the degradation of materials.

b. Warm, damp atmospheres in unventilated areas provide ideal conditions for promotion of corrosion, chemical attack, and fungus growth.

c. Induced low levels of humidity during transportation can influence the characteristics of electrical/electronic components and affect the calibration, stability, and accuracy of electronic systems when used immediately after the transportation.

3.2.2. Transportation

a. Induced damp-heat conditions (e.g., created inside unconditioned platform compartments, in individual materiel permanent shelters, or under temporary covers on ships above deck) result from a combination of inadequate ventilation and enforced breathing of moisture. Such breathing accelerates the degradation of materials and causes a higher frequency of malfunction of materiel than would exposure to the local meteorological conditions alone. Reduction or breakdown of insulation resistance of circuitry and components can result in degraded performance, safety hazards, reduced reliability, or total failure of electrical/electronic systems. Performance of surveillance materiel may be reduced by high humidity and by accumulations of moisture in optical systems. Low levels of humidity can influence the characteristics of electrical/electronic components and affect the calibration, stability, and accuracy of electronic systems.

b. Warm, damp atmospheres in unventilated areas provide ideal conditions for the promotion of mould growth and aggravated attack by corrosive agents. Issues to be addressed are the effects of moisture on materiel, achieving and maintaining dry interiors, standards and methods of sealing, water vapour barriers, drying out procedures, and humidity monitoring methods.

c. Low levels of humidity may reduce the moisture content of materials used in the manufacture of electrical/electronic components, changing their characteristics affecting the stability that is necessary to maintain performance of systems within specified tolerances. Operating efficiency of mechanical systems can be reduced due to degradation of lubricants by both dry and damp atmospheres.

3.3. Air Pressure

3.3.1. Air Transportation

3.3.1.1. Pressure Differentials

Low air pressure at flight altitude and rates of change of pressure induced during flight sorties may create pressure differentials across the walls of cases and protective covers of materiel and components. Components may deform, fail structurally, or interfere with internal parts, causing those parts or platform materiel to malfunction. Although materiel may be fitted with pressure equalisation devices, rates of change of pressure during flight sorties may exceed design values. Extreme cases may occur during emergency situations in normally pressurised compartments when explosion or implosion of the container may occur.

3.3.1.2. Cooling

Heat-dissipating materiel that relies on convection for maintaining an acceptable operating temperature, may exhibit degraded performance due to the reduced efficiency of the cooling system because of lower air pressure at flight altitude.

3.3.2. Sea Transportation

Air pressure above standard ambient may cause problems. Sealed or partially sealed materiel with low leakage rates may be susceptible to temporary distortion or permanent mechanical damage if located in compartments employing overpressure to provide an airtight seal. Protective covers of large items that withstand normal variations of standard atmospheric pressure may be of particular concern.

When subjected to hydraulic pressure, materiel of closed construction may be subjected to structural deformation, impairing the integrity of joints and seals, allowing water to enter or fluids and gasses to escape.

3.4. Icing

3.4.1. General

Frosting or freezing of accumulations of moisture caused by induced variations of temperature and pressure may result in degraded performance or total failure of materiel in partial or no-conditioned areas.

3.4.2. Sea Transportation

Due to ship's manoeuvres, icing on materiel located above deck may occur. This icing will be similar to that due to natural conditions. The operation of linkages, release mechanisms and actuation systems become impaired or completely blocked due to interference caused by the buildup of ice. Frosting and icing of sensors and optical devices can reduce the performance of surveillance and navigation systems.

3.5. Dust and Sand

The effects of exposure to dust and sand-laden atmospheres include impaired performance of optical systems due to accumulations of particulates, corrosion of exposed underlying materials, blockage of apertures, and reduced efficiency of cooling and ventilation systems. Dust deposits inside materiel may cause short-circuiting of insulators, tracking and buildup of static electricity, interference between moving parts and contamination of lubrication systems.

3.6. Immersion, Precipitation, and Spray

3.6.1. General

The effects of exposure to precipitation and spay are described in Leaflet 2311/3.

3.6.2. Sea Transportation

Materiel subjected to immersion, precipitation, and spray is likely to suffer ingress of water through apertures, seals, joints, and seepage. This ingress affects materials and operational performance of materiel in the same manner as accumulations of moisture through breathing in of high-humidity atmospheres.

4. TEST SELECTION

4.1. General

a. Test procedures that may be used for simulating induced climatic environments that may be experienced by materiel during transportation, shall be determined from reference to the LECP. The choice of test method for temperature and humidity will depend on whether there are any requirements to simulate climatic variations such as heating effects of solar radiation when materiel is transported within enclosures, or just the maximum or minimum temperatures experienced during transportation.

b. Preferably, test severities should be derived from specific measurements made on the intended transporting platform, on the intended flight platform, at the location in the compartment, or the area on deck during representative worst-case conditions expected in service. Alternatively, severities derived from data obtained for other examples of materiel transported in similar applications may be used.

4.2. Test Severities

4.2.1. Temperature and Humidity

4.2.1.1. General

a. Temperature severities used in tests simulating high-temperature conditions during air carriage should be derived using one or both of the following methods in descending order of preference:

(1) From specifically measured data recorded during hot and cold weather trials. Measurements should be made at the relevant location on the intended flight platform. Other factors influencing temperature severities, such as sources of dissipated heat and supplies of conditioned air, should be represented correctly. The trials programme should include flight sorties likely to produce worst-case conditions in service (e.g., aerodynamic heating).

(2) From data for a similar application with adjustments for differences in the factors referred to in (1) above.

b. Values of temperature and humidity are quoted (Leaflet 2311/2) for external ambient (meteorological conditions) and conditions induced by transportation (Leaflet 2310/1). In the absence of specifically measured data, values for the latter should be assumed to represent worst-case induced conditions experienced by material during transportation.

c. The quoted values of temperature and humidity are likely to be attained or exceeded in the most severe (hottest/coldest) location for 1 percent of the most extreme month of the year.

4.2.1.2. Sea Transportation

Generally, test methods using diurnal cycles will be applicable to materiel in enclosed areas on or above deck. In many cases, conditions for materiel in compartments between decks can be simulated using test procedures that apply constant conditions. Testing for exposure to low temperatures in all areas of the ship normally will be satisfied using test procedures that give steady state conditions. In some instances, particularly for materiel of large mass and a thermal time constant comparable to or longer than the diurnal cycle, the closer realism of a cyclic test may be preferred to ensure that seals and components are stressed representatively.

4.2.2. Air Pressure

4.2.2.1. Air Transportation

a. Severities for low air pressure tests may be determined from the Environmental Requirements documents and from the performance of the platform aircraft (e.g., operational altitude, rates of climb, and descent and the provision or otherwise of pressurisation at the location of the transported materiel).

b. When simulating ground pressure testing for materiel installed in pressurised compartments, test severities for air pressures above standard ambient should be obtained from the airframe manufacturer or aircraft operator.

4.2.2.2. Sea Transportation

Severities for simulating air pressure above standard ambient conditions and hydrostatic pressure should be specified in the Environmental Requirement for the materiel or obtained from the builder or design authority for the ship. Representative simulation of blast pressure waves from explosions, gunfire, and weapon launch is best achieved by subjecting materiel to the real-life environment.

4.2.3. Icing

During sea transportation, tailoring environmental conditions such as icing and various forms of wetting is unlikely to be cost effective. Recommended fall-back severities should be used.

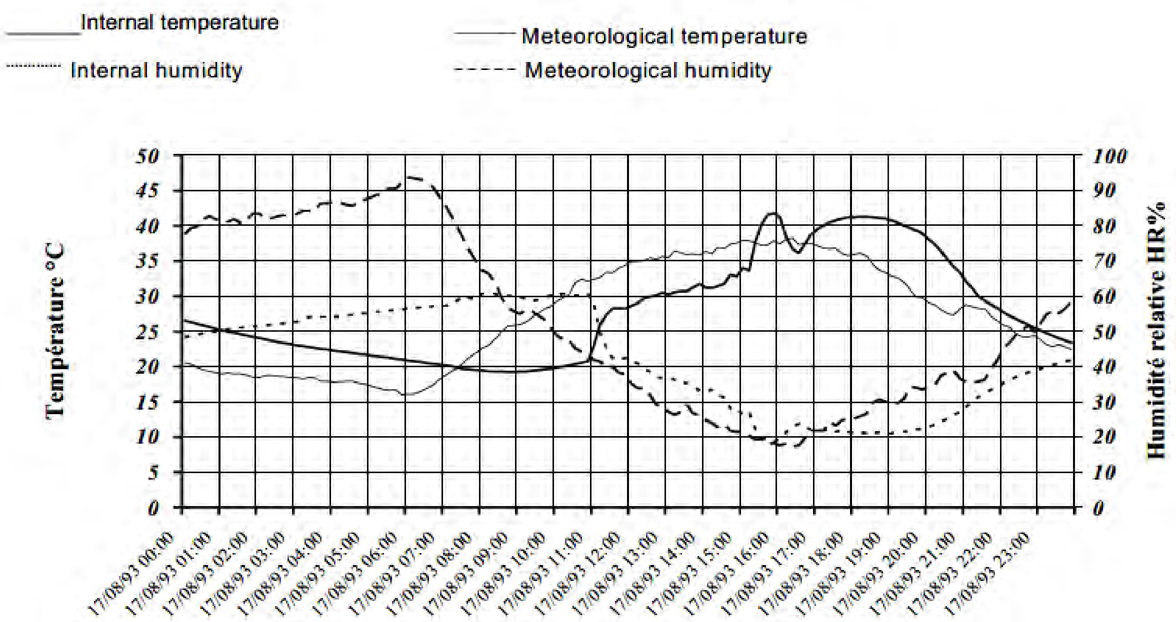
4.2.4. Wind-Blown Sand and Dust

For artificially aerated dust and sand-laden open-sky atmospheres, turbulent dust is the preferred method. Simulated wind-blown dust and sand may be used when the former cannot adequately demonstrate penetration and erosion by sharp-edged particles.

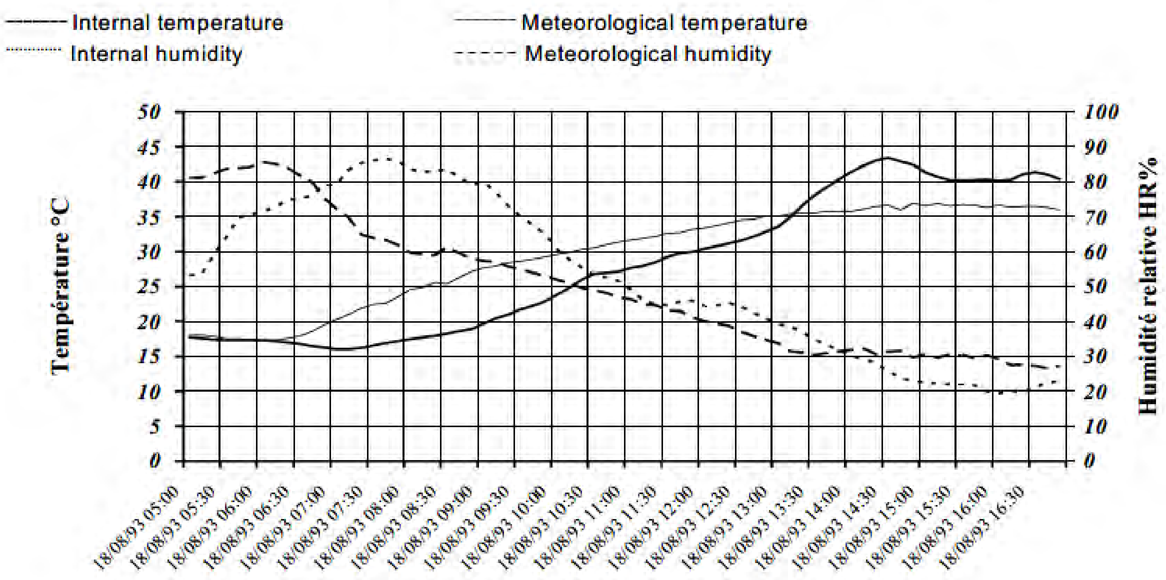
ANNEX A

EXAMPLES OF ENVIRONMENTAL DATA FOR ROAD AND AIR TRANSPORTATION PLATFORMS (FIGURE A-1)

STORAGE IN COMMON CARRIER "G260" cover

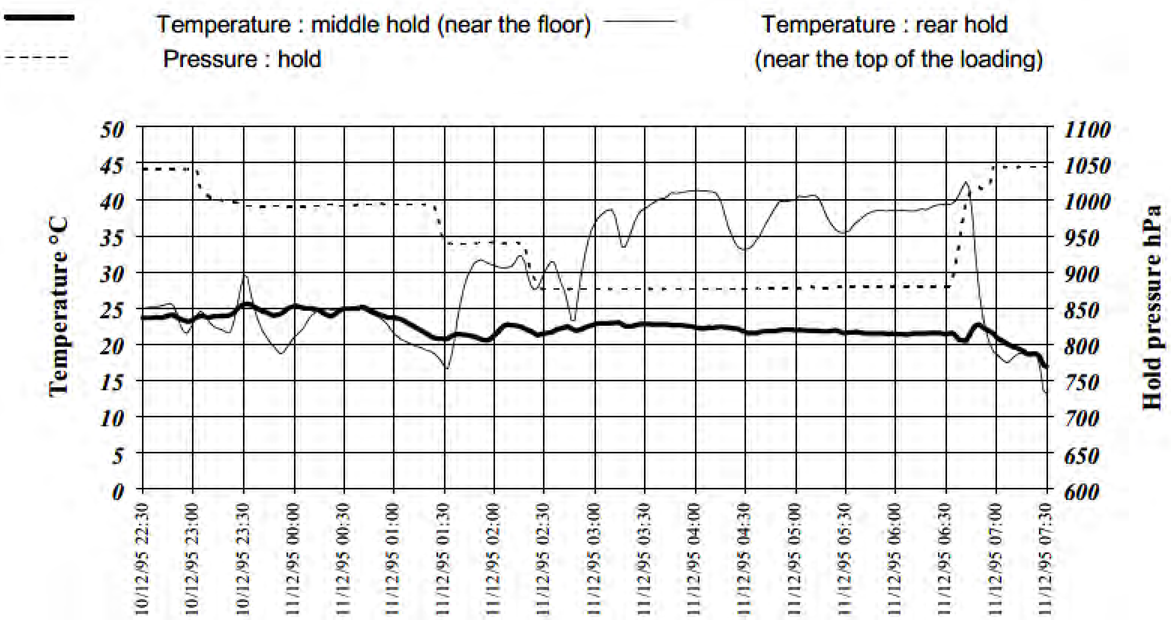


TRANSPORTATION IN COMMON CARRIER " G260" cover



AIR TRANSPORTATION : HERCULES C130

area A1-C0 --> area A2-A3-C0



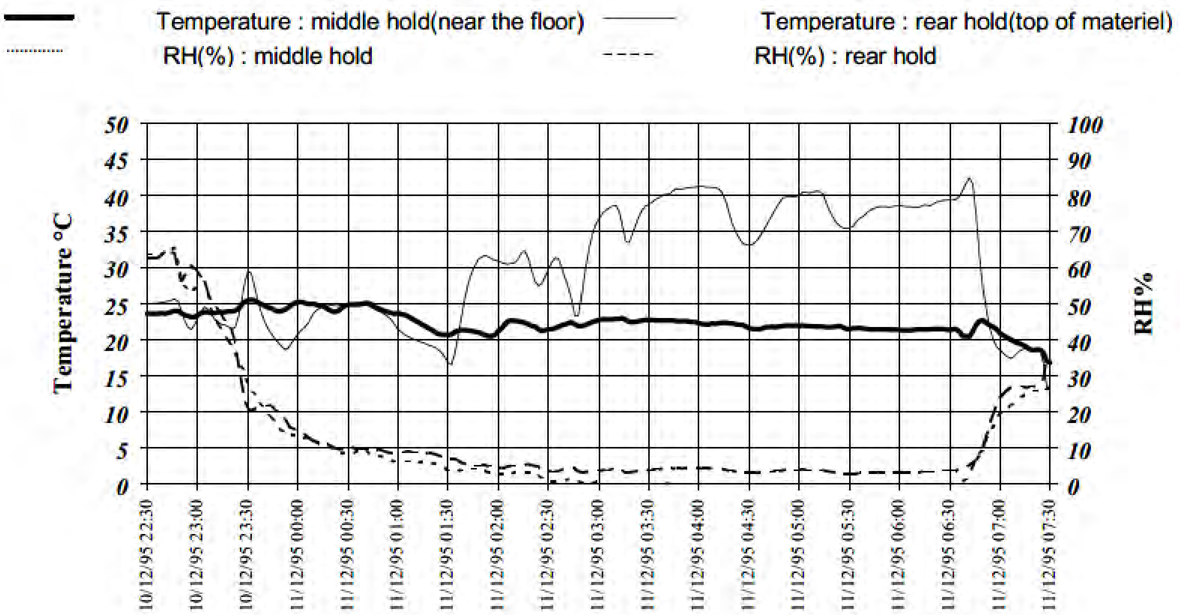


Figure A1: Environmental Data for Road and Air Transportation Platforms

SECTION 233
LEAFLET 233/1
HANDLING AND STORAGE

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SECTION 233
LEAFLET 233/1
HANDLING AND STORAGE

1. GENERAL

a. This leaflet addresses climatic environments that may be experienced by materiel during storage and handling. Characteristics of the climatic environments are presented, discussed, and supplemented by data sheets. Advice is given on potential damaging effects, treatment options and, where relevant, selection of the appropriate AECTP-300 Test Method. References are given in Annex B.

b. For the purpose of this sub-section, materiel exposed in storage or handling environments may be unprotected or within some form of protection package or container.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS

General types and causes of induced climatic environments are described in Section 231. Characteristics of open sky ambient climatic environments (e.g., for materiel on the ground not under cover) are described in Section 2311.

2.1. Temperature

2.1.1. Storage And Handling

2.1.1.1. Light Closed Cover

Light closed cover for this chapter encompasses buildings of light construction, containers, and other light temporary structures. The temperature range of the diurnal cycle experienced by materiel may be different to the meteorological conditions, especially in hot-tropic regions, where the diurnal cycle is characterised by high temperatures and high rates of solar radiation during the day. The minimum temperature experienced during storage may be warmer than the meteorological minimum. The diurnal cycle of temperature experienced by material during storage is out of phase with meteorological diurnal cycle. Thus, for a sunny day, the maximum temperature of the day is reached in the light closed cover before the maximum meteorological temperature is reached.

2.1.1.2. Heavy Closed Cover (e.g., explosives storage igloos)

The temperature range over the diurnal cycle experienced by material is less wide than the meteorological conditions for all kinds of climatic conditions. Examples are provided in Annex A for storage in heavy closed cover for zones A3–C3 and B3. Also, in Annex A is an example of data obtained during natural desert environment storage of materiel.

2.1.2. Handling Out-of-Doors

a. For out-of-doors situations, most environmental characteristics are described in Leaflet 2311/2.

b. Materiel may experience transient temperatures when moving or being moved from one place to another that has different climatic environments. For example, materiel may be moved from the open air to an air-conditioned room where the temperature is several degrees lower.

c. The magnitude of associated thermal shocks may be evaluated by calculating the difference of air temperature between the final location and the primary location. The bigger the heat capacity of the materiel, the smaller the temperature gradient experienced within the materiel.

2.2. Humidity

2.2.1. Storage and Handling

a. Absolute humidity experienced by materiel during storage is similar to the meteorological absolute humidity.

b. For heavy closed cover, because temperature variations are attenuated the magnitude of the diurnal cycle of relative humidity experienced by materiel is less than the meteorological conditions for all kinds of climatic conditions.

c. Condensation may occur on materiel when moved from a cold area to a hot, wet one due to the difference of temperature.

2.3. Icing

Icing of storage materiel is unlikely to occur except for cold climatic zones. Icing of materiel in a light closed cover normally arises entirely from the prevailing meteorological conditions, with a lower probability of occurrence.

2.4. Dust and Sand

Operation and movement of common carriers are likely to generate clouds of dust and sand that penetrate inside light closed covers because they are not dustproof. Concentration and distribution severities of particles are generally less in closed areas than those experienced in open-sky situations.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

3.1.1. Storage

Induced temperatures experienced by materiel during storage can affect the physical and chemical properties of materials used in their manufacture. Expansion and contraction of structural components, accompanied by reductions in mechanical strength and changes in ductility, result in interference and separation between adjacent parts. These factors could impose unacceptable levels of stress and strain leading to deformation or mechanical failure. Induced variations in the characteristics of electrical/electronic components and changes in viscosity of lubricants reduce accuracy, reliability, and operating efficiency.

3.1.2. Handling

Induced transient temperatures experienced by materiel when handled may generate unacceptable levels of stress due to differential thermal expansion or contraction between materials. This phenomenon also may cause separation between adjacent parts.

3.2. Humidity

Storage and handling problems occur in enclosures experiencing high humidity. Induced damp-heat conditions accelerate the degradation of materials. These conditions occur inside enclosures from a combination of inadequate ventilation and forced breathing of moisture. Warm, damp atmospheres in unventilated areas provide ideal conditions for promotion of corrosion, chemical attack and fungal growth. Induced low levels of humidity during storage can influence the characteristics of electrical/electronic components and affect the calibration, stability and accuracy of electronic systems when used immediately after the storage.

3.3. Icing

The potential damaging effects of icing of materiel are the stresses imposed on joints and interfaces of adjacent parts; damage incurred as a result of the methods used to remove the ice; and the subsequent accumulation of moisture after melting the ice.

3.4. Dust and Sand

Materiel can be affected by dust and sand during storage and handling. The effects include, but are not necessarily limited to, impaired performance of optical systems due to accumulations of particulate matter, corrosion of exposed underlying materials, blockage of apertures, and reduced efficiency of cooling and ventilation systems. Dust deposits inside materiel may cause short-circuiting of insulators, tracking and buildup of static electricity, interference between moving parts, and contamination of lubrication systems.

3.5. Precipitation and Spray

The effects of exposure to wetting are described in Leaflet 2311/3.

4. TEST SELECTION

4.1. General

AECTP-300 includes test procedures that may be used to simulate the effects of induced climatic environments on materiel during storage. The choice of test procedures will depend on whether there is a requirement to simulate diurnal variations (including the heating effects of solar radiation when open-sky-stored) or just the maximum or minimum temperatures of a diurnal cycle. Preferably, test severities should be derived from specific measurements made on the intended enclosure during representative worst-case conditions expected in service. Alternatively, severities derived from data obtained for other examples of materiel stored in similar applications may be used.

4.2. Fallback Test Severities

If no specific environmental measurements are available, the fallback test severities given in the AECTP-300 test procedures should be used.

4.3. Tailored Test Severities

4.3.1. Temperature and Humidity

AECTP-300's test procedures give values of temperature and humidity for external ambient (meteorological) conditions and for conditions induced by storage. In the absence of specifically measured data, values for the latter should be assumed to represent worst-case induced conditions experienced by materiel during storage. The quoted values of temperature and humidity are those that are likely to be attained or exceeded in the most severe location for 1 percent of the most extreme month of the year.

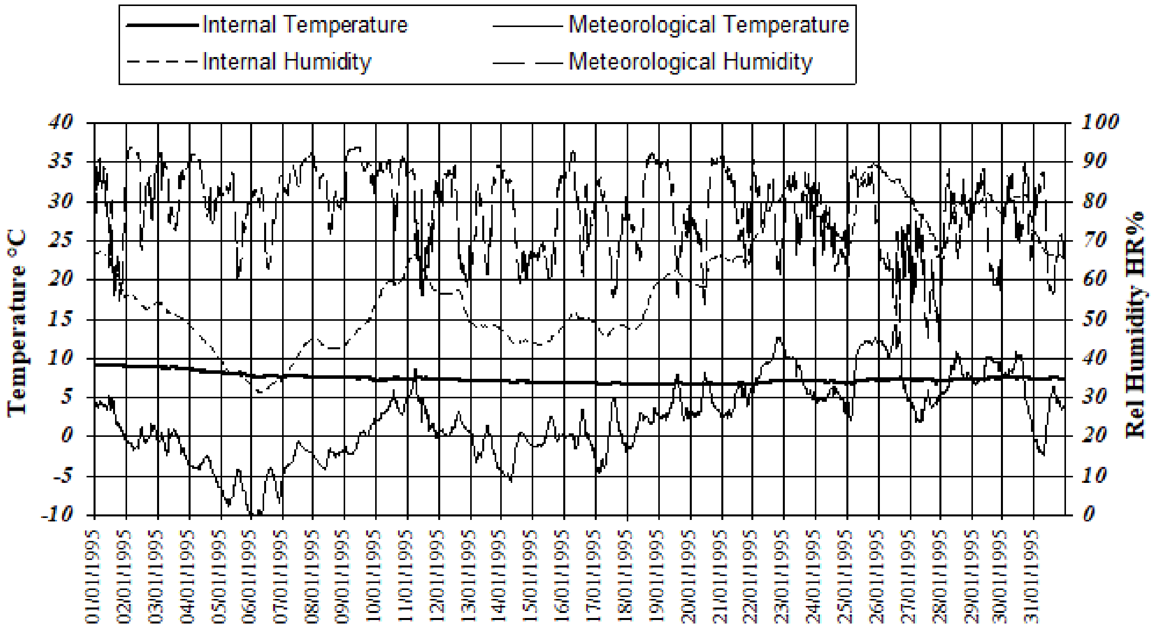
4.3.2. Dust and Sand

For artificially induced dust and sand-laden open-sky atmospheres, blowing dust is the preferred test procedure. Simulated windblown dust and sand may be used when blowing dust cannot adequately demonstrate penetration and erosion by small, sharp-edged particles.

ANNEX A

EXAMPLE OF STORAGE CONDITIONS IN A HEAVY COVER (IGLOO) (FIGURES A-1–A-4)

"Heavy cover : TYPE IGLOO, Category A3 - C1"



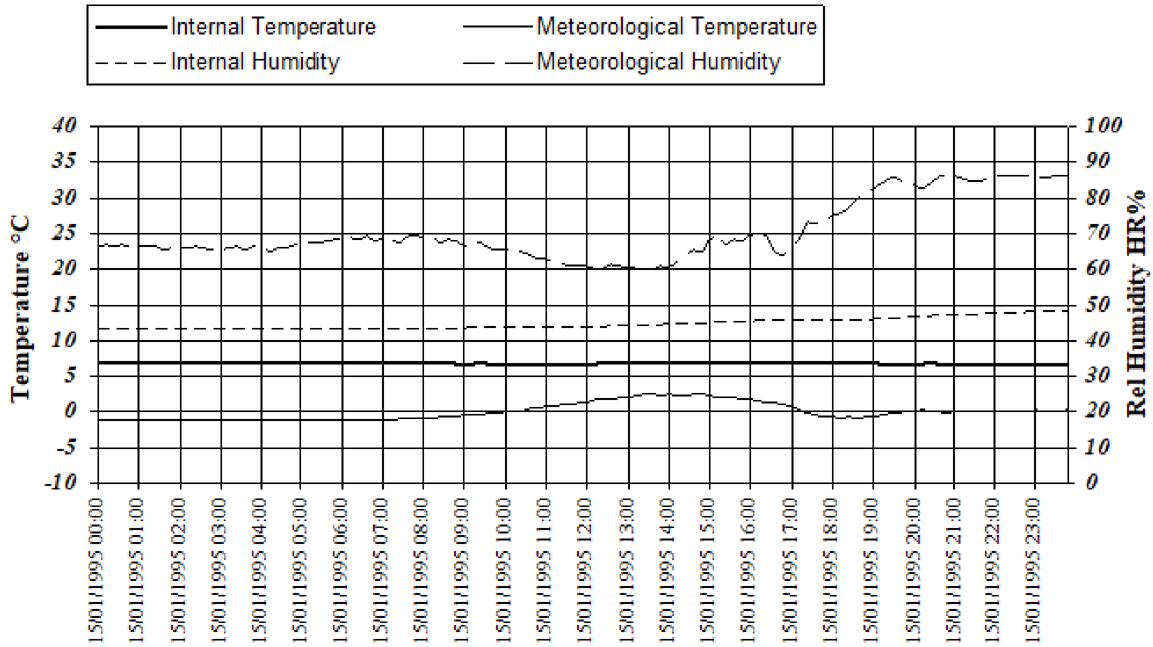
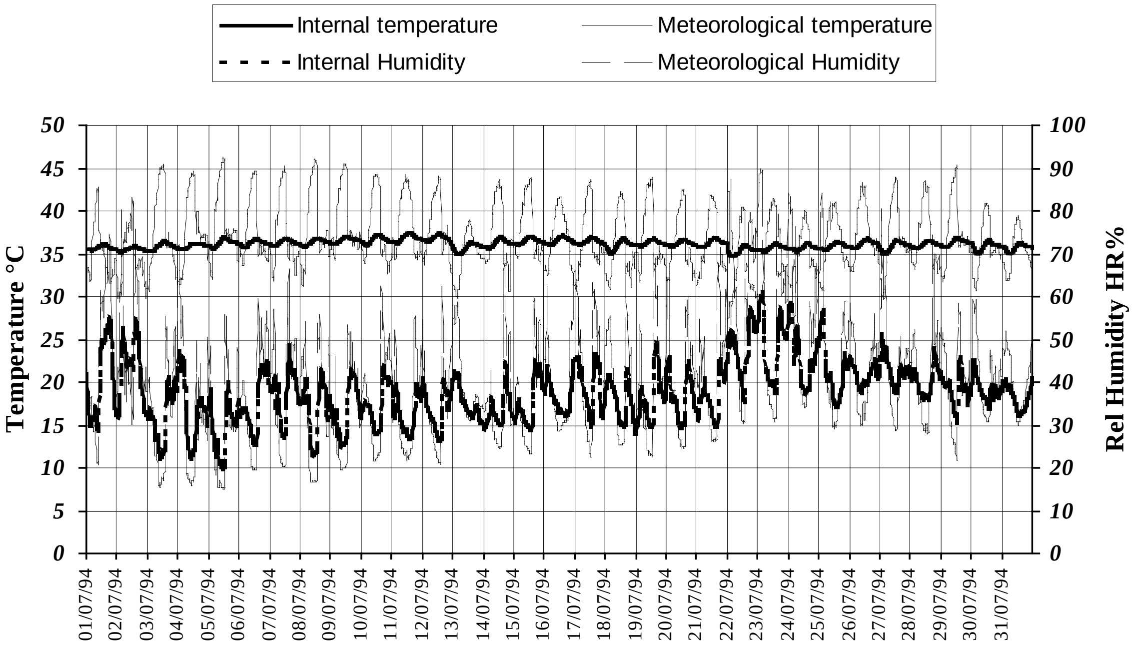


Figure A1: Example of Storage Conditions in Heavy Cover Categories A3–C1

Heavy cover : TYPE IGLOO, Category A3 - B3



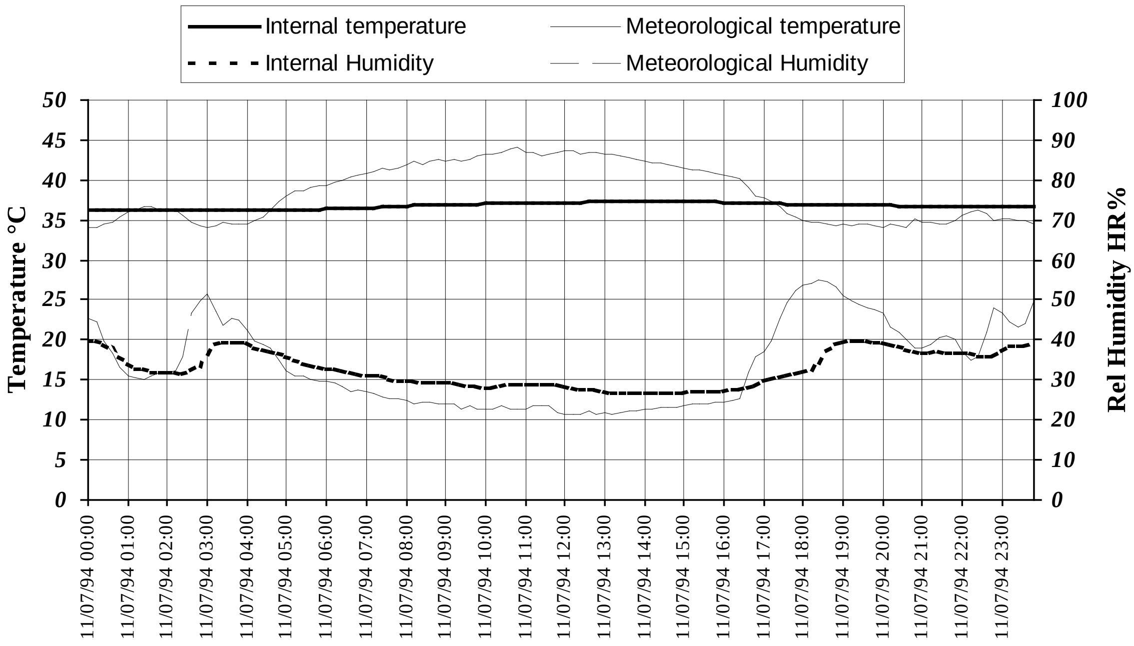
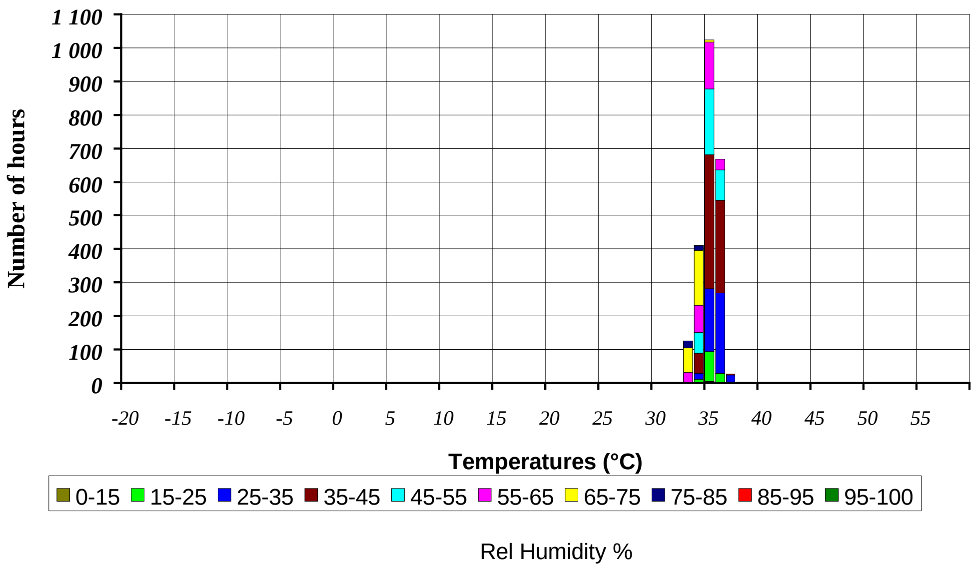


Figure A2: Example of Storage Conditions in Heavy Cover Categories A3–B3

Heavy cover : TYPE IGLOO, Category A3 - B3

Measures : 25/05/94 to 27/08/94 (95 days)

Histogram for IGLOO temperature and humidity



Histogram for meteorological temperature and humidity

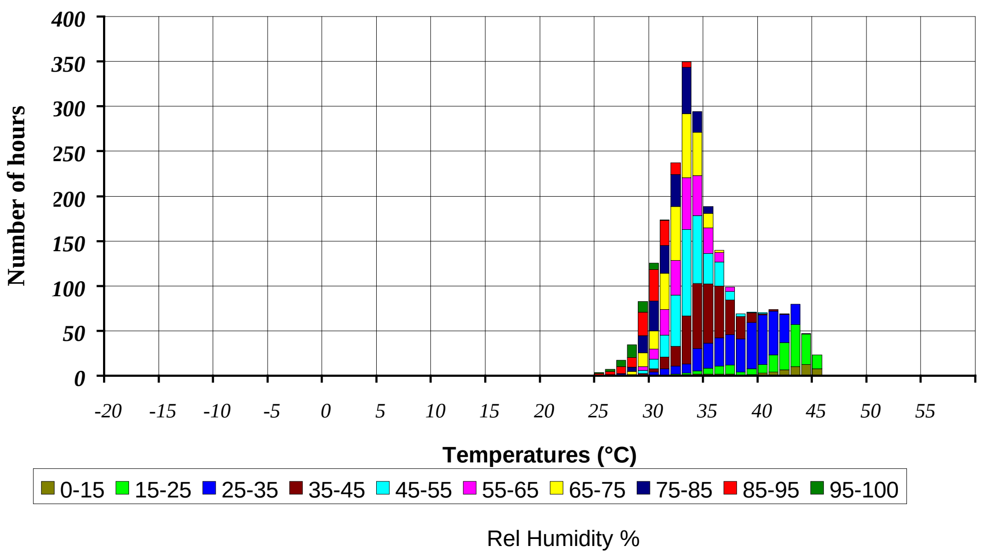


Figure A3: Example of Data Measurements for Two Types of Materiel

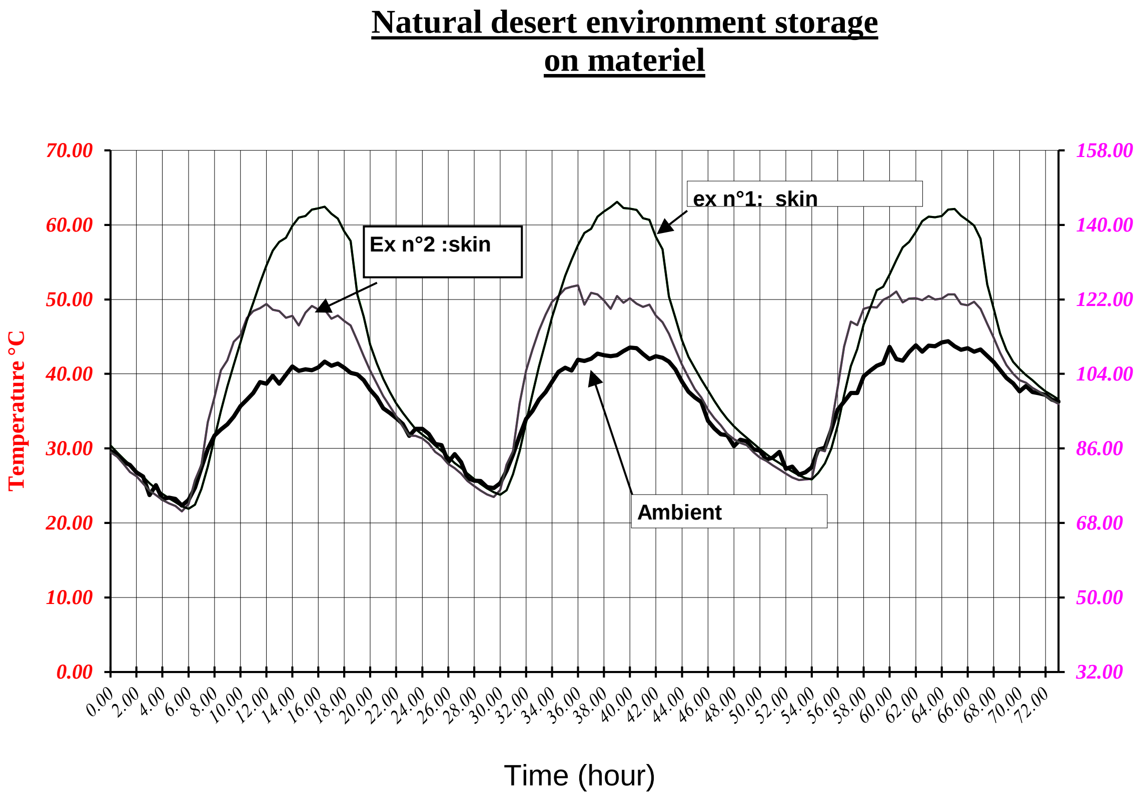


Figure A4: Natural Desert Environment Storage on Materiel

ANNEX B

REFERENCES

B.1. STORAGE

B.1.1. Title

Methodology Investigation Final Report of Chamber Simulation of Test Item Response.

Author:	A.K. Groff, Randolph B. Patrick
Source:	U.S. Army Yuma Proving Ground
Ref. N°:	7-CO-R87-YPO-006
Date:	June 1991
Pages:	15

B.1.2. Mission/Platform

Natural Desert Environment Storage.

B.1.3. Summary of Technical Data

Ambient, skin, and inside-skin temperature during storage.

SECTION 234
LEAFLET 234/1
MAN-MOUNTED AND PORTABLE

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SECTION 234
LEAFLET 234/1
MAN-MOUNTED AND PORTABLE

1. GENERAL

a. This leaflet addresses the induced climatic, chemical, and biological environmental conditions likely to be encountered by man-mounted and portable materiel (i.e., materiel deployed on or carried by personnel) such as small arms, ammunition, weapon launchers and communications, and surveillance equipment. The environmental conditions covered by this leaflet are primarily those likely to be incurred by materiel carried and used by land-based forces such as foot soldiers and crewmembers of military vehicles when operating beyond forward storage bases and on the battlefield.

b. Advice is given on potentially damaging effects of induced climatic, chemical, and biological environments and, where relevant, the appropriate AECTP-300 test methods and severities are recommended for simulation of the effects of those environments.

c. For the purpose of this leaflet the materiel is assumed to be devoid of its transportation package but may still be protected by some form of “battlefield” container of closed or open construction. The environmental descriptions and severities relate to the totally exposed or containerised materiel as appropriate.

d. For those types of man-mounted and portable materiel designed for tri-Service use and likely to be deployed on military aircraft, surface ships or submarines, reference should also be made to the appropriate leaflet of AECTP-230, for the relevant induced climatic, chemical, and biological conditions.

e. In many cases, man-mounted and portable materiel will be directly exposed to the prevailing meteorological conditions during deployment beyond forward storage bases. Exceptions could include periods of tactical transportation in enclosed areas of military vehicles such as trucks, personnel carriers, fixed-wing, and rotary-wing aircraft or in temporary buildings. For some types of materiel such as portable communications equipment, it may be a requirement for prolonged periods to be spent inside vehicles such as mobile command posts, gun carriers or main battle tanks. In these cases, the severity of meteorological conditions are likely to be enhanced by the form of the enclosure, the level of ventilation and heat and moisture emitted by operational equipment installed on the vehicle. The frequency and durations of exposure in these conditions will be determined by the operational requirements.

f. Tactical requirements may include carrying and handling materiel over various types of terrain, negotiating obstacles, immersion in various depths of water, and exposure to dust and sand-laden atmospheres, which are likely to result in contamination and ingress of foreign substances including non-pure water.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS[2]

2.1. Temperature

a. Dependent on the provision or otherwise of an appropriate level of ventilation, the temperatures of materiel in confined spaces of land-based military vehicles during tactical transportation are likely to exceed those of external ambient.

b. Conditions may be aggravated by heat dissipated from vehicle power units, installed operational equipment, and personnel carried on board. Similar effects are likely to occur inside temporary buildings and ad hoc improvised structures that may be employed in the battlefield. These effects may be of particular concern where man-mounted materiel such as communications equipment relies on the convection and radiation to the surrounding atmosphere to maintain an acceptable operating temperature.

c. Conversely, surfaces of semi-permanent buildings and temporary covers are liable to be better radiators to the night skies than the ambient atmosphere. Consequently, dependent on the insulation of materials used in their construction and the presence or otherwise of heat-dissipating equipment, temperatures in the enclosed areas may be lower than the external ambient during the low temperature part of a diurnal cycle.

d. The circumstances in which man-mounted and portable materiel are likely to be deployed worldwide are infinitely variable. Therefore, the temperature severities given for transit and storage in hot regions (Category A) and cold regions (Category C) in Leaflet 2310/1 should be assumed to apply. Reference should also be made to Leaflet 2311/1 to determine the grade of severity for a particular area of deployment, for example C0, C1, or C2, etc. The values of temperature are those which are likely to be attained or exceeded in the hottest/coldest locations for approximately 7.4 hours (1 percent of one month) of the hottest/coldest period of the year. Additional guidance is given in Leaflet 2311/2 and Leaflet 2310/1 to enable severities for other probabilities of occurrence to be derived. Special consideration will be necessary where materiel, enclosed behind transparent surfaces and exposed to solar radiation in hot regions, could experience temperatures above 85 °C.

e. Temperatures experienced in battle-ready configuration during air carriage on fixed-wing transport aircraft are likely to be similar to those given in Leaflet 236/237/1 of this document that addresses transportation of materiel in aircraft. Flight altitudes of battlefield helicopters during flight sorties carrying land-based fighting personnel are likely to be such that temperatures experienced by man-mounted materiel (up to altitudes of approximately 900 m) will be similar to meteorological values at sea level. Guidance is given in Leaflet 2311/2 for correction factors which may be applied for higher altitudes. Temperatures during the deployment of fighting personnel from naval vessels such as assault ships and landing craft will be similar to the prevailing meteorological conditions at sea level, except for any item which may be carried under cover, in which case the indirect effect of solar radiation may be relevant, as discussed in subparagraph a above. However, for man-mounted and portable materiel specifically intended for deployment on fixed- and rotary-wing aircraft, surface ships, and submarines, reference should be made to the appropriate leaflet of this document.

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[2] General types and causes of induced climatic environments are described in Section 231of this document. Characteristics of open sky ambient climatic environments are described in Section 2311.

f. Man-mounted and portable materiel may be subjected to rapid change of temperature during transfer from air-conditioned buildings to external ambient conditions when deployed in geographical regions noted for their extremes of temperature (both high-to-low and low-to-high temperatures). A similar situation applies to materiel air dropped from conditioned cargo bays of fixed-wing transport aircraft or brought up from below decks on naval vessels, for example, when operating in low temperature regions. Temperatures will change rapidly from those given in Leaflet 236/237/1 for cargo areas of transport aircraft and in Leaflet 238/1 for naval vessels, to the prevailing meteorological conditions.

2.2. Humidity

a. Materiel carried onto the battlefield by ground troops is likely to be subjected to levels of relative humidity in excess of the local ambient if deployment includes periods spent under temporary cover or enclosed spaces without appropriate levels of ventilation. Examples include materiel located in compartments of military vehicles, trailers, and temporary covers used as command posts or for conducting covert surveillance. Such conditions are particularly applicable to enclosures deployed or erected in open spaces in hot, wet tropical regions where diurnal cycling over a wide temperature range is aggravated by the indirect effect of solar heating of the external surfaces. Heating and cooling produces pressure differentials across the walls of the enclosure causing external air to be drawn in. The level of ventilation is likely to be such that any moisture in the incoming air is liable to be retained during the heating phase of the next diurnal cycle, raising the relative humidity and dewpoint temperature inside the enclosure. Circumstances contributing to conditions will be infinitely variable and unless materiel is to be deployed in a particular defined installation, it should be assumed that saturation may occur during the low temperature part of the cycle.

b. Pressure differentials are likely to occur across the walls of partially sealed cases and protective covers of individual materiel, causing moisture to be breathed in and retained. Although heat dissipated by equipment while operating will help to reduce the relative humidity, heating and cooling associated with its duty cycle may also aggravate the situation.

c. The combined effects of induced high temperatures and dissipated heat may result in very low levels of relative humidity occurring inside confined spaces of materiel deployed in hot, dry regions of the world. Relative humidities lower than 30 percent are common for naturally occurring conditions in hot, dry regions of the world. Leaflet 2311/2 gives recorded values of relative humidity (RH) as being as low as between 3 and 8 percent. Therefore, similar or lower levels may be assumed to occur inside confined areas in which there are sources of dissipated heat.

2.3. Air Pressure

a. Materiel carried or worn by airborne troops will be subjected to air pressure below standard ambient when flown and subsequently parachuted into the battlefield. Values of air pressure below standard ambient in pressurised cargo bays of fixed-wing aircraft during normal conditions of air carriage are given in Leaflet 236/237/1 of this document. Low air pressures and explosive decompression associated with emergency flight conditions, during which carried materiel must not present any potential danger to aircraft and crew, are also specified. Low air pressure during air carriage to battlefield areas by rotary wing aircraft are likely to be similar to those of normal conditions in cargo bays of fixed-wing aircraft.

b. Materiel carried or worn by ground troops may be subjected to benign levels of pressure above local ambient, during tactical transport in military vehicles which employ overpressure to prevent contamination of the atmosphere inside the vehicle, in the event of nuclear, chemical, or biological attack.

2.4. Dust and Sand

a. When operating in hot, dry desert regions, or where the surface is liable to break up into small particulate, virtually any movement of the carrier or of the carried materiel is likely to result in contamination by dust and sand. The movement of military vehicles in desert areas is liable to result in dust and sand-laden atmospheres in which localised concentrations may approach those of naturally produced dust and sandstorms. Once disturbed, fine dust can remain in the atmosphere for days. Even materiel located in partially sealed enclosures are vulnerable. Materiel carried or worn by ground support personnel during operation of aircraft on airfields is also likely to be directly subjected to artificially blown dust and sand.

b. During tactical manoeuvres that require foot soldiers to crawl along the ground, any man-mounted or portable materiel carried or dragged over the surface is vulnerable to ingress of small particulate dust and sand.

c. The characteristics of dust and sand-laden atmospheres including the distribution and physical characteristics of particulate, and the levels of concentration associated with the operation of military vehicles are given in Leaflet 232/1 of this document.

2.5. Immersion, Precipitation, and Spray

a. Wherever water has to be negotiated during tactical operations or battlefield conditions, man-mounted and portable materiel is likely to experience some form and degree of wetting. Materiel is liable to be subjected, accidentally or intentionally, to splashing and spray, or to partial or total immersion in water. Circumstances are infinitely variable and waterproofing requirements such as depths and durations of immersion and expected levels of survival or subsequent operation should be specified in the Environmental Requirements document.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

3.1.1. High Temperature

Examples of the effects of high temperature include the following:

a. Reduced strength and increased elasticity of materials, causing overload.

b. Dimensional changes and differential thermal expansion of structural and mechanical components, causing:

- Distortion and failure of structural components.
- Binding and seizure of moving parts.
- Failure of bonded joints.

c. Changes in the characteristics of shock and vibration isolation systems, reducing the life of materiel protected from mechanical environments.

d. Dimensional changes and permanent sets, reducing effectiveness of gaskets and seals.

e. Reduced efficiency of cooling systems, particularly those that depend on convection and radiation to the surrounding atmosphere, resulting in:

- Changes in electrical characteristics of materials used in the manufacture of electrical/electronic components.
- Failure of internal connections of electronic components.
- Degraded performance or total failure of electrical/electronic systems.

f. Lowering of viscosity and reduced efficiency of lubricants.

g. Discoloration and crazing of protective finishes.

h. Increased burning rates of explosives and propellants.

3.1.2. Low Temperature

Examples of the effects of low temperature are as follows:

a. Embrittlement and reduced elasticity of materials (especially non-metallic), reducing resistance to mechanical shock.

b. Dimensional changes and differential thermal contraction of structural mechanical components, causing:

- Distortion and failure of structural components.
- Seizure of mechanical systems.
- Failure of bonded joints.

c. Changes to characteristics of shock and vibration isolation systems.

d. Reduced performance from batteries.

e. Changes in characteristics of materials used in manufacture of electronic components, causing:

- Failure of mechanical joints and mechanical supports of electronic components.
- Degraded performance or total failure of electrical/electronic systems.

f. Increased viscosity of lubricants reducing performance of mechanical systems.

g. Decreased burn-rate of explosives and propellants.

3.1.3. Rapid Change of Temperature

Examples of effects and faults arising from rapid change of temperature are as follows:

a. Rapid expansion and contraction of materials resulting in deformation and failure of structural components.

b. Failure of bonded joints.

c. Crazing of protective finishes.

d. Cracking of grains and pellets of explosives and propellants.

3.2. Humidity

Reference 1 of Annex A gives information on the protection of materiel from the effects of moisture-laden atmospheres. The effects on materiel, achieving and maintaining dry enclosures, standards and methods of sealing, water vapour barriers, and drying out procedures are discussed.

3.2.1. High Humidity

Examples of the effects of high humidity are as follows:

a. Absorption of moisture by non-metallic materials, causing:

- Swelling and reduction in mechanical strength.
- Increased weight.
- change in thermal and electrical characteristics.

b. Absorption and adsorption of moisture reducing insulation resistance and producing unwanted low resistance paths in electrical/electronic circuitry.

c. Total failure or degraded performance of electrical/electronic system and components, due to a and b.

d. Galvanic corrosion of metallic parts and components especially in areas of high strain and where protective finishes have been defaced.

e. Seizure of moving parts and contamination of lubricants by corrosion products.

f. Creation of micro-climates in (often hidden) areas of entrapped moisture.

g. Acceleration of chemical and biological attack.

3.2.2. Low Humidity

Very low levels of relative humidity can result in a buildup of static electricity causing flash-over and failure of low voltage electronic components.

3.3. Pressure

Pressure sensitive devices designed to detect and respond to small changes in pressure may incur permanent damage during air carriage in cargo bays of transport aircraft. The walls of sealed or partially sealed containers with leakage rates lower than induced rates of change of pressure may suffer temporary or permanent distortion, which in turn may cause interference with contained components.

3.4. Dust and Sand

Examples of the effects of dust and sand-laden atmospheres are as follows:

a. Blockage of apertures, resulting in reduced efficiency of ventilation and cooling systems.

b. Scratching and etching of lenses, transparent panels, and surface finishes, causing:

- Corrosion of exposed underlying materials.
- Impaired performance of optical systems.

c. Clogging or seizure of mechanical devices.

d. Contamination of electrical/electronic systems, causing:

- Introduction of unwanted low-resistance paths.
- Reduced reliability.

e. Contaminated lubrication systems.

3.5. Immersion, Precipitation, and Spray

Materiel subjected to immersion is liable to ingress of water (including contained contaminants) causing seepage and swelling of materials and inducing faults and failures similar to those associated with condensation and high levels of humidity (see paragraph 3.2.1)

4. TEST SELECTION

4.1. General

a. AECTP-300 gives test procedures that may be used for simulating induced climatic environments that may be experienced by man-mounted and man-portable materiel. The choice of test method for temperature and humidity will depend on whether there are any requirements to simulate diurnal variations including the heating effects of solar radiation or steady-state conditions.

b. The characteristics of the materiel and previous experience of the response of similar types of materiel to real-life conditions (e.g., the effects of thermal cycling on explosives and propellants) may also influence the choice of test procedure. Careful consideration of the configuration of the test item, within its enclosure where applicable, is required when simulating the effects of solar heating. Test procedures that apply to steady-state conditions are likely to be relevant to materiel required to spend periods of time in areas where temperature and levels of humidity are determined by dissipated heat from power supplies and operational equipment.

c. Preferably, test severities should be derived from specific measurements made at the location representative of the worst-case conditions expected in service. Alternatively, severities derived from data obtained for other situations in similar applications may be used.

4.2. Test Severities

4.2.1. Temperature and Humidity

a. Test severities used in the simulation of induced temperature (and humidity) conditions should be based on information given in Operational and Environmental Requirements documents. This information should include the geographical areas where the materiel is likely to be deployed, and the detailed logistical requirements for the man-mounted/man-carried materiel. Preferably, test severities should be derived from specifically measured data including the influence of any form of conditioned or non-conditioned enclosure such as a military vehicle or temporary shelter. Test severities derived from measured data should include worse-case conditions.

b. In the absence of specifically measured data, values of temperature given in Leaflet 2310/1 for transit and storage in hot (Category A) and cold (Category C) climates should be assumed to represent worst-case induced conditions. In the case where materiel may be placed in an unventilated enclosure behind transparent panels directly exposed to solar radiation, temperatures greater than 85 °C should be assumed.

c. Where the capacity of the test facility allows, test severities representative of meteorological conditions, including radiative heating, may be applied to a simulated structure or enclosure containing the test item(s). Preferably, the enclosure should stand on a surface with the same reflective properties as those on which it will stand in service. Alternatively, the test item(s) should be subjected to the diurnal temperature cycle derived from data measured inside the confined space, or the relevant Category A (for dry heat) or Category B (for heat and humidity) diurnal cycle for transit and storage given in Leaflet 2310/1.

d. Where it is required to test materiel to induced high temperatures when diurnal variations are so small as to have an insignificant effect on the materiel, or where it is considered that the response of the test specimen or its component parts are not related to temperature cycling, constant high temperature may be used.

e. In many cases, testing materiel for exposure to induced low temperatures will be satisfied using constant low temperature. In those cases where low temperature cycling is considered more appropriate, a low temperature diurnal cycle test should be used. Typical examples include materiel containing explosives or seals and other components that need to be representatively stressed.

f. The diurnal temperature cycle should be derived from specifically measured data, or the relevant Category C diurnal cycle for transit and storage given in Leaflet 2310/1.

4.2.2. Air Pressure

Where it is required to simulate low air pressures experienced by man-mounted and portable materiel when deployed beyond forward storage base, the relevant procedure of AECTP-300 Method 312 should be used. Test severities should be matched to the particular application. Reference should be made to Operational and Environmental Requirement documents

4.2.3. Dust and Sand

a. Where it is required to determine the effects on man-mounted and portable materiel to exposure to dust and sand-laden atmospheres, AECTP-300 Method 313 should be used. Materiel directly exposed to artificially blown dust and sand should be tested to the Wind-Blown Dust and Sand test.

b. The sand and dust concentration, air velocities and duration of exposure should be selected from the listed severities in accordance with the guidance given in Method 313. Any attempt to tailor test severities to specifically measured data for the Dust and Sand test is unlikely to be cost effective.

c. The Drag Test of Document D.14 of NATO AC 225, Panel III, which simulates small arms being carried or trailed by a soldier while crawling through sand, may be considered appropriate to other man-mounted or portable materiel.

4.2.4. Immersion, Precipitation, and Spray

a. Where it is required to determine the effects on materiel that may be subjected to immersion, AECTP-300 Method 307 should be used. The depth and duration of immersion for a particular test item will depend on the need for it to continue to operate while immersed in water, and/or of the benefits arising from its retrieval. In the absence of specific information, test severities should be selected from those listed in Method 307.

b. Determination of the performance of materiel when subjected to spray and splashing may be satisfied by testing for the effects of natural precipitation (e.g., driving rain or drip-proofness) (AECTP-300 Method 310).

ANNEX A

REFERENCES AND BIBLIOGRAPHY

A.1. REFERENCES

1. Review of Climatic Protection Techniques for Electronic Equipment; E. Napper, Procurement Executive, Ministry of Defence, RSRE Malvern, Worcs, RSRE Memorandum No. 3530.

2. QSTAG 362 Chemical Environmental Contaminants affecting the Design of Military Materiel.

3. DEF STAN 01-5 Fuels, Lubricants and Associated Products.

4. DEF STAN 08-41, Chemical and Biological Hardening of Military Equipment, Part 1 General Requirements, Assessment and Testing.

5. QSTAG 361 Fungal Contamination Affecting the Design of Military Materiel.

6. BS 2011 Part 2.1J (IEC 60068 -2-10) Test J and Guidance; Mould Growth. Appendix F.

7. DEF STAN 00-3 Issue 3 Design Guidance for the Transportability of Equipment.

8. BS 2011 Part 2.1R (IEC 60068-2-18) Test R Water and Guidance.

9. Acid Deposition in the United Kingdom, Third Report of UK Review Group on Acid Rain, J G Irwin and F B Smith, Warren Springs Laboratory, Stevenage, 1990.

A.2. BIBLIOGRAPHY

Further information on the environmental conditions addressed in this leaflet and the effects on materiel may be found in the following leaflets of Part 4 of this Standard and the associated lists of bibliography.

1. DEF STAN 00-35 Part 4 Section 2 Leaflet 2-01 Temperature and Leaflet 2-02 The Effects of Temperature.

2. DEF STAN 00-35 Part 4 Section 3 Leaflet 3-01 Solar Radiation and Leaflet 3-02 The Effects of Solar Radiation.

3. DEF STAN 00-35 Part 4 Section 4 Leaflet 4-01 Humidity and Leaflet 4-02 The Effects of Humidity.

4. DEF STAN 00-35 Part 4 Section 8 Leaflet 8-01 Deleterious Atmospheres and Leaflet 8-02 The Effects of Corrosives and Contaminants.

5. DEF STAN 00-35 Part 4 Section 9 Leaflet 9-01 Dust and Sand and Leaflet 9-02 The Effects of Dust and Sand.

6. DEF STAN 00-35 Part 4 Section 10 Leaflet 10-01 Atmospheric Pressure and Leaflet 10-02 The Effects of Air Pressure.

7. DEF STAN 00-35 Part 4 Section 11 Leaflet 11-01 Biological Hazards and Leaflet 11-02 The Effects of Biological Hazards.

SECTION 235
LEAFLET 235/1
DEPLOYMENT OR INSTALLATION ON OR IN VEHICLES

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SECTION 235
LEAFLET 235/1
DEPLOYMENT OR INSTALLATION ON OR IN VEHICLES

1. GENERAL

a. This leaflet addresses the induced climatic environmental conditions likely to be encountered by materiel deployed on, or installed in, land-based vehicles. The vehicles include wheeled and tracked (fighting) vehicles, and associated trailers, used as Service platforms for materiel, or used for transportation of materiel beyond forward storage bases and on the battlefield.

b. Advice is given on potentially damaging effects of induced climatic environments and, where relevant, the appropriate AECTP-300 test methods and severities are recommended for simulation of the effects of those environments.

c. For the purpose of this leaflet, materiel includes items that may be packaged or unpackaged, or materiel contained within some form of battlefield container. The environmental descriptions and severities relate to the totally exposed or containerised materiel as appropriate.

d. Induced climatic conditions experienced by materiel during transportation between factory and forward storage bases are addressed in Leaflet 232/1 of this document. Induced climatic environments that are liable to be experienced during the loading and unloading of transported materiel are addressed in Leaflet 233/1.

e. The armoured structure and temporary covers provided on military vehicles for protection against the weather and armed attack can aggravate the effects of the local meteorological conditions such as solar radiation and damp heat, especially where logistical and operational requirements preclude the provision of appropriate levels of ventilation. The induced temperatures are liable to impose thermal stresses more severe than those caused by naturally occurring meteorological conditions.

f. It should be assumed that materiel fitted to, or carried on, external surfaces will be subjected to the ambient conditions associated with the geographical area of deployment. Dependent on the provision or otherwise of appropriate levels of ventilation or forced-air conditioning, materiel carried or installed within the protective structure or under temporary covers of trucks, trailers and fighting vehicles is liable to be subjected to conditions in excess of the local ambient due to the response of the vehicle to the external ambient conditions, heat emissions from power sources and operating systems carried on the vehicle and their duty cycles.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS[3]

2.1. Temperature

a. High temperatures inside vehicle compartments are liable to exceed external ambient temperatures due to indirect effect of solar radiation on the armoured structure or temporary covers.

b. The relative angle of elevation between the source and the external surfaces of the vehicle, the prevailing cloud cover, the heat capacity of the exposed structure or cover, its colour and surface finish, and the duration of exposure will all contribute to the amount of heat absorbed within the enclosed area and the induced temperatures. The latter may be tempered by some form of natural or man-made shade or ventilation.

c. Conversely, such protective structures and temporary covers are also liable to be better radiators to the night skies than the ambient air, such that temperatures in enclosed compartments may be lower than the external ambient.

d. In the absence of specifically measured data, temperature severities given Leaflet 2310/1, for Transit and Storage in Category-A and Category-C climatic areas, should be assumed to represent worst-case conditions inside parked, non-operating vehicles deployed in hot and cold regions.

e. In those cases where materiel is intended to be installed in enclosed areas behind transparent panels of land-based vehicles, ambient temperatures greater than 85 °C may be experienced when directly exposed to solar radiation in hot, dry regions of the world.

f. The values referred to in subparagraphs d and e above are more applicable to non-operational periods of this phase of deployment. When the vehicle and/or installed equipment is operational, temperatures inside enclosed areas will also depend on packing density of carried equipment, the levels of natural and forced air cooling and heat dissipated by operational equipment (e.g., from engine compartments or racks of electrical/electronic systems, etc.). Ambient temperatures surrounding individual materiel will also depend on the location inside the vehicle (i.e., whether it is located in an open or stagnant area within the vehicle). Preferably, temperature severities at the intended location of materiel on the vehicle should be determined from specifically measured data recorded during worst-case service conditions. Alternatively, information regarding characteristics of built-in ventilation systems and levels of heat dissipated by installed operational equipment should be sought from the vehicle and equipment manufacturers, and balanced against thermal response of the enclosure to meteorological conditions.

g. Where specifically measured data have not been available, maximum switch-on temperatures for both conditioned and non-conditioned compartments of vehicles deployed in hot, dry regions should be taken as equivalent to maximum induced temperatures for ground transit and storage given in Leaflet 2310/1 for Category A1 environmental conditions. For materiel subject to solar radiation behind transparent surfaces, switch-on temperatures greater than 85 °C should be assumed.

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[3] General types and causes of induced climatic environments are described in Section 231 of this document. Characteristics of open sky ambient climatic environments are described in Section 2311.

h. For long-term ground running in hot, dry regions, and where characteristics of cooling air are unknown, ambient temperatures in conditioned compartments are assumed to stabilise at 15 °C lower than at switch-on. While it may be assumed access doors and panels will have been open for a period sufficient to allow external ambient air to have some alleviating effect, in order to take account of dissipated heat from operational equipment, the temperatures at switch-on should be assumed to prevail in non-conditioned areas of the vehicle. Where such areas are behind transparent panels, a temperature of 70 °C should be assumed. In cases of externally carried stores, in which packing densities of heat dissipating systems and components are liable to be relatively high, final temperatures and rates of increase are likely to be in excess of those given above. Indeed, long-term ground running without forced air cooling should be avoided in hot, dry regions to prevent permanent damage or degraded reliability.

i. Internal temperatures of individual materiel will depend on similar factors to those discussed above. Packing density and heat dissipation of components, the thermal paths to external surfaces of the materiel, and the incorporation of systems to distribute cooling mediums will influence the temperatures produced. Where the temperatures of the internal air space or of individual components are of concern, they should be estimated using thermal analysis programmes using specific measurements made in representative conditions.

j. For deployment in low temperature regions, in the absence of measured data, the following severities may be assumed to represent worst-case conditions at switch-on for materiel in enclosed compartments of which the skin surfaces are better radiators of heat to the night sky than the ambient air is to the materiel:

Area of Deployment (Climatic Category)*	Induced Temperature (°C)
C0	-21
C1	-33
C2	-46
C3	-51
C4	-57

*See Leaflet 2310/1

k. Severities may be alleviated by the on-board environmental control system during long-term ground running and/or heat dissipated by operational equipment.

2.2. Humidity

2.2.1. High Humidity

a. Dependent on the provision or otherwise of natural or artificial ventilation, levels of relative humidity in enclosed areas of the vehicle may exceed those of local ambient. Diurnal temperature cycles may induce a reduction in air pressure inside the vehicle, causing a pressure differential across the walls of the enclosure or temporary cover, encouraging the breathing-in of external moist air. Some of the moisture is liable to be retained if the enclosure is not sufficiently ventilated when the temperature rises and airflow is reversed. Such conditioning is particularly applicable to materiel installed on vehicles deployed in open spaces in wet tropical regions of the world. In addition to the indirect effects of solar heating, the effect may be aggravated by the heat given off by installed equipment. The operational pattern of the vehicle and the duty cycle of installed equipment may temper or further aggravate the effects. Dew-point temperatures inside the enclosed areas may increase with the number of temperature cycles, such that conditions approaching saturation eventually occur.

b. In the absence of specific information, severities of temperature and high humidity given in Leaflet 2310/1 for Transit and Storage for Category B conditions should be assumed to represent worst-case conditions during non-operational phases of deployment. Levels of relative humidity (RH) during operational phases will depend on the provision of natural and forced air cooling and heat and moisture dissipated by installed equipment.

c. Individual items of materiel deployed or installed on the vehicle are liable to experience a similar pattern of induced breathing and retention of moisture. Internal temperatures of unventilated, partially sealed, heat-dissipating equipment are liable to cause even greater pressure differentials. In the case of externally mounted materiel, the situation will be aggravated by the indirect effects of solar heating. Dew point temperatures are liable to rise and conditions approaching saturation may occur with an increasing number of diurnal cycles.

d. When deployed in vehicles in dense jungle or under overcast conditions in wet tropical regions, diurnal variations will be far less pronounced. Once temperature-stabilised, moisture penetration will be more by absorption than induced pressure differentials and by natural or forced-air circulation. These more constant conditions are more likely to favour mould growth and corrosion by acidic deposits. Equipment containing refrigeration systems will be particularly susceptible to condensation throughout a 24-hour period.

e. Worst-case operational conditions in wet tropical regions are likely to be at switch-on, especially if that occurs during the low temperature phase of the diurnal cycle. As systems warm up, conditions will tend to stabilise and levels of RH will probably decrease with heat dissipated by operational equipment. Exceptions to the latter may be where the vehicle is associated with services that generate moisture such as field kitchens and laundries. Conditions during continuous (24 hour) operation may be characterised by the diurnal ambient cycle. The latter is liable to be less evident when deployed in dense jungle areas where diurnal variations are less pronounced.

2.2.2. Low Humidity

When deployed in vehicles in hot, dry regions of the world, heat generated by operational equipment is liable to result in exceptionally low levels of relative humidity within compartments and enclosures of individual items of materiel. Relative humidities of less than 30 percent are common for naturally occurring conditions in hot desert regions. Leaflet 2311/2 quotes recorded values of RH as low as 3 percent, therefore similar levels may be assumed to occur inside confined areas in which there are sources of dissipated heat.

2.3. Air Pressure

Materiel is liable to experience air pressure above local ambient when installed in internal compartments of military vehicles which employ overpressure to prevent contamination of vehicle compartments by ingress of the external atmosphere during periods of chemical and biological exposure. Values of overpressure for particular applications should be determined by reference to Operational and Environmental Requirements documents or the vehicle manufacturer.

2.4. Icing

Materiel fitted on external surfaces of land vehicles will experience icing arising from direct exposure to meteorological conditions. Some level of icing may be experienced by materiel fitted on internal surfaces of the panels forming the outer walls of vehicle compartments. Diurnal cycling about the freezing point may result in alternate freezing and thawing of accumulations (possibly hidden pockets) of moisture condensed out of the atmosphere inside the vehicle.

2.5. Dust and Sand

a. Materiel mounted on external faces and inside compartments of military vehicles are liable to be subject to mechanically generated dust and sand-laden atmospheres. While worst-case conditions will occur in desert regions, some level of contamination can be expected wherever military vehicles are operated over dry surfaces composed of small loose particulate material. The heavier particles thrown up by vehicle tracks and wheels are likely to be found up to around one metre above the surface and quickly return to the ground, while fine dust can remain suspended in the atmosphere at higher altitudes for days.

b. Externally mounted equipment up to wheel height may be subjected to conditions simulating windblown dust and sand thrown up by the wheels and tracks of the host or other vehicles operating in the area. Similar conditions may be experienced by externally mounted materiel fitted at higher levels on land-based vehicles that are within the range of wind-blown dust and sand artificially generated by aircraft propulsion systems (including rotary wing aircraft).

c. As in the case of naturally created conditions, the finer dust particles are likely to be found in suspension especially where turbulent airflows exist. They may penetrate seals and interfaces, and/or settle on surfaces of materiel installed in internal compartments.

d. The characteristics of dust and sand-laden atmospheres, including the distribution and physical characteristics of particulate and the levels of concentration associated with the operation of military vehicles, are given in Leaflet 2311/3.

2.6. Immersion, Precipitation, and Spray

a. Materiel may be subject to dripping water as a result of condensation formed when cold overhead surfaces meet warm moist air, for example materiel carried on vehicles fitted with air conditioning systems, when used in temperate and tropical regions.

b. Materiel required to remain in-situ is liable to wetting when pressure-fed devices are used in cleaning and de-icing operations of the vehicle.

c. When vehicles are required to negotiate water, externally mounted materiel is liable to experience partial or total immersion, dependent on the depth of water and the location (height above ground) on the vehicle. Some level of immersion may be experienced by internally fitted materiel dependent on the efficiency of sealing of doors and hatches. Circumstances are infinitely variable and waterproofing requirements such as depths and durations of immersion and expected levels of survival or subsequent operation should be specified in Environmental or Operational Requirements documents.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

3.1.1. High Temperature

Examples of the potentially damaging effects or faults resulting from high temperatures are as follows:

a. Reduced strength and increased elasticity of materials, causing overload.

b. Dimensional changes and differential thermal expansion of structural and mechanical components, causing:

- Distortion and failure of structural components.
- Binding and seizure of moving parts.
- Failure of bonded joints.

c. Dimensional changes and permanent sets in gaskets and seals reducing sealing efficiency.

d. Melting and exudation of non-metallic materials; the latter is possibly a result of (b) and (c) above.

e. Unintentional functioning of thermally activated devices.

f. Changes in characteristics of shock and vibration isolation systems.

g. Overloading performance of cooling systems, resulting in:

- Changes in the characteristics of electrical/electronic components.
- Failure of internal connections of electronic components.
- Degraded performance or failure of electrical/electronic systems.

h. Buildup of static electricity especially where humidity is low.

i. Accelerated ageing and cracking, crazing, or discoloration of protective finishes.

j. Increased burning rates of explosives and propellants.

k. Reduced viscosity of lubricants and efficiency of lubrication systems.

3.1.2. Low temperature

Examples of the potentially damaging effects or faults caused by low temperatures are as follows:

a. Embrittlement and reduced elasticity of materials (especially non-metallic), reducing resistance to mechanical shock.

b. Static fatigue of restrained glass.

c. Dimensional changes and differential thermal contraction of structural and mechanical components, causing:

- Distortion and failure of structural components.
- Seizure of mechanical systems.
- Failure of bonded joints.

d. Changes in characteristics of shock and vibration isolation systems.

e. Reduced performance of batteries.

f. Changes in characteristics of electrical/electronic components leading to:

- Failure of external connections and internal joints of electronic components.
- Failure or degraded performance of electrical/electronic systems.

g. Increased viscosity of lubricants reducing performance of mechanical systems.

h. Reduced burning rate of explosives and propellants.

3.2. Humidity

Reference 1 of Annex A gives advice on the protection of materiel from the effects of moisture-laden atmospheres. The effects on materials, achieving and maintaining dry enclosures, standards and methods of sealing, water vapour barriers, and drying-out procedures are addressed.

3.2.1. High Humidity

Examples of effects of exposure to damp heat are as follows:

a. Swelling and general deterioration of materials due to absorption of water causing:

- A reduction in mechanical strength.
- Degraded performance of electrical/electronic components.
- Increased weight.

b. Absorption and adsorption of moisture reducing insulation resistance causing unwanted low resistance paths in electrical/electronic circuitry.

c. Failure or degraded performance of electrical/electronic systems and components due to items a and b.

d. Galvanic corrosion of metallic parts and components especially in areas of high strain.

e. Creation of micro-environments caused by entrapped moisture encouraging localised (and often hidden) areas of chemical and biological attack.

f. Contamination of lubricants by corrosion products.

3.2.2. Low Humidity

Examples of the effects of very low humidity are as follows:

a. Excessive drying out, resulting in reduced performance of some materials.

b. Changes in characteristics of electrical/ electronic components affecting the stability and accuracy of electronic systems.

c. Tracking and reduced insulation especially when combined with dust deposits.

d. Excessive friction and electrical losses in commutators and slip rings resulting in increased temperatures and brush wear.

3.3. Pressure

Levels of overpressure used to seal vehicle compartments are benign. However, pressure-sensitive materiel designed to respond to small changes in pressure, and walls of partially sealed containers with leakage rates lower than induced rates of change of pressure, may suffer temporary or permanent damage or distortion.

3.4. Icing

Icing, frosting or freezing of trapped moisture may result in blockage or seizure of affected mechanical and electro-mechanical systems.

3.5. Dust and Sand

Examples of effects and faults caused by dust and sand are as follows:

a. Blockage of apertures; reduced efficiency of ventilation and cooling systems.

b. Scratching and etching of lenses, transparent panels, and surface finishes, causing:

- Impaired performance of optical systems.
- Corrosion of exposed underlying materials.

c. Seizure of mechanical devices.

d. Deposits on electrical/ electronic systems, causing:

- Buildup of static electricity.
- Introduction of unwanted low resistance paths.
- Failure or degraded performance.

e. Contaminated lubrication systems.

3.6. Immersion, Precipitation, and Spray

The effects of dripping water and partial immersion will depend on the watertightness of vehicle doors and hatches and protective cases of installed materiel. Moisture accumulated internally may be retained dependent on the provision or otherwise of suitable drainage facilities, the effects of which are likely to be similar to those already listed in Paragraph 3.2.1.

4. TEST SELECTION

4.1. General

a. AECTP-300 gives test procedures that may be used for simulating climatic environments that may be experienced by materiel deployed on, or installed in, land-based vehicles. The choice of test method for temperature and humidity will depend on whether there are any requirements to simulate diurnal variations including the heating effects of solar radiation or steady-state conditions.

b. The characteristics of the materiel and previous experience of the response of similar types of materiel to real-life conditions (e.g., the effects of thermal cycling on explosives and propellants) may also influence the choice of test procedure. Careful consideration of the configuration of the test specimen, within its enclosure where applicable, is required when simulating the effects of solar heating. Test procedures that apply steady state conditions are likely to be relevant to materiel required to spend periods in areas where temperature and levels of humidity are determined by dissipated heat from power supplies and operational equipment.

c. Preferably, test severities should be derived from specific measurements made on the intended vehicle during representative worst-case conditions expected in service. Alternatively, severities derived from data obtained for other situations in similar applications may be used.

4.2. Test Severities

4.2.1. Temperature and Humidity

a. Test severities used in the simulation of induced temperature (and humidity) conditions should be based on information given in Operational and Environmental Requirements documents. This information should include the geographical areas where the materiel is likely to be deployed, and the detailed logistical requirements for the materiel. It is preferred that test severities should be derived from specifically measured data including the influence of any form of conditioned or non-conditioned enclosure such as a temporary shelter. Test severities derived from measured data should include the expected worse-case climatic category conditions.

b. In the absence of measured data, test severities should be based on information given in Operational and Environmental Requirements documents such as the intended geographical areas of deployment, the type of vehicle, and the location on the vehicle. Temperatures given in Leaflet 2311/1 for external ambient (meteorological) and Leaflet 2310/1 for induced (transit and storage) in Hot-Dry (Category A), Hot-Humid (Category B), and Cold (Category C) regions should be assumed to be the worst-case conditions while the vehicle is non-operating. The quoted values of temperature are those which are likely to be attained or exceeded in the hottest/coldest locations in the climatic category for 1 percent of one month of the hottest/coldest period of the year. Additional data and guidance are given in Leaflet 2311/2 and Leaflet 2310/1 to enable the severities for 5 percent and 10 percent occurrence to be derived.

c. Preferably high temperatures inside compartments when the vehicle is in the operational mode should be derived from recorded data in simulated worst-case operational conditions. Alternatively, temperatures should be assessed taking into account indirect effects of external ambient conditions, the form and level of ventilation, and heat dissipated by vehicle systems such as engine compartments, power generators, and installed equipment. Information should be sought from the vehicle manufacturers and vehicle system design authorities. For an individual materiel, location on the vehicle should also be taken into account (i.e., the influence of an air flow or a stagnant area).

d. Where the capacity of the test facility allows, test severities representative of meteorological conditions, including radiative heating, may be applied to a simulated structure or enclosure containing the test item(s). Preferably, the enclosure should stand on a surface with the same reflective properties as those on which it will stand in Service. Alternatively, the test item(s) should be subjected to the diurnal temperature cycle derived from data measured inside the confined space, or the relevant Category A (for dry heat) or Category B (for heat and humidity) diurnal cycle for transit and storage given in Leaflet 2310/1.

e. Where it is required to test materiel to induced high temperatures when diurnal variations are so small as to have an insignificant effect on the materiel, or where it is considered that the response of the test specimen or its component parts are not related to temperature cycling, constant high temperature may be used.

f. In many cases, testing materiel for exposure to induced low temperatures will be satisfied using constant low temperature. In those cases where low-temperature cycling is considered more appropriate, a low-temperature diurnal cycle test should be used. Typical examples include materiel containing explosives or seals and other components that need to be representatively stressed. The diurnal temperature cycle should be derived from specifically measured data, or the relevant Category C diurnal cycle for transit and storage given in Leaflet 2310/1.

4.2.2. Air Pressure

Where it is required to simulate low air pressures experienced by materiel on vehicles, the relevant procedure of AECTP-300 Method 312 should be used. Test severities should be matched to the particular application. Reference should be made to Operational and Environmental Requirement documents

4.2.3. Dust and Sand

a. Where it is required to determine the effects on vehicle mounted materiel to exposure to dust and sand-laden atmospheres, AECTP-300 Method 313 should be used. Materiel directly exposed to mechanically blown dust and sand should be tested to the Blowing Dust or Blowing Sand test.

b. The concentration, air velocities and duration of exposure should be selected from the listed severities in accordance with the guidance given in Method 313. Any attempt to tailor test severities to specifically measured data for the Dust and Sand test is unlikely to be cost effective.

c. The Blowing Dust method should be used for materiel installed in partially sealed compartments or those which are likely to be opened for routine inspection and maintenance.

d. If the effects of static electricity are thought to be significant (see paragraph 3.4) advice should be sought on an appropriate test method and severity.

4.2.4. Immersion, Precipitation, and Spray

a. Where it is required to determine the effects of immersion on materiel, AECTP-300, Method 307 should be used. The depth and duration of immersion for a particular test item (measured from the highest point on the specimen to surface of the water) will be determined by its position on the vehicle and the maximum depth of water which the vehicle is required to negotiate.

b. Determination of the performance of materiel when subjected to spray and splashing may be satisfied by testing for the effects of natural precipitation (e.g., driving rain or drip-proofness) (AECTP-300, Method 310).

c. Confirmation of the sealing efficiency of hatches and protective covers of externally fitted materiel may be satisfied by AECTP-300, Method 310, “Driving Rain”, conducted to determine the effects of exposure to natural forms of precipitation. The Drip test may be used to determine the effects of dripping water from overhead surfaces.

ANNEX A

REFERENCES AND BIBLIOGRAPHY

A.1. REFERENCES

1. Review of Climatic Protection Techniques for Electronic Equipment; E. Napper, Procurement Executive, Ministry of Defence, RSRE Malvern, Worcs, RSRE Memorandum No. 3530.

2. DEF STAN 01-5 Fuels, Lubricants and Associated Products.

3. DEF STAN 00-3 Issue 3 Design Guidance for the Transportability of Equipment.

4. BS 2011 Part 2.1R (IEC 60068-2-18) Test R Water and Guidance.

A.2. FURTHER READING AND BIBLIOGRAPHY

Further information on the environmental conditions addressed in this leaflet and the effects on materiel may be found in other leaflets in AECTP-230, Section 231.

SECTION 236/237
LEAFLET 236/237/1
DEPLOYMENT ON AIRCRAFT

TABLE OF CONTENTS

SECTION 236/237
LEAFLET 236/237/1
DEPLOYMENT ON AIRCRAFT

1. GENERAL

This leaflet addresses the climatic environments that may be experienced by materiel when deployed or installed on fixed-wing aircraft and on helicopters. Characteristics of the induced climatic environments are presented, discussed, and supplemented by data sheets. Also, advice is given on potential damaging effects and treatment options. Where relevant, appropriate AECTP-300 Test Methods are identified.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS

2.1. Aircraft Parked

2.1.1. Temperature

a. High temperatures inside unventilated compartments are likely to exceed local ambient temperatures due to the indirect effects of solar radiation on the aircraft skin and through transparent panels. The latter may be particularly significant for those types of helicopters for which a comparatively large area of the skin of the cockpit is transparent. Materiel and components contained in carried stores will be affected similarly. Externally fitted materiel shaded by the aircraft structure may still be subject to radiation reflected off the parking apron or landing pad.

b. The relative angle of elevation between the source and exposed surface, the prevailing cloud cover, the heat capacity of the exposed structure, its colour and surface finish, and the duration of exposure will contribute to the amount of heat absorbed and the induced temperature of enclosed areas. It is possible for extreme values of ambient air temperature and solar radiation to occur on the same day, but experience shows the probability of this happening is low.

c. Test conditions, therefore, should be determined from specific measurements for the particular application. Results from Sea Harrier FRS MK1 hot weather trials (Ref. 1) suggest that equipment bay temperatures would stabilise approximately 20 °C above the external ambient air temperature. Temperatures of 85 °C or higher have been used to represent worst-case conditions inside cockpits or other areas behind transparent panels.

d. Results from hot weather trials on a helicopter suggest that equipment bay temperatures would stabilise approximately 20 °C above the external ambient air temperature. Temperatures up to 85 °C or greater have been used to represent worst-case conditions inside cockpits or other areas behind transparent panels.

e. The skin of the flight platform is likely to be a better radiator to the sky than is the ambient air during hours of darkness. For materiel deployed on aircraft operating in cold regions, it should be assumed that non-heat-dissipating materiel installed in enclosed compartments may experience low temperatures similar to those given for Storage and Transit in the appropriate Category C climatic areas.

f. Induced low temperatures in un-powered parked aircraft may be assumed to be no more severe than those of the local conditions for storage and transit.

2.1.2. Humidity

a. Materiel fitted inside unventilated equipment bays and similar areas of air-carried stores deployed on parked, un-powered aircraft are likely to experience high levels of humidity. This is particularly applicable at airfields in hot, wet tropic regions, where the diurnal cycle (characterised by high temperatures during the day and low temperatures at night) produces variations of pressure in partially sealed, unventilated compartments. Pressure variations induce the breathing-in of moisture, some of which is retained when the high temperature is restored. If the aircraft remains idle and compartments remain closed, or if areas susceptible to ingress are protected by unventilated temporary covers, there is likely to be an accumulation of moisture.

b. During the hotter part of the diurnal cycle, especially when external surfaces, skins, or compartment covers are subjected to solar radiation, equipment or components within may experience levels of damp heat in excess of the external ambient conditions. The accumulation of moisture automatically leads to a higher dew-point temperature and, therefore, to a greater likelihood of saturation occurring during the lower temperature part of the cycle.

c. Preferably, test severities should be derived from data obtained on the intended flight platform while located in the expected geographical area of deployment. In the absence of measured data, it should be assumed that conditions will be the same as those given for Transport and Storage conditions for Category B climatic areas.

d. Moisture is likely to be formed on external and internal surfaces of materiel during flight sorties as a result of the transfer between prevailing temperatures at ground level and flight altitude and vice-versa, especially when operating into and out of airfields in sub-tropic or tropic regions. Warm air in the compartments and individual items of equipment mixes with lower temperature ambient air during the climb to altitude. Also, when cold surfaces meet relatively warmer air during descent and landing, moisture condenses out as the air temperatures are reduced below their respective dew points. In the latter case, conditioning is aggravated by the change in air pressure forcing in warm damp air. It should be assumed that RH levels in conditioned compartments will reach 90–95 percent, while in unconditioned compartments, saturation will occur.

2.1.3. Air Pressure

a. While on the airfield, materiel deployed on aircraft normally will experience air pressures equal to those of local ground ambient with the exceptions given below.

b. Materiel fitted in aircraft compartments that are pressurised during flight may be required to remain in-situ while subject to routine ground pressurisation tests to determine the integrity of seals. Where applicable, the value of overpressure likely to be experienced should be agreed between the aircraft manufacturer or operator and the design authority for the installed materiel.

2.1.4. Icing

Icing of materiel deployed externally on aircraft while static on the airfield normally arises entirely from the prevailing meteorological conditions at ground level.

2.1.5. Dust and Sand

Operation and ground movement of other aircraft, especially with vertical and/or short take-off and landing (VSTOL) or hover capability, are likely to generate considerable accumulations of turbulent and driven dust, particularly when deployed in hot, dry desert regions. To a lesser extent, the wheels and tracks of land-based vehicles also generate clouds of dust and sand. Severities of concentration and distribution of particles above ground level depend on the same factors as for naturally occurring dust and sand clouds.

2.1.6. Erosion by Impact

Erosion of materiel fitted externally on parked aircraft will be limited to that caused by natural precipitation, windblown and vehicle generated dust and sand. The levels of damage that can arise are usually of less concern than damage levels that can occur during flight.

2.1.7. Immersion and Spray

a. If materiel is mounted at low positions on the aircraft (e.g., on undercarriages or appendages close to the ground) and it is possible that the aircraft may be required to be parked on airfields or temporary landing pads susceptible to flooding or accumulations of water, consideration may be given to the possibility of the materiel being partially or totally immersed.

b. Materiel deployed externally on the aircraft may be subject to pressurised spray when the aircraft is hosed down during cleaning or de-icing operations in preparation for flight.

2.2. Ground Running

2.2.1. Temperature

a. When power is applied either directly from the engine or from external supplies, onboard environmental control systems will distribute conditioned air to some compartments of the aircraft and to any aircraft carried stores to alleviate the effects of environmental conditions. At initial switch-on, external ambient air is drawn in and distributed around the aircraft before the system has had time to become effective. When deployed in cold regions, materiel in conditioned compartments may experience an initial higher rate of cooling than would be expected from warmer ambient air. As ground running continues, the environmental control system becomes effective and, in cold regions, materiel begins to benefit from any self-generated heat and that is given off by other systems and equipment. During long term ground running in hot regions, the combined effect of heat radiated from adjacent structures and operational equipment may tend to counteract the effects of the conditioned air.

b. Temperatures inside aircraft compartments and externally carried stores during ground running depend on the external ambient air temperature, equipment packing densities, the heat radiated from adjacent structures, heat given off by operational equipment, the level of any conditioning and the period of operation. Characteristics of the conditioned air supplied by the aircraft environmental control system should be obtained from the aircraft manufacturer.

c. Data on induced temperatures should be derived from measurements made at the intended location of materiel on the flight platform during representative worst-case conditions.

d. Historically, where specifically measured data have not been available, maximum switch-on temperatures for materiel carried in both conditioned and non-conditioned areas of aircraft deployed in hot, dry regions have been taken as equivalent to maximum values of the storage and transit diurnal cycle. For materiel subject to solar radiation when located behind transparent surfaces, switch-on temperatures of 85 °C are assumed for fixed-wing aircraft, and 90 °C for helicopters. For long-term ground running in hot, dry regions and where characteristics of cooling air are unknown, ambient temperatures in conditioned compartments are assumed to stabilise at 15 °C lower than at switch-on. While it may be assumed cockpit canopies, access doors and panels will have been open for a period sufficient to allow external ambient air to have an alleviating effect (dissipating heat from operational equipment), temperatures at switch-on should be assumed to prevail in non-conditioned areas. Where such areas are behind transparent panels, a temperature of 70 °C should be assumed. For externally carried stores in which packing densities of heat dissipating equipment are likely to be greater than that in aircraft compartments, final temperatures and rates of increase are likely to be in excess of those given above. Indeed, long-term ground running without forced-air cooling should be avoided in hot, dry regions, otherwise permanent damage or degraded reliability is likely to occur.

e. Internal high temperatures of individual materiel will depend on similar factors to those discussed above. Packing density and heat dissipation of components, the thermal paths to external surfaces, and the incorporation of cooling systems will influence temperature severities. Where internal ambient temperatures or those of individual components are of concern, they should be estimated using thermal analysis programs incorporating the severities given above and supported by specific measurements made in representative conditions.

f. For deployment in low temperature regions, in the absence of measured data, the following severities may be assumed to represent worst case conditions at switch-on for materiel in enclosed compartments of which the skin surfaces are better radiators of heat to the night sky than is the ambient air:

Area of Deployment (Climatic Category)	Induced Temperature (°C)
C0	-21
C1	-33
C2	-46
C3	-51
C4	-57

g. Severities may be alleviated by the on-board environmental control system during long-term ground running and/or heat dissipated by operational equipment.

2.2.2. Humidity

a. When materiel is intended to be used in warm, damp atmospheres or wet tropical regions, in the absence of measured data, it should be assumed that the conditions will be similar to those for Transit and Storage in Category B climatic areas.

b. It may be assumed that when engines are running or aircraft systems are operating from external power supplies, canopies and hatches will be open and air conditioning systems will be operating, providing ventilation and a reduction in the level of moisture of the atmosphere in the previously closed compartments. The relative humidity inside installed equipment with semi-sealed, unventilated enclosures will be reduced gradually by self-dissipated heat, although moisture content is unlikely to be reduced. When power is switched off and the equipment cools, the differential air pressure on either side of the walls of the case may cause the enclosure to breathe in external air and increase the level of retained moisture.

c. For externally carried stores, especially when deployed on aircraft operating in wet tropic regions, the variation in temperature of the internal atmosphere resulting from operation of the equipment, may have a similar effect.

d. Materiel deployed or installed on aircraft operating in hot, dry regions of the world, may experience extremely low levels of humidity when subjected to the indirect effects of solar heating or when located close to sources of dissipated heat during ground running. Electrical/electronic systems with high packing densities, on-board air-carried armaments and stores subject to ground running may be affected similarly. No recorded data are readily available for such induced dry atmospheres. Relative humidity of less than 30 percent is common for naturally occurring conditions in hot, dry regions of the world. Therefore, equivalent or lower levels of RH may be assumed to occur inside nominally dry aircraft compartments or similar areas of individual materiel subjected to induced high temperatures.

2.2.3. Air Pressure

See paragraph 2.1.3.

2.2.4. Icing

Icing of materiel deployed externally on aircraft while static on the airfield normally arises entirely from the prevailing meteorological conditions at ground level. Icing may be counteracted by on-board de-icing systems during ground running.

2.2.5. Dust and Sand

When the host aircraft is ground running on airfields in hot, dry desert regions, on temporary landing strips, or any other areas where there may be accumulations of small particulate materiel, the backwash from propellers, the efflux from jet engines, or the downwash from helicopter rotors can produce considerable concentrations of air-borne dust and sand. Helicopters can be enveloped in dense clouds of dust or sand. Areas forward of jet tail pipes are also vulnerable if reverse thrust mechanisms are exercised during engine runs. In the absence of specifically measured data, severities should be considered to be equivalent to naturally occurring dust and sandstorms for the duration of the events.

2.2.6. Erosion by Impact

See paragraph 2.1.6.

2.2.7. Immersion, Precipitation, and Spray

See paragraph 2.1.7.

2.3. Flight Sorties

2.3.1. Temperature

2.3.1.1. Fixed-Wing Aircraft

a. Temperature levels:

(1) Materiel installed inside aircraft compartments may be subjected to high ambient temperatures due to heat given off by engines and auxiliary power units, engine exhaust systems, avionics, and electrical equipment or due to being located in a stagnant area such as an equipment rack or behind an instrument panel. The cooling efficiency of materiel located in partially or non-conditioned compartments may be affected by lower density air at flight altitude and may cause operating temperatures to rise to unacceptable levels.

(2) Stabilised low temperatures experienced by materiel in unconditioned compartments of aircraft and externally carried stores (not subject to aerodynamic heating) may be assumed to correspond with the ambient air temperatures at flight altitude given in the tables of reference atmospheres (e.g., Table 1 of AECTP-300 Method 317).

b. Aerodynamic heating:

(1) Materiel located in forward compartments and close to leading edges of high-performance aircraft and similar areas of externally carried stores, can be subjected to high temperatures caused by aerodynamic heating during air-carriage at supersonic speeds. The amount of heat generated in the airframe is determined by the “recovery temperature” and the heat transfer coefficient (i.e., the ability of the boundary layer to transfer heat to the structure), which in turn depends on properties of the material forming the skin and the temperature and characteristics of the air at flight altitude. Temperatures produced in the airframe are determined by structural details or thermal paths that allow any radiative or conductive exchange of heat between the structural elements and the internal atmosphere, and the distance from the “stagnation point” (i.e., the point immediately in front of the forward surface or leading edge at which the air is brought to rest). If aerodynamic heating is a transient condition, the body temperature also will depend on thermal capacity (i.e., whether it is “thick” or “thin-skinned”). The temperatures experienced by installed materiel will depend on the heat transfer coefficient of the attachment to the airframe and the amount of heat absorbed by the surrounding air.

(2) Periods of aerodynamic heating will depend on the performance of the host aircraft and mission and flight profiles.

(3) A basis for estimating temperatures in enclosed compartments is given in Annex A to this chapter. Where possible, estimates should be supported by measured data.

2.3.1.2. Helicopters

a. Temperature levels:

(1) High temperatures may be experienced by installed materiel during flight as a result of being located in close proximity to main or auxiliary power units, jet pipes, electrical/electronic equipment dissipating heat, and/or being located in a semi-stagnant area. Estimation of induced high temperatures is a complex process and should be substantiated by measurement during flight trials in representative worst-case conditions.

(2) Stabilised low temperatures experienced by materiel installed in unconditioned compartments of aircraft and air carried stores may be assumed to correspond with the ambient conditions for the flight altitude given in standard tables. Information regarding low temperatures that may be experienced by materiel installed in conditioned compartments should be sought from the airframe manufacturer. Where applicable, adjustments should be made for heat dissipated by operational equipment (e.g. Table 1 of AECTP-300 Method 317).

b. Rates of change of temperature:

(1) For fixed-wing aircraft, transition times (between ambient temperatures at ground level and flight altitude and vice-versa during take-off and landing) are likely to result in materiel in non-conditioned areas being subjected to rapid rates of change of temperature. Even faster rates of change over a wider range of temperature extremes are likely to occur when materiel is subjected to aerodynamic heating during short-burst, high-speed manoeuvres of high-performance aircraft. In the absence of measured data, severities can be derived from knowledge of maximum rates of climb and descent for the host aircraft. Rates of change associated with dynamic heating should be determined from data obtained during representative flight trials.

(2) For helicopters, transition between temperature extremes at ground level and altitude during take-off and landing may result in deployed materiel, particularly externally carried stores, being subjected to faster rates of change of temperature than those occurring while the aircraft is on the ground. In the absence of measured data, worst-case severities may be determined from the maximum climb and descent rates of the aircraft and the maximum difference in ambient temperatures between ground level and flight altitude likely to be experienced in service.

2.3.2. Humidity

Moisture is likely to be formed on external and internal surfaces of materiel during flight sorties as a result of the transfer between prevailing temperatures at ground level and flight altitude and vice-versa, especially when operating into and out of airfields in sub-tropic or tropic regions. Warm air in the compartments and individual items of equipment mixes with lower temperature ambient air during the climb to altitude. Also, when cold surfaces meet relatively warmer air during descent and landing, moisture condenses out as the air temperatures are reduced below their respective dew points. In the latter case, conditioning is aggravated by the change in air pressure forcing in warm damp air. It should be assumed that RH levels in conditioned compartments will reach 90–95 percent, while in unconditioned compartments, saturation will occur.

2.3.3. Air Pressure

2.3.3.1. General

a. Normally during flight, materiel installed in pressurised compartments will experience air pressures ranging between local ground ambient and some lower value equivalent to that at a predetermined altitude, say 3000 m, which is then maintained above that of the external ambient pressure by an amount known as the differential pressure. Alternatively, materiel installed in un-pressurised areas will be subject to ambient air pressure at flight altitude.

b. In most cases the pressures experienced by materiel during flight sorties will vary between the ambient pressures at ground level and flight altitude, details of which may be found in Leaflet 2311/3 or international standards of reference atmospheres such as ISO 5878.

2.3.3.2. Rates-of-Change of Pressure

a. Positive and negative rates of change of pressure during flight sorties vary from those resulting from normal take-off and landing to those associated with high-speed manoeuvres such as diving and climbing to and from low-level targets or during air-combat. Rates of change experienced by carried materiel depend on aircraft performance, the flight or mission profile, and whether the materiel is carried in a pressurised or non-pressurised area.

b. Details of climb and descent rates should be obtained from the aircraft manufacturer. In the absence of manufacturer climb and descent rates, a (inclined) rate of climb and descent of 10.2 m/s (2000ft/m) should be assumed for helicopters. However, it should be noted that nominal rates of climb and descent may differ by up to 40 percent dependent on the type and/or role of the aircraft. A similar allowance may be required with regard to aircraft manoeuvres.

2.3.3.3. Rapid and Explosive Decompression

Abnormal rates of change of pressure may occur in normally pressurised compartments during emergency situations. The rate of depressurisation following failure of the pressurisation system will depend on the volume of the compartment and the initial pressure differential. In the absence of specific information regarding the size of compartments, a maximum duration of one minute should be assumed. Structural failure of the airframe may result in explosive decompression for which a maximum period of 100 msec should be assumed.

2.3.3.4. Overpressure

a. For exposed materiel on leading edges and on forward facing surfaces during normal forward flight, the pressure will exceed the local ambient pressure by an amount directly proportional to the square of the velocity of the flight platform related by the following formula:

$$p = 0.5\rho\, v^2$$

Where p = dynamic pressure in pascals
ρ = density of air at flight altitude in kg/m^3
v = velocity of the flight platform in m/s

b. Unless shielded by the aircraft structure, externally deployed materiel located close to gun muzzles and air carried weapons will be likely to blast pressure waves during gunfire and weapon launch. No data are readily available regarding characteristics of the pressure waves, but the environment is more often characterised in terms of the shock and vibration induced in the structure of the aircraft and any attached materiel.

2.3.4. Icing

a. Impact icing can occur at all stages of flight dependent on the prevailing atmospheric conditions and velocity of the flight platform.

b. Accretions of ice on frontal areas and leading edges of externally carried stores result from impact with super-cooled water droplets in rain, fog, and cloud formations that are in an unstable state, thereby freezing when subjected to mechanical shock. Impact icing depends on the impact velocity and the temperature of the impacting surface with respect to that of the water droplets, including the effect of any kinetic heating.

c. Super-cooled water droplets can exist at temperatures ranging from 0 to -40 °C. The altitudes at which this temperature band exists vary with geographical location, season of the year, and the prevailing climatic conditions. Icing at lower temperatures may arise as a result of the adherence of ice crystals. This can occur when the flight speed through clouds of ice crystals raises the temperature of frontal areas of the flight platform sufficiently to melt the intercepted crystals and cause them to adhere. Therefore, ice accretion can occur on exposed surfaces at all stages of flight dependent on the prevailing atmospheric conditions and the velocity of the flight platform.

d. Rates of ice accretion are determined by the amount of free super-cooled water per unit volume of air, drop size, and its presence in terms of rain, fog, or type of cloud formation.

e. Impact icing severity is defined as the rate of accumulation of ice in weight per unit area per unit time. However, in practice, grading is highly subjective in terms of “severe”, “moderate”, or “light.” It is suggested that “severe”, as quoted by experienced aircrews, is represented by a rate of 4g/cm^2/h.

f. Dependent on the provision or otherwise of localised drainage, accumulations of water generated are likely to be frozen by low temperatures at flight altitude. The transition between ground level and flight altitude and vice-versa may lead to the production of considerable amounts of condensation and ingress of moisture by materiel installed in partial or non-conditioned compartments. Dependent on the provision of localised drainage, a buildup of retained moisture may occur which in turn may be frozen at one or more stages of flight sorties. The severity will depend on the provision or otherwise of any conditioning on the flight platform and the prevailing ambient conditions. No data giving severity of this type of icing are readily available.

g. Close proximity to deployed systems that depend on built-in refrigeration and transfer of refrigerant, can result in adjacent equipment being subjected to deposits of ice and moisture. Operation of certain types of system may depend on built-in refrigeration equipment and the transfer of refrigerant. Close proximity to low temperature components combined with deposits of moisture may result in the formation of ice on the surfaces of adjacent equipment.

2.3.5. Dust and Sand

See paragraph 2.3.6.3.

2.3.6. Erosion by Impact

2.3.6.1. Hail

a. Meteorological conditions normally required for the formation of hail are similar to those associated with the development of thunderstorms (i.e., warm, moist, and unstable air). Larger stones are produced when powerful up-draughts and a plentiful supply of moisture prevail. However, hail sometimes forms in convective clouds that do not develop into thunderstorms. Hailstorms are found more frequently in the sub-tropics and middle latitudes where larger stones are more likely to occur over large land masses. A study on hailstorms reported that occurrence of hail is greatest between altitudes of 3000 and 6000 m (7 times that at ground level), and is very low above 14000 m.

b. Damage potential from impact with individual stones depends on the type and density of the ice and the size and impact velocity. Forward-facing surfaces and leading edges of cockpit canopies, aerial and radar housings, surveillance and tracking systems, landing and navigation lights, and wing or aerofoil sections are particularly susceptible to damage.

2.3.6.2. Rain

a. Rainfall is generally more frequent in tropic regions. Heavier rainfalls occur in mountainous regions especially where the mountain range runs parallel to the coast and intercepts on-shore, moisture-laden winds. In temperate latitudes, rain is most likely in coastal regions. Rainfall amounts are generally low inside large continental land masses. However, rainfall patterns are entirely variable both in terms of time and space, and detailed advice regarding rainfall characteristics in specific localities should be obtained from the meteorological centres. The maximum diameter of raindrops that have reached their terminal velocity is around 6 mm.

b. Factors affecting the erosion of materiel by rain include drop size, impact velocity, characteristics, and properties of materials used in the construction, shape, and surface finish of the impacted surface, and the number of drops and rapidity of impact. Repeated collisions at the same point influence the pattern of stress and erosion buildup of the impacted surface. Resistance is expressed in terms of the time required for droplets of 2 mm diameter in a simulated rainfall of 25 mm/hr and with an impact velocity of 225 m/s to produce various degrees of erosion.

2.3.6.3. Dust and Sand

Studies of dust storms in hot, dry desert regions indicate that dust remains suspended in the atmosphere for a considerable period after the storm has abated. Particles of up to 10 μm reach heights of 1500 m with an upper limit for dust of around 3000 m. The severity of erosion of frontal areas and leading edges of materiel externally deployed on aircraft operating at low altitudes over such regions depends on the impact velocity, the form and hardness of the particulate and of the material or surface finish of the impacted surface.

2.3.7. Precipitation and Spray

a. Materiel installed in partially or non-conditioned compartments of aircraft or externally carried stores is subject to precipitation by condensation formed on overhead surfaces during descent from low temperature at altitude to warmer atmospheres at ground level. This occurs especially when flying into airfields in hot, wet tropic regions of the world. Precipitation rates equal to the heaviest intensities of rain for short periods are known. Dependent on the provision or otherwise of drainage facilities within the compartment, some degree of immersion may occur.

b. Materiel located within the backwash of propellers, at low positions on undercarriages or when under-slung from pylons/launcher rails, etc., is vulnerable to spray from ground surface water or runway de-icing fluids.

c. When operating helicopters at low level over expanses of water, especially in the hover mode, externally deployed materiel is likely to be exposed to considerable amounts of spray generated by the airflow from the rotor. No records of spray rates for such events are readily available.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

a. Induced high and low temperatures experienced by materiel when deployed on aircraft can affect the physical and chemical properties of materials used in their manufacture. Expansion and contraction of structural components accompanied by reductions in mechanical strength and changes in ductility result in interference and separation between adjacent parts and impose unacceptable levels of stress and strain. Such stress and strain lead to deformation or mechanical failure. Induced variations in the characteristics of electrical/electronic components and changes in viscosity of lubricants reduce accuracy, reliability, and operating efficiency. High and low temperatures affect physical and chemical characteristics of rocket fuels. These altered characteristics may cause motors of guided weapons to malfunction.

b. Aerodynamic heating rapidly generates large temperature gradients and thermal stresses (i.e., thermal shock) in the structure of the flight platform. The rapid application of thermal stress can embrittle materials and cause more failures at lower levels of strain than would be the case with a slower rate of increase to the same severity. Although normally brittle materials are more susceptible, ductile materials can fatigue under repeated cycling.

c. Thermal shock can induce dynamic effects by modifying torsional and flexural stiffness and can modify the performance of aerofoils.

3.2. Humidity

a. Induced damp heat conditions (resulting from a combination of inadequate ventilation and enforced breathing of moisture created inside aircraft compartments, air-carried stores, and individual equipment) accelerate the degradation of materials, causing more system malfunctions than would exposure to local meteorological conditions alone. Reduction or breakdown of insulation resistance of circuitry and components can result in degraded performance, reduced reliability, or total failure of electrical/electronic systems. Performance of surveillance materiel may be reduced by misting and accumulations of moisture in optical systems.

b. Warm damp atmospheres in unventilated areas provide ideal conditions for promotion of fungal growth and aggravate attack by corrosive agents. The effects of moisture on materiel, achieving and maintaining dry enclosures, standards and methods of sealing, water vapour barriers, drying out procedures, and registering levels of humidity need to be addressed.

c. Induced low levels of humidity can influence the characteristics of electrical/electronic components and affect the calibration, stability, and accuracy of electronic systems.

3.3. Air Pressure

3.3.1. Pressure Differentials

a. Low air pressure at flight altitude and rates of change of pressure induced during flight sorties may create pressure differentials across the walls of cases and protective covers of materiel and components. Such pressure differentials may cause protective covers to deform, incur structural failure, or interfere with internal parts, and, thereby, cause malfunction of the materiel. Although materiel may be fitted with pressure equalisation devices, rates of change of pressure during flight sorties may exceed design values.

b. Materiel which relies on the density of the surrounding atmosphere for maintaining an acceptable operating temperature, may exhibit degraded performance or become unreliable due to the reduced efficiency of the cooling system while at flight altitude.

3.3.2. Cooling

Heat-dissipating materiel that relies on convection for maintaining an acceptable operating temperature may exhibit degraded performance due to the reduced efficiency of the cooling system because of lower air pressure at flight altitude.

3.4. Icing

a. Impact icing of externally deployed materiel may degrade performance of release mechanisms, linkages, actuation systems, and control surfaces, and may block apertures and impair performance of optical systems. While loading imposed by ice buildup is an important consideration, unequal distribution may be of more concern because carried stores may become unbalanced and induce unacceptable levels of compensating actions during captive flight.

b. Frosting or freezing of accumulations of moisture caused by induced variations of temperature and pressure may result in degraded performance or total failure of materiel in partial or non-conditioned areas.

c. Malfunction of materiel may be caused by frosting or freezing of accumulations of moisture produced by condensation and variations in temperature and pressure during flight sorties.

3.5. Dust and Sand

a. The effects of exposure to dust and sand-laden atmospheres at ground level include impaired performance of optical systems due to accumulations of particulates, etching, and scratching of surface finishes, corrosion of exposed underlying materials, blockage of apertures, and reduced efficiency of cooling and ventilation systems.

b. Dust deposits inside materiel are likely to cause short-circuiting of insulators, tracking and buildup of static electricity, interference between moving parts, and contamination of lubrication systems.

3.6. Erosion by High-Velocity Impact

a. During flight, impact with hail, rain, dust and sand may reduce sensitivity of tracking and surveillance systems by eroding radomes and protective covers. A significant reduction in the optical quality of aircraft windscreens has been reported after low-level flights at velocities of 290 to 320 m/s over desert areas. Etching and scratching of surface finishes may encourage corrosion of underlying materials.

b. Impact with rain, hail, and dust can result in the buildup of electrostatic charges and cause malfunction or failure of sensitive components of electronic systems.

3.7. Immersion, Precipitation, and Spray

Materiel subjected to immersion, precipitation, and spray is likely to suffer ingress of water, (including any contained contaminants), through apertures or by seepage of materials, seals, and joints, affecting structural integrity of packaging and operational performance of equipment in a manner similar to that described in paragraph 3.2, above.

4. TEST SELECTION

4.1. General

a. AECTP-300 provides test procedures that may be used for simulating induced climatic environments against which materiel may be subjected when deployed or installed on fixed-wing aircraft. Choice of test method for temperature and humidity will depend on whether there is a requirement to simulate diurnal variations, including the heating effects of solar radiation (e.g., when the aircraft is parked on the airfield) or steady state conditions (e.g., in aircraft compartments during flight sorties), or just the maximum or minimum temperatures of a diurnal cycle. Guidance is given in the relevant chapters regarding the selection of the appropriate test procedure, test severities and performance evaluation to which reference should be made.

b. Preferably, test severities should be derived from specific measurements made on the intended flight platform during representative worst-case conditions expected in service. Alternatively, severities that are derived from data obtained for other examples of materiel deployed in similar applications may be used.

4.2. Fallback Test Severities

a. If specific measurements are not available, the fallback severities in the AECTP-300 test methods should be used.

b. Values of temperature and humidity are quoted in Leaflet 2311/2 for external ambient (meteorological) and Leaflet 2310/1 for induced (Transit and Storage) conditions. In the absence of specifically measured data, values for the latter should be assumed to represent worst-case induced conditions experienced by materiel deployed on aircraft while parked on airfields and naval platforms. In the case of materiel carried in cockpits or in other areas behind transparent panels, maximum temperatures of at least 85 °C should be assumed.

c. In Leaflet 2310/1, the quoted values of temperature and humidity are those that are likely to be attained or exceeded in the most severe location for 1 percent of the most extreme month of the year (excluding C3 and C4 where it may be as much as 20 percent of the coldest month).

4.3. Tailored Test Severities

4.3.1. Temperature and Humidity

a. Temperature severities used in tests (i.e., simulating high temperature conditions during air carriage) should be derived using one or both of the following methods in descending order of preference:

(1) From specifically measured data recorded during hot and cold weather trials. Measurements should be made at the relevant location on the intended flight platform. Other factors influencing temperature severities such as sources of dissipated heat and supplies of conditioned air should be represented correctly. The trials program should include flight sorties likely to produce worst-case conditions in service (e.g., aerodynamic heating).

(2) From data for a similar application with adjustments for differences in the factors referred to in (1) above.

b. Temperature severities used in tests simulating low temperatures during air carriage may be derived from the 1 percent occurrence ambient air temperatures at altitude. In the absence of measured data, a worst-case temperature of -20 °C should be assumed in temperature conditioned compartments.

c. For materiel carried at external locations on the aircraft, rapid rates of change of temperature during transition between ground and flight altitude and vice-versa may be determined from rates of climb and descent of the flight platform and the respective temperatures at altitude and ground level for the geographical area of deployment.

d. Worst-case levels of humidity during air carriage are normally those associated with descent from altitude to ground level, especially when operating in hot, wet tropical regions. Levels of relative humidity will be close to, or actually at saturation, especially for materiel located in non-conditioned areas. Similar severities may occur inside equipment thought to be of closed construction due to the aggravating effects of varying air pressure.

4.3.2. Aerodynamic Heating and Thermal Shock

When the effects of dissipated heat cannot be predicted satisfactorily by calculation or modelling, testing to simulate the effects of aerodynamic heating during air carriage may be appropriate. Alternatively, testing for the effects of the thermal stresses induced by rapid rates of change of temperature may be more appropriate.

4.3.3. Air Pressure

a. Severities for low air pressure tests may be determined from environmental requirements documents and from performance of the host aircraft (e.g., operational altitude, rates of climb, and descent), and the provision or otherwise of pressurisation data at the location of the deployed materiel on the aircraft or flight platform.

b. When simulating ground pressure testing for materiel installed in pressurised compartments, test severities for air pressures above standard ambient should be sought from the airframe manufacturer or aircraft operator. Representative simulation of blast pressure waves from explosions, gunfire and weapon launch is achieved best by subjecting the materiel to the real-life environment.

4.3.4. Dust and Sand, Icing, Erosion, and Induced Wetting

For other environmental conditions [e.g., dust and sand, icing (induced moisture and impact), spray, etc.], it is unlikely that tailoring to specifically measured data will be cost effective. In those cases, appropriate fallback severities should be selected. For artificially created dust and sand-laden atmospheres, turbulent dust is the preferred method. Simulated windblown dust and sand may be used where artificially created dust and sand cannot adequately demonstrate penetration and erosion by sharp edged particulate. Testing for erosion by impact high velocity is usually limited to sample materials.

ANNEX A

ESTIMATION OF ENCLOSURE TEMPERATURES

A.1. Enclosure boundary

Typical features forming an enclosure boundary are the missile or aircraft skin, bulkheads forming the section of the missile or flight platform, or the walls of a cover or equipment rack. Providing sufficient parameters are known, it is possible to estimate the mean internal temperature within the boundary.

A.2. Heat transfer parameters

A.2.1. Mean-Specific Heat

Most materiel use a range of materials with widely differing specific heats. For electronic equipment contained in guided weapons with conventional structures, mean values of specific heat ranging between 600 and 1000 J/kg °C have been measured.

A.2.2. Overall Heat Transfer Coefficient

The overall heat transfer coefficient enables the quantity of heat transferred from external sources through the enclosure walls to be calculated. It is possible to calculate the theoretical coefficient itself for some applications though missile structures are normally assessed by wind tunnel experiment. The coefficient may be a total expressed in watts per °C or may be quoted in similar units per unit area of specified wall thickness. Given the higher wall surface temperature, the temperature on the opposite face of the wall may be calculated.

A.3. Heat Extracted by Forced-Air Cooling

Forced cooling facilities are often built into materiel where it is known that adversely high temperatures would otherwise exist. Blown air is normally used for this purpose and, from a knowledge of the mass flow, its specific heat, and temperature rise, the heat extracted may be calculated.

A.4. Calculation of Internal Temperatures, Symbols, and Units

The following symbols and units are used in the development of the heat transfer equation to determine the temperature profile over a particular time interval:

t_1 = enclosure outer surface temperature, °C

t_2 = mean internal temperature at start of time interval, °C

t_3 = mean internal temperature at end of time interval, °C

U = overall transfer coefficient, W/°C

θ = temperature rise, °C

m = materiel mass, kg

c = mean specific heat, J/kg °C

H = net heat input, W

H_d = heat dissipated by materiel, W

H_e = heat extracted by cooling, W

H_a = heat lost or gained to adjacent equipment, W

A.5. Equipment Inert

When the enclosure temperature is likely to be high without heat dissipated by contained equipment (e.g., due to external ambient conditions or supersonic flight) it may be useful to determine conditions inside the compartment without the contained equipment operational.

Heat taken in from external environment:

$$H = U(t_1 - t_2) \text{ watts}$$

Heat supplied = $m\ c\ \theta$ joules

Thus, internal temperature rise = $U(t_1 - t_2)/mc$ °C from which t_3 may be determined.

Thus, for materiel on the ground, values of t_3 may be plotted say at 15-minute intervals while for a missile in flight 10 second intervals against the flight profile may be more appropriate.

A.6. Equipment Operational

For heat input:

$$H = H_d + U(t_1 - t_2) - H_e \pm H_a$$

$$\text{Internal temperature rise} = (H_d - He \pm H_a)/mc + U(t_1 - t_2)/mc\ °C$$

From which t_3 may be determined and expressions developed for t_2 in terms of t_1 and t_3. It should be noted that H_d, H_e, and H_a may not be fixed quantities and may vary with temperature and/or materiel duty cycles.

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SECTION 238
LEAFLET 238/1
DEPLOYMENT ON SHIPS

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SECTION 238
LEAFLET 238/1
DEPLOYMENT ON SHIPS

1. GENERAL

This leaflet addresses the climatic environments that may be experienced by materiel when deployed on or installed in surface ships powered by nuclear or conventional means and in submarines. The characteristics of climatic environments are presented in Leaflet 2310/1. Advice is given on potential damaging effects and treatment options. Where relevant, advice on selecting appropriate AECTP-300 Test Methods is provided.

2. CHARACTERISTICS OF INDUCED ENVIRONMENTS

2.1. Above Deck on Surface

2.1.1. Temperature

a. Where no ventilation or assisted cooling is provided, high temperatures inside unventilated shelters or under temporary covers exposed to solar radiation are likely to exceed those outside of the enclosed area. Clearly the most severe conditions will occur when ship-borne materiel is installed or carried above deck in hot, dry regions of the world. The relative angle of elevation between the source and the exposed surface, the prevailing cloud cover, the surface finish, the colour, and heat capacity of the radiated surface and the duration of exposure will determine the amount of heat absorbed. The induced ambient temperature of the enclosed atmosphere will depend on the provision or otherwise of any ventilation or forced air cooling. It is possible for extreme values of ambient air temperature and solar radiation to occur on the same day, but experience shows the probability is low.

b. Information on the temperatures induced inside sheltered areas or under temporary covers above deck on surface ships is not readily available and should be determined from specific measurements for particular applications. In the absence of measured data, the temperatures given for Transit and Storage diurnal cycles should be assumed to apply. The severities for high-temperature areas on open seas (category M1, Leaflet 2310/1) tend to be around 2 °C lower than those for overland (category A1), implying the latter should be taken into account if the ship is to operate in and out of ports in those geographical regions. A similar consideration is more appropriate with regard to temperature severities for Transit and Storage in the colder regions of the seas, (M3), where temperatures may be up to 12 °C higher than those over land in the same geographical areas (C2).

2.1.2. Thermal Shock

Materiel brought on deck when the ship is operating in low temperature regions may experience changes in temperature in the order of 45 °C over a period of 2–3 minutes or less. Conversely, materiel exposed to solar radiation, could experience a change in temperature in the order of 50 °C in a similar period, if immediately after a temperature soak, it is immersed in the sea or if a submarine dives immediately after a high-temperature soak.

2.1.3. Humidity

a. Materiel installed or stored on deck in unventilated shelters or under temporary covers is likely to be subjected to induced high levels of humidity, especially when deployed in hot, wet tropic regions. Worst cases occur where the diurnal cycle is characterised by high temperatures during the day and low temperatures at night, producing corresponding variations of pressure in the covered areas, causing them to breathe in moisture some of which is retained when the external ambient temperature rises again. Solar radiation on the external surfaces of shelters or temporary covers during the hotter part of the diurnal cycle can result in enclosed equipment being subjected to a damp heat environment more severe than the external ambient conditions. The accumulation of moisture can lead to a higher dew point temperature and, therefore, the possibility of saturation occurring during the cooler part of the cycle.

b. Preferably, conditions for particular applications should be determined from specifically measured data. The levels of relative humidity may be reduced by heat from operational equipment. In the absence of measured data, the conditions for Transit and Storage for category B climatic areas given in Sections 232/1 and 233/1 should be assumed.

2.1.4. Air Pressure

Materiel installed above deck will normally experience pressures equivalent to the local ambient air pressure at sea level. Materiel may be required to survive or continue to operate following exposure to blast waves from a large-scale chemical explosion or a nuclear explosion in the lower atmosphere.

2.1.5. Icing

Materiel on open decks is likely to be subjected to accumulations of ice formed from freezing spray. The interaction of the vessel's manoeuvres and the prevailing sea conditions can increase the amount of spray generated. Rates of ice accretion of up to 40 mm/hr have been reported for ships operating in the Arctic region.

2.1.6. Immersion, Precipitation, and Spray

No measured data are readily available that indicate severities of induced forms of wetting experienced by materiel installed or carried above deck. Subjective observations indicate that materiel may experience short periods of precipitation equivalent to heavy rain and accumulations of water of depths up to 150 mm. Unprotected materiel fitted to external surfaces of submarine hulls will be subjected to total immersion when the submarine operates below the surface.

2.1.7. Hydraulic Pressure

Materiel carried on board for subsequent immersion in the sea, will be subjected to hydraulic pressure dependent on the depth of immersion defined in the design requirement for the individual equipment. Pressure is related to the depth of immersion by the following formula:

$$p = 9.8d$$

Where p is the hydraulic pressure in kPa

d is the depth of immersion in meters.

2.2. Air-Conditioned Compartments

2.2.1. Temperature/Humidity

Temperatures in air-conditioned compartments on surface ships of minesweeper (minehunter) size and above, range from 15 °C–30 °C with relative humidity ranging from 30–70 percent. Variations within those limits will depend on external ambient conditions and the amount of heat given off by operational materiel and personnel occupying the compartment, but may be considered constant once established in the climatic area of operation. In the event of an interruption in the supply of conditioned air, a temperature of 40 °C with relative humidity of 70 percent should be assumed to occur for periods of up to 20 minutes for surface ships; for submarines, a temperature of 50 °C with relative humidity of up to 100 percent should be assumed to occur for periods of up to 20 minutes.

2.2.2. Air Pressure

2.2.2.1. General

Air pressure inside compartments contained within the citadel boundary of a ship is raised above the local ambient air pressure to provide a gas tight seal against the ingress of contamination from Nuclear, Chemical, and Biological attack. The absolute pressure experienced by materiel contained within the compartment should be assumed to be the maximum value of ambient pressure likely to occur at sea, (in the order of 1060 mbar), plus the specified level of overpressure. In the absence of a specified value, a level of 8 kPa (80 mbar) should be assumed.

2.2.2.2. Air Pressure Above Standard Ambient

The level of overpressure that materiel will experience when it is required to remain installed during routine pressure testing of submarine compartments is referenced in the relevant design requirement document. Alternatively, guidance should be sought from the shipbuilder. The absolute pressure experienced by materiel should be assumed to be the maximum value of ambient pressure likely to occur at sea (1060 mbar), plus the specified value of overpressure. Absolute pressures of up to 1314 mbar (131 kPa) may be assumed to occur in submarine compartments while the vessel is submerged.

2.2.2.3. Air Pressure Below Standard Ambient

Air pressure in submarine compartments is likely to be reduced to 872 mbar (87 kPa) for periods of up to 3 hours during “snorting”. Cyclic variations inducing further reductions of up to 160 mbar (16 kPa) are likely to occur.

2.2.3. Precipitation and Spray

The levels of precipitation associated with condensation on overhead surfaces and emergencies such as fractured and leaking joints on water pipes, etc. are unpredictable. Historically, a minimum rate of 280 litres/m^2/h is used when testing materiel for compatibility with this type of conditioning, including the spray from fire sprinklers.

2.3. Partial and Non-Conditioned Compartments

2.3.1. Temperature and Humidity

2.3.1.1. Surface Ships

a. The influence of external ambient conditions on the levels of temperature and humidity in partial and non-conditioned compartments will depend on the location of the compartment within the vessel. The further the compartment is below the main deck and towards the centre of the hull, the more likely the influence of external ambient conditions will be diminished. In some cases, the heat and moisture dissipated by operational machinery will be the dominant factor such that when the vessel is operational, constant ambient conditions ranging from dry to damp heat can occur. Some conditions may be localised to particular areas of a compartment. The closer an unconditioned compartment above the water line is to the outside walls of the hull or the main deck, then the greater will be the indirect effects of solar heating of ships structure on the ambient temperature in the compartment, particularly when operating in category A climatic areas.

b. In the absence of measured data, conditions in fresh air ventilated compartments range from 15 °C–45 °C with relative humidity of 30–85 percent, but for the reasons given above, severities for particular installations should be determined from specifically measured data. Steady-state conditions in machinery compartments are quoted as ranging from 0 °C–80 °C with 30–80 percent relative humidity with abnormal excursions up to 100 °C. The higher temperatures are more likely to be experienced as a result of being attached or in close proximity to operational machinery with high surface temperatures or located in stagnant areas not served by any form of ventilation.

c. Some items of materiel may be located in refrigerated areas or close to external hatches. Unless otherwise specified, operational materiel should maintain correct operation down to temperatures as low as -10 °C and with degraded performance at temperatures as low as -30°C.

2.3.1.2. Submarines

a. In the absence of measured data, conditions in fresh air ventilated compartments should be assumed to range from 15 °C–45 °C with relative humidities of 30–85 percent. While the submarine is underwater, conditions in all compartments are essentially induced and will depend on the level of conditioning of the air supplied to the individual compartments and the heat and moisture given off by operational materiel and crew members contained within. In machinery rooms, heat and moisture dissipated by operational plants are likely to be the dominant factors. Some conditions may be localised to particular areas of the compartment.

b. Ideally, severities should be determined from data obtained at the intended location of the equipment. If measured data, are not available, severity estimates may be based on other sources. Continuous conditions in machinery rooms are quoted as ranging from 0 °C–40 °C with relative humidities of 20–80 percent plus abnormal conditions (for periods of up to 20 minutes) of up to 80 °C and RH approaching 100 percent. Continuous conditions in reactor compartments are quoted as ranging from 0 °C–60 °C and relative humidity 30–80 percent with abnormal conditions (for periods of up to 20 minutes) as for machinery rooms. Some items of materiel may be located in refrigerated areas or close to external hatches during which, unless otherwise specified, operational materiel should maintain correct operation down to temperatures as low as -10 °C and with degraded performance at temperatures as low as -30 °C.

2.3.2. Air Pressure

Ambient air pressures in non-conditioned compartments may be assumed to be equivalent to and vary in accordance with the local external ambient pressure.

2.3.3. Immersion, Precipitation, and Spray

When materiel is installed or stored in unconditioned compartments (e.g., cargo bays, aircraft hangers, garages for deck vehicles, engine and generator rooms, workshops, laundries, and galleys) there is a greater probability of materiel being subjected to some form of wetting, including in some cases the possibility of partial immersion. Severities of up to 280 litres/m^2/hr should be assumed for precipitation and depths of up to 150 mm for immersion.

3. POTENTIAL DAMAGING EFFECTS

3.1. Temperature

a. Induced high and low temperatures can affect the basic properties of materials used in the construction of materiel. Temporary or permanent changes in dimensions, reductions in mechanical strength or elasticity, chemical reaction, and variations in electrical characteristics may reduce operational performance, cause malfunction, reduce reliability, or cause total failure of systems and components.

b. Thermal shock induces high rates of expansion and contraction, resulting in stress and fracture of materials, failure of bonded joints, and degraded performance of seals.

3.2. Humidity

a. Induced damp heat conditions created inside permanent shelters or under temporary covers above deck, unconditioned compartments and individual equipment are likely to cause faster rates of degradation of materials and a higher frequency of equipment malfunction than might result from direct exposure to the external meteorological conditions. Reduction or breakdown of insulation resistance of circuitry and components is likely to cause safety hazards, degraded performance, reduced reliability, or total failure of electrical/electronic systems. Performance of optical systems may be reduced by misting and deposits of moisture on lenses.

b. Warm damp atmospheres in unventilated areas provide ideal conditions for the promotion of mould growth and aggravated attack by corrosive agents. Additional factors are the effects of moisture on materiel, achieving and maintaining dry interiors, standards and methods of sealing, water vapour barriers, drying-out procedures, and indication of levels of humidity.

c. Induced low levels of humidity may reduce the moisture content of materials used in the manufacture of electrical/electronic components, changing their characteristics, and affecting the stability that is needed to maintain performance of systems within specified tolerances. Operating efficiency of mechanical systems can be reduced due to degradation of lubricants by both dry and damp atmospheres.

3.3. Pressure

a. Sealed or partially sealed materiel with low leakage rates may be susceptible to temporary distortion or permanent mechanical damage if located in compartments employing overpressure to provide a gas tight seal. Protective covers of large items that withstand normal variations of standard atmospheric pressure may be of particular concern.

b. When subjected to hydrostatic pressure, materiel of closed construction is vulnerable to structural deformation that can impair the integrity of joints and seals and can allow ingress of water or the escape of any contained fluids and gases.

3.4. Icing

Because ship manoeuvres on the surface can influence the depth and pattern of ice formation, icing of materiel located above deck will be similar to that due to natural conditioning alone. The operation of linkages, release mechanisms, and actuation systems becomes impaired or completely blocked due to interference caused by the buildup of ice. Frosting and icing of sensors and optical devices can reduce the performance of surveillance and navigation systems.

3.5. Immersion, Precipitation, and Spray

Materiel subjected to immersion, precipitation and spray is likely to suffer ingress of water (through apertures, seals, and joints) and seepage affecting materials and operational performance of equipment in the same manner as accumulations of moisture. For materiel installed or stored in engine and generator rooms, workshops, laundries, and galleys, there is a greater probability of being subjected to some form of wetting or partial immersion due to condensation, fractures, and leaking joints on water pipes. Severities of up to 280 litres/m^2/h should be assumed for precipitation and depths of up to 150 mm for immersion.

4. TEST SELECTION

4.1. General

AECTP-300 includes test procedures that may be used for simulating climatic environments experienced by materiel when deployed on surface ships and submarines. Preferably test severities should be determined from data obtained at the location in the compartment or the area on deck in which the materiel is to be installed.

4.2. Fallback Test Severities

In the absence of measured data, the fallback severities given in the test methods in AECTP-300 should be used.

4.3. Tailored Test Severities

a. Test tailoring is the preferred method of specifying severities for temperature tests, especially when the test specimen is equipment which will be located where severities are determined by heat and moisture given off by operational equipment and for which data for naturally induced conditions are inappropriate. Ideally, data for deriving test severities should be recorded at the location on the ship at which the materiel is to be installed during simulated worse case service conditions.

b. Generally, test methods using diurnal cycles will be applicable to materiel in enclosed areas on or above deck. In many cases, conditions for materiel in compartments between decks can be simulated using test procedures that apply constant conditions. Testing for exposure to low temperatures in all areas of the ship normally will be satisfied by using test procedures that give steady state conditions. In some instances, particularly with equipment of large mass and thermal time constant comparable to or longer than the diurnal cycle, the closer realism of a cyclic test may be preferred to ensure that seals and components are stressed representatively.

c. Severities for simulating air pressure above standard ambient conditions and hydraulic pressure should be specified in the Environmental Requirement for the materiel or obtained from the builder or design authority for the ship. Representative simulation of blast pressure waves from explosions, gunfire, and weapon launch is best achieved by subjecting equipment to the real-life environment.

d. For other environmental conditions such as icing and various forms of wetting, it is unlikely test tailoring will be cost effective. In such cases, recommended fallback severities should be used.

SECTION 239
LEAFLET 239/1
AIR AND SURFACE WEAPONS

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SECTION 239
LEAFLET 239/1
AIR AND SURFACE WEAPONS

1. GENERAL

This leaflet addresses the climatic environments that may be encountered by air and land weapons, including guided missiles, bombs, and projectiles during their separation from the host platform and during their autonomous flight to the target. The sources and characteristics of the climatic environments are presented and discussed. Advice is given on potential damaging effects and treatment options. Where relevant, appropriate AECTP-300 Test Methods are selected.

2. CAUSES OF INDUCED CLIMATIC ENVIRONMENTS

2.1. General

a. Munitions are likely to be subjected to induced climatic conditions at launch and during the trajectory between the launch platform and the intended target. The induced conditions may be different or more severe than those due to prevailing meteorological conditions alone as a result of operational or tactical procedures and the method of deployment required to have the desired effect of the munition on the target.

b. Induced climatic environments experienced by munitions at launch and during the flight to target will depend on the method of execution (i.e., the motive force and control or otherwise of trajectory). The former will range from free-fall to ejection and/or explosive propulsion and gliding, continuous motorised flight or some combination of these forms of delivery. Trajectories will be determined by various methods ranging from initially set fixed parameters to partially or fully autonomous flight control systems. Also included are those munitions that, after dispatch and laying, rely on the target approaching and emitting some form of stimulation. The success rate can depend on the reaction to the climatic conditions encountered.

2.2. Temperature

2.2.1. Induced Temperatures at Launch

Characteristics and severities of temperatures due to meteorological conditions alone are covered in Leaflet 2311/2. Reference should be made to the appropriate leaflet for causes, characteristics, and effects of induced temperatures that may be experienced at separation from the launch platform (i.e., land vehicle, surface ship, submarine, fixed, or rotary-winged aircraft). In some cases, the elapsed time on the launcher will be such that the effects of the various factors that induce temperature extremes will not be fully realised. Anticipated exposure times should be determined from the Operational and Environmental Requirements documents for the weapon and the service platform.

a. Temperature of munitions at launch will depend on the following factors:

(1) The geographical area of deployment.

(2) The type of launch platform and the extent to which it exposes the munition to internal and external conditioning (e.g., underground silos, canisters, or exposed launchers on land or surface ships, enclosed weapons bays, or exposed launch rails on aircraft).

(3) The elapsed time on the launcher at the prevailing ambient conditions, including the influence of solar heating or of aerodynamic heating resulting from velocity of the launch platform.

b. Temperature of systems and components carried on or within the weapon depend on the following:

(1) The location on the weapon (i.e., ventilated or unventilated area or compartment).

(2) The indirect effects of solar heating.

(3) The provision or otherwise of any temperature control at the location of the system or component.

(4) Any heat dissipated by systems and components required to be operational prior to launch.

(5) Packing density of equipment such as electrical and electronic systems.

2.2.2. Induced Temperatures During Free Flight

2.2.2.1. General

a. Factors determining temperatures experienced by munitions during free flight include the following:

(1) Ambient air temperature along the flight path.

(2) Flight velocity.

(3) Thermal capacity of the munition.

(4) Duration of flight.

b. Temperatures of individual systems and components during free flight depend on the following:

(1) Effects of aerodynamic heating and characteristics of the thermal path within the structure of the flight platform.

(2) Proximity to heat-dissipating equipment such as propulsion, actuation, control, and guidance systems.

(3) Packing density of electrical/electronic systems.

(4) Flight duration.

(5) Flight altitude (air density).

2.2.2.2. Glide and Free-Fall Munitions

a. The flight velocities and time scales associated with the free-flight phase of glide and free-fall munitions such as bombs and air-launched underwater weapons are such that any changes in temperature due to heat lost or gained normally can be ignored.

b. An exception may be munitions that, near the end of the trajectory, loiter while searching and tracking the target, during which time temperatures may tend towards ambient air temperature balanced against any heat emissions from operational systems carried on board. The temperatures obtained will need to be determined by thermal analysis and confirmed by measurements made during flight trials.

c. The thermal influences affecting temperatures of air-launched underwater weapons between release and immersion will be similar to those for other weapons which reach the target by gliding and free-fall. In some cases, the trajectory and flight velocity may be controlled by the deployment of aerofoils and parachutes. For weapons launched from surface ships, the thermal effects of the trajectory before immersion normally will be insignificant.

d. The most significant thermal event for underwater weapons is likely to be the rate of change of temperature experienced during the transfer from air to water. Examples are as follows: dropping from aircraft into warm sea water following conditioning at the low ambient temperature at flight altitude during air carriage; launch into cold sea water from the deck of a surface ship while at high temperature induced by solar heating. For ambient temperatures at altitude, reference should be made to tables of standard atmospheres such as ISO 5878.

e. Temperatures experienced on board torpedoes when submerged after launch, will depend on the heat generated by power supplies and propulsion and control systems, the “flight time” and the heat flow out of the structure into the surrounding water. Actual severities should be determined by thermal analysis supported by measurements made during sea trials.

f. See paragraph 2.2.3 below regarding temperatures experienced by target-activated weapon systems such as land and sea mines after laying or launching.

2.2.2.3. Powered Flight/Aerodynamic (Kinetic) Heating

Rocket and turbojet propelled munitions are likely to be subjected to aerodynamic or kinetic heating caused by compressive and viscous effects when they move at high speed through the atmosphere. This has the effect of rapidly increasing the temperature of the body in a manner governed by various parameters as described in Annex A. For most practical applications (i.e., for weapons moving at supersonic speeds and with short flight times) the effect of aerodynamic heating swamps any other transitory temperature effect such as internal heat dissipation. However, in the case of projectiles such as shells, the time scales involved are such that the effects due to heat flow may be ignored.

2.2.3. Induced Temperatures in Target Activated Weapon Systems (TAWS)

a. Once laid or primed, land-based TAWS may be subject to induced temperatures greater than the surrounding ambient conditions especially in hot, dry tropical regions. Weapons placed under unventilated cover (including the topsoil, etc., forming the surface of the ground), or inside enclosures exposed to solar radiation, are likely to experience temperatures of up 20 °C or more above local ambient. Higher temperatures may occur if the item used to cover the weapon comprises transparent material, typically 85 °C–90 °C in hot, dry regions.

b. When submerged, temperatures of sea mines, sonar, and surveillance systems will stabilise at those of the surrounding seawater. In the case of pre-laid torpedoes, temperatures during “flight” will depend on the heat generated by power supplies and propulsion and control systems, the “flight time” and the heat flow out of the structure into the surrounding water. Actual severities should be determined by thermal analysis supported by measurements made during sea trials.

2.3. Humidity

2.3.1. Induced Humidity at Launch

Factors affecting the levels of humidity experienced by munitions, sub-systems and components at launch are similar to those for temperature given in paragraph 2.2.1.1 above. Severities and effects of natural conditions are covered in Leaflet 2311/2. Reference should be made to the appropriate section of this AECTP for induced levels of relative humidity dependent on the launch platform (i.e., land based, surface ship, submarine, fixed-wing aircraft, or rotary-winged aircraft). In some cases, the period on the launcher will be such that the full effects of the various influences will not occur. Anticipated exposure times should be determined from the Operational and Environmental Requirements documents for the weapon and service platform.

2.3.2. Induced Humidity During Flight

For air to air and air to surface weapons, any changes in humidity in compartments of munitions during flight are likely to be linked to induced temperatures. Heat dissipated by on-board systems and components and/or that due to kinetic heating is likely to reduce relative humidity inside compartments. The potential for an increase in relative humidity (RH) levels exists where moisture is contained in any gases given off by propulsion systems and batteries that provide electrical power. Normally, the effects of changes in humidity during this phase are regarded as insignificant.

2.3.3. Induced Humidity in Deployed Underwater Weapons

a. The relative humidity inside sections and compartments of mines and torpedoes launched from surface ships may change on immersion due to the overall change in temperature of the weapon when transferred from air to water. Areas containing systems and components particularly sensitive to humidity may be filled with dry gas.

b. Subsequent changes in relative humidity inside compartments of sea mines are negligible. Humidity inside torpedoes during “flight” may be increased by moisture contained in gases given off by batteries powering propulsion systems. The effect may be reduced where compartments are charged with a dry inert gas and/or balanced by heat generated by power supplies and operational systems on board.

2.3.4. Induced Humidity in Deployed Target Activated Weapon Systems (TAWS)

When TAWS are laid under unventilated cover especially in open areas in hot wet tropical regions, solar heating of the cover or enclosure may induce levels of relative humidity in excess of the ambient conditions. Pressure differentials created by the diurnal variations in temperature encourage moisture to be breathed in and accumulated, gradually raising the dewpoint which could result in saturation occurring during the cooler phases of the cycle.

2.4. Air Pressure

2.4.1. Air Pressure at Launch

Levels of ambient air pressure experienced by munitions at launch and inside unsealed compartments, systems, and components will be determined by the type of launch platform (i.e., land based, surface ship, submarine, or aircraft) and whether they are exposed directly to the prevailing ambient conditions or launched from a pressurised container or launch tube. Extremes of ambient air pressure on land and at sea level are given in Leaflet 2311/3. Levels of ambient air pressure experienced by air-carried weapons at launch will be determined by the altitude of the flight platform at the time of firing or release. Values of ambient air pressure at altitude may be determined from international standards of reference atmospheres such as ISO 5878. Levels of air pressure in conditioned containers or launch tubes on surface ships and submarines should be determined by reference to Design Requirements documents, the shipbuilder or manufacturer of the launch system.

2.4.2. Air Pressure During Free Flight

Ambient air pressures experienced by munitions during free flight will be determined by the profile of the flight altitude. For bombs, mines, and projectiles that reach their target by un-powered flight, the flight profile may vary from a simple free-fall to a ballistic trajectory (induced by aircraft flight manoeuvres or gun fire). Pressures will vary directly with the variation in flight altitude and rates of climb and descent determined by the deployment or otherwise of flight control devices. While the same factors apply to rocket propelled and motor-powered guided missiles, profiles of the flight altitude are likely to be more varied with considerably greater rates of change of climb and descent, especially when pursuing high-speed moving targets. Severities that may be experienced by a particular type of weapon should be determined by considering all the various flight paths and trajectories included in the design requirements for the munition.

2.4.3. Dynamic Air Pressure

Forward facing surfaces and leading edges of air-carried weapons which are exposed to the airstream at the time of launch or release and of all weapons deployed to the target at high speed through the atmosphere will be subjected to dynamic pressure related by the formula:

$$q = 0.5\,\rho v^2$$

Where q = dynamic pressure kg/m²

ρ = air density at flight altitude kg/m^3

v = flight velocity m/s

2.5. Hydraulic Pressure

a. Underwater weapons launched from submarines will be subjected to hydraulic pressure corresponding to the depth of immersion of the vessel at the time of launch. Torpedoes will be subjected to pressurised water in the launch tube. Maximum pressures likely to be experienced should be determined by reference to the Design Authority for the launch system or the builder of the submarine.

b. After launch, torpedoes and other types of underwater weapons will be subjected to hydraulic pressure related to the depth of immersion in accordance with the following formula:

$$p = 9.8d$$

Where p = water pressure in kPa

d = depth below the surface of the water in meters.

c. Pressure experienced by systems and components will depend on whether they are installed in sections of open or closed construction.

2.6. Icing

2.6.1. Icing of Ground and Ship-Launched Weapons

a. Icing of land-based weapons at launch will depend on local meteorological conditions and the duration of exposure on the launcher before separation. Orientation with respect to the prevailing wind and shielding provided by the launcher will contribute to the pattern and severity of icing.

b. When operating in low temperature conditions, the interaction of ships' manoeuvres and wave motion may contribute to the amount of spray and level and pattern of icing experienced by structures, such as weapon launchers on open decks. The loading and pattern of icing experienced by individual weapons will depend upon shielding provided by the launcher and the influence of heat dissipated by systems required to be operating before separation. Rates of ice accretion of up to 40 mm/hr have been reported for structures on open decks of ships operating in Arctic regions. Minimum rates of 25 mm/hr and survival of a loading of 120 kg/m^2 should be assumed for operations in cold regions.

2.6.2. Icing of Air-Launched Weapons

a. Dependent on the velocity of the flight platform, air-carried weapons exposed to the airstream during captive flight are likely to be subjected to impact icing, the effects of which are likely to become apparent during launch or release from the weapon rack or carrier. Impact icing of materiel while deployed on aircraft and resulting severities that can occur are described more fully in paragraph 3.6.

b. During free-flight the speed of rocket-propelled and motorised guided weapons will normally be such as to preclude any further formation and that which has accumulated will melt and/or be dispersed by the action of the control surfaces.

2.7. Impact with Hail, Rain, Dust, and Sand

Forward-facing surfaces and leading edges of air-carried weapons exposed to the airstream during captive flight and of munitions intended to be launched in all weathers may be subjected to high velocity impact with hail, rain, dust, and sand. External surfaces may become deformed or suffer abrasion, erosion, or pitting. Panels manufactured from composite materials may suffer hidden physical damage.

2.7.1. Hail

Guidance on the risk of hail encounters related to altitude, geographical area, season, and time of day is given in Leaflet 2311/3. Damage potential from impact with individual stones depends on the type and density of ice and the diameter and impact velocity. Forward-facing surfaces of guided weapons such as radomes and lenses of tracking systems and leading edges of aerofoils and control surfaces are likely to become damaged.

2.7.2. Rain

Raindrops may be encountered up to altitudes of 20 km with the greater intensities occurring between sea level and 6 km. Factors affecting erosion of materials by rain include impact velocity, the material shape and finish of the impacted surface, drop size, and number and frequency of impact. Repeated collisions at the same point influence the pattern of buildup of stress and erosion of the impacted surface. A complex relationship between erosion resistance and physical properties of materials exists. Resistance is expressed in terms of the time required for drops of 2 mm diameter in a simulated rainfall of 25 mm/hr, and with an impact velocity of 225 m/s, to produce various degrees of erosion.

2.7.3. Dust and Sand

Studies of dust storms in hot, dry desert regions indicate that dust remains suspended in the atmosphere for a considerable period after the storm has abated. Particles of up to 10 µm can reach heights of 1500 m with an upper limit for dust of around 3000 m. The severity of erosion of frontal areas and leading edges of guided weapons depends on the impact velocity, the form, and hardness of the particulate and of the material or surface finish of the impacted surface.

3. POTENTIAL DAMAGING EFFECTS

3.1. High and Low Temperature

a. The effects of high and low temperature encountered by munitions on the launch platform up to separation are covered in the relevant section of this AECTP (i.e., for deployment on land vehicle, surface ship, submarine, fixed-wing aircraft, and rotary-winged aircraft).

b. The rapid rates of change of temperature experienced by munitions when subjected to aerodynamic heating and during rapid transfer from air to water are likely to induce high rates of thermal stress in structures, systems, and components. Although the resultant stress level may be the same, the high rate of application can embrittle some materials and cause failure at a much lower strain level than with a more gradual application of the temperature.

3.2. Humidity

For high-speed guided weapons and projectiles, any harmful effects attributable to humidity are more likely to arise from previous conditioning during storage, transportation, or deployment on the launch platform than as a result of the conditioning received during the comparatively brief final stage of deployment. High temperatures generated in sections and compartments are more likely to reduce the levels of relative humidity within enclosed sections and compartments. While the same rationale may be considered to apply to torpedoes, changes in relative humidity may be relevant to the deployment of other types of underwater weapons, especially where compartments are not charged with inert gas. In the case of mines that are likely to remain in a quiescent state for comparatively long periods until approached and activated by the target, an increase in relative humidity generated as a result of deployment may cause subsequent malfunction. Reduction or breakdown of insulation resistance of circuitry or components can reduce reliability, induce self-ignition, or cause total failure.

3.3. Air Pressure

a. Because the amount of heat lost to the atmosphere by convection is proportional to the density of the surrounding air, the cooling efficiency at altitude will be reduced below that obtained at ground level. The working temperature of heat-generating systems and components during flight may rise above that necessary for optimum performance. Lower air density also encourages flash-over between electrical conductors, arcing within electrical/electronic components, and corona discharge in the areas with strong electric fields (e.g., around aerials) causing electromagnetic interference.

b. Rapid rates of climb and descent achieved by guided weapons and projectiles may cause pressure differentials across the walls of partially sealed compartments and enclosures of individual equipment and components causing them to distort and possibly interfere with mechanical and electrical/electronic devices. The result is malfunction or total failure of the weapon. Rapid or explosive decompression may be a potential hazard for totally sealed materiel.

c. The migration of compounds used to improve heat transmission and the operation of components that rely on lubricating properties of air can cause malfunction and degraded performance.

3.4. Dynamic Pressure

Air pressure is a significant factor in determining severity of induced vibration caused by turbulent flow around guided weapons and projectiles.

3.5. Hydraulic Pressure

Hydraulic pressure imposes mechanical loads on the structure and outer casing of underwater weapons. This pressure may cause distortion at joints and seals. Any ingress of water may result in malfunction of arming and sensing devices compromising reliable operation of the munition.

3.6. Icing

a. Impact icing of air-carried weapons, launch rails, weapon racks, and pylons and the carrier/weapon interface can cause interference or total blockage of linkages and release mechanisms and present a serious hazard in terms of flight safety of the aircraft and vulnerability in combat. The pattern of ice formation may induce dynamic loads, impede a clean separation, impair the aerodynamics of both the weapon and the flight platform, or interfere with deployment of aerofoils on the weapon after release.

b. Similar problems are likely to be encountered when launching from open decks of surface ships when operating in low temperature conditions, especially in those cases where the weapon is held unprotected on the launcher or firing involves the opening of some form of canister likely to be enveloped in ice.

c. Frosting and accumulations of ice on radomes and optical parts of infra-red, laser, and TV seeker heads can reduce the performance of guidance systems or render firing of the weapon impracticable.

3.7. Impact with Hail, Rain, Dust, and Sand

Abrasion, deformation, erosion, and pitting of external surfaces of radomes and optical devices of seeker heads of guided weapons caused by high velocity impact with hail, rain, dust, and sand can reduce the sensitivity and performance of the guidance system. Delamination or fibre fracture may occur within panels manufactured from composite materials. A buildup in electrostatic charges on the impacted surfaces may cause malfunction or failure of sensitive low voltage systems and components and compromise reliability of arming devices, firing systems, and operation of the warhead.

4. TEST SELECTION

4.1. General

a. AECTP-300 provides test procedures that may be used for simulating climatic environments experienced by weapons at launch and during the final stage of deployment to target. The choice of a test method for temperature and humidity will depend on whether there is a requirement to simulate climatic variations, including the heating effects of solar radiation, or just the maximum or minimum temperatures experienced during flight.

b. Reference should be made to the guidance given in the relevant chapters regarding the selection of the appropriate test procedure, severities, test techniques, and performance evaluation.

c. Preferably, test severities should be derived from specifically measured data recorded during trials conducted in climatic conditions representative of those expected in service, or from data obtained during deployment of similar types of munitions. For guided weapons and projectiles, data may be required for more than one type of trajectory in order to establish worst-case conditions in flight expected in service. Alternatively, severities derived from data obtained for other examples of weapons in similar applications may be used.

d. Test methods for combined environments of temperature and low pressure are included for guided weapons with a subsonic speed during flight to target, and where the effect of the combined environments could be more stressful or different than each environment alone.

e. Tests simulating kinetic heating are recommended only when the effects generated cannot be predicted satisfactorily by calculation or computer modelling. Guidance on testing techniques involved (including guidance on control of test parameters) is given in AECTP-300. In some cases, it may be appropriate to simulate the thermal stress imposed on materiel using the simpler thermal shock test.

f. For many types of munitions, any harmful effects from environments such as humidity or high velocity impact with hail, rain, dust, or sand are more likely to be incurred as a result of previous conditioning. The impacts of those factors during the comparatively very short period of launch and flight to target are of little consequence. Exceptions to that are land mines and possibly some underwater weapons that, once laid and primed, are likely to be subject to conditions that are more severe and/or of longer duration than those experienced during earlier phases of service life. The high temperatures, temperature gradients, low air pressures, and rates of change of pressure experienced by guided weapons and projectiles during free flight will be far in excess of those experienced during previous stages of service life.

g. Preferably, specimens subjected to tests simulating induced climatic conditions experienced at launch and the final stage of deployment should first be subjected to environmental conditioning representing the climatic and mechanical environments that are likely to occur during earlier stages of service life. Where this is not possible, this factor should be taken into account in assessing test results especially where operational performance is found to be marginal.

4.2. Fall-Back Test Severities

Fall-back test severities and guidance on their selection are given in the relevant section of AECTP-300 for those cases where no specific information is available for tailoring severities to the particular application.

4.3. Tailored Test Severities

4.3.1. Temperature and humidity

a. Test severities used to simulate temperature and humidity conditions at launch should be based on information given in the Operational and Environmental Requirements documents regarding the intended geographical areas of deployment and characteristics of the flight profiles.

b. Leaflet 2311/2 classifies climatic conditions on land into three main categories, Hot-Dry (Cat. A), Hot-Wet (Cat. B), and Cold (Cat. C). Geographical areas in each category are graded by severity based on data recorded over many years. Values of temperature and humidity are quoted for external ambient (Meteorological). Induced (Transit and Storage) conditions are given in Leaflet 2310/1. In the absence of specifically measured data, values for the latter should be assumed to represent worst-case induced conditions experienced by equipment immediately before launch from land and naval platforms and by mines after being laid.

c. The quoted values of temperature and humidity are those that are likely to be obtained or exceeded in the most severe location for 1 percent of the most extreme month of the year.

d. Temperature severities used in tests simulating kinetic (aerodynamic) heating and combined temperature-low pressure tests should be derived using one or both of the following in descending order of preference:

(1) From specifically measured data recorded during hot weather trials. Measurements should be made at the relevant locations on the munition. Other factors influencing temperature severities such as configuration, thermal mass, sources of dissipated heat, cooling air, and any other types of thermal protection system should be correctly represented. The trials programme should specify flight trajectories likely to produce worst-case conditions in service.

(2) From data recorded for a similar application with adjustments for differences in the factors referred to in (1) above.

(3) From data derived from calculations and computer modelling.

4.3.2. Air Pressure and Hydraulic Pressure Tests

a. Severities for simulation of low air pressure may be determined from the Operational and Environmental Requirements documents for the munition (i.e., equivalent pressures related to maximum operational altitude, envelope of flight trajectories, and rates of climb and descent). International tables of standard atmospheres may be found in standards such as ISO 5878.

b. Severities for high air pressure and hydraulic pressure tests are determined by the working pressure of the launch system and the maximum depth of immersion at which the weapon will be launched or during deployment to target. Pressure severities at launch should be determined by reference to Design Requirements documents or the Design Authority for the launch system. Once launched, hydraulic pressures will be related to depth of immersion as defined in paragraph 2.5, above.

4.3.3. Icing

It is unlikely that tailoring test severities to specifically measured data for simulating induced icing will be cost effective, in which case the severities are given in Method 311 of AECTP-300.

4.3.4. Impact with Rain, Dust, and Sand

AECTP-300 gives a test method for simulation of impact with rain, dust, and sand. Testing is more applicable to air-carried stores likely to receive a number of captive flights before launch. Test facilities may not be available to simulate the higher velocities that occur during free flight.

ANNEX A

FACTORS INFLUENCING TEMPERATURES ARISING FROM KINETIC HEATING

A.1. Stagnation Temperature

When a body moves through the atmosphere, the air is deflected around it except at a point immediately in front of the body known as the "stagnation point," where the air is brought to rest. Due to compressive effects, the temperature of the air rises at this point. The temperature attained is known as the "stagnation temperature." At moderate Mach numbers (i.e., < 3, providing the air is chemically stable and the specific heats of air at constant pressure and constant volume are invariant), stagnation temperature, T_S, is given by the following equation:

$$T_S = T_\infty \left[1 + \frac{\gamma - 1}{2} M_\infty^2 \right] \text{°K}$$

Where T_∞ is the free stream temperature in degrees Kelvin (i.e., the temperature in the region of undisturbed relative flow)

γ the ratio of specific heats

M_∞ the flight Mach number.

A useful approximation which gives the rise in temperature at the stagnation point is

$$T_S - T_\infty \approx 5 \times \left[\frac{\nu}{100} \right]^2 \text{°C}$$

Where v is the flight speed in meters per second.

A.2. Rate of Heat Transfer

The rate of heat transfer determines the temperature inside the flight platform during flight. This rate which may vary considerably is dependent on the following factors:

1. The characteristics of the boundary layer air enveloping the vehicle which in turn is governed by the altitude, speed, temperature, and whether the airflow is laminar or turbulent.

2. The surface finish of the skin, which influences the boundary layer and the effect of radiation transfer.

3. The influence of heat generated by equipment carried inside the vehicle.

A.3. Flight Profile

During periods of acceleration, heat flow into the skin of the flight platform is likely to be very high. The initial temperature differentials created in the structure present not only the problem of the temperature itself, but also the more serious one of thermal stresses. During subsequent steady flight velocities, the inflow of heat into the structure is reduced and there follows a tendency towards a more settled heat balance with a reduction in differential stresses. The temperature distribution within the flight platform thus becomes more equable. Under these conditions, the mean temperature distribution may result in temperature limits for materials and the functional devices within the vehicle being exceeded.

A.4. Estimation of Skin Temperature Due to Aerodynamic Heating

a. The estimation of temperatures resulting from aerodynamic heating is, in general, complex and no general solution can be given. However, some guidance regarding methods of approach, limitations and restrictions can be recommended. This is only a simplified approach to the general problem and it is recommended that specialist agencies should be consulted.

b. The main factors involved are the recovery temperature of the boundary layer and the heat transfer coefficient. Both quantities are functions of the particular trajectory flown. In the simplified approach described here, both are taken as applying to flat plates only at zero incidence. The following symbols and units are used:

c = specific heat of skin material, J/(kg °C)

d = thickness of skin material, m

h = heat transfer coefficient, W/(m^2 . °C)

k = thermal conductivity of skin material, W/(m^2 . °C)

M_∞ = free stream Mach number

Q = rate of heat flow, W/m^2

r = recovery factor

Tb = body or skin temperature, Kelvin

Tr = recovery temperature, Kelvin

T_∞ = free stream temperature, Kelvin

v_∞ = velocity of flight platform relative to undisturbed flow, m/s

x = distance from stagnation point, m

γ = ratio of specific heats

α = diffusivity $\left\{ = \frac{k}{\rho c} \right\}$, m²/s

ρ = density of skin material, kg/m³

ρ_∞ = free stream air density, kg/m³

c. The **recovery temperature** is defined as the temperature at which zero heat transfer takes place between the boundary layer and the skin of the body or, the maximum temperature the skin can achieve under steady-state conditions.

A simplified relationship for the estimation of recovery temperature is given by:

$$T_r = T_\infty \left[1 + r\left(\frac{\gamma - 1}{2}\right) M_\infty^2 \right] \text{°K}$$

The product $r\left(\frac{\gamma - 1}{2}\right)$ can be simplified further to give 0.17 for laminar flow in the boundary layer or 0.18 for turbulent flow. It is usual to assume turbulent flow as this gives slightly pessimistic answers.

d. The **heat transfer coefficient** is a measure of the ability of the boundary layer to transfer heat from itself to the skin of the body. Heat transfer coefficients are functions of the type of flow (laminar or turbulent), characteristics of the trajectory, the shape of the body and the position on the body in relation to the stagnation point. Heat transfer coefficients can be expressed in various forms for different applications. For weapon design applications where the most pessimistic conditions must be considered, the following formula has been found to give reasonable results for flight speeds up to Mach 5:

$$hx^{0.167} = \frac{2.362\left(\rho_\infty v_\infty T_\infty\right)^{0.83}}{A^{0.583}\left(A + 117\right)^{0.167}}$$

Where $A = 0.45T_b + T_\infty\left(0.55 + 0.035M_\infty^2\right)$

When considering heat transfer to small, angled cones or leading edges, an approximation can be made to the heat transfer coefficient by adding 15 percent to the value from the above formula.

A.5. Heat Transferred from the Boundary Layer

At any instant, the amount of heat transferred from the boundary layer to the skin of a body will be governed by the recovery temperature and the heat transfer coefficient in the following manner:

$$Q = h\left(T_r - T_b\right)$$

Where T_b is a function of time

h and T_r can also be functions of time defined by the trajectory

A.6. Estimation of Body Temperatures

Body temperature is a function of the constructional details of the body (i.e., whether there is any radiative or conductive exchange of heat between various parts of the body) and the external finish, that governs the amount of heat re-radiated as well as the heat input to the body from the boundary layer. In the case of transient temperatures, the body temperature is also a function of its thermal capacity and whether it can be considered “thin” or “thick” skinned.

The criterion for a “thin” skin is that $\left\{\frac{hd}{k}\right\} < 0.1$.

(1) Thin-skin temperatures:

Thin skins can be defined as being of high conductivity materials, including metallic skins of thickness used normally in weapon construction. They are skins in which the temperature gradient across the skin can be considered negligible. For the simplified case of a thin skin with no conduction or radiation losses, the temperature-time history for a body subjected to aerodynamic heating can be found by employing a step-by-step method of analysis as follows.

$$(T_b)_2 = P(T_r)_1 + (1-P)(T_b)_1$$

Where $P = \left\{\frac{2B}{1+B}\right\}$ and $B = \left\{\frac{h\Delta t}{2rcd}\right\}$

Δt is the time interval in seconds. Subscripts 1 and 2 refer to temperatures before and at the end of the time interval respectively. Values of h and c can, if necessary, be considered to be time dependent. In this case average values over each time interval should be used.

(2) Thick-skin temperatures:

Normally, thick-skinned materials are low conductivity materials. For most practical weapon design cases, they will be insulating materials. They are skins in which appreciable temperature gradients will exist. In the case of a thick-skinned or insulating material, the transfer of heat throughout the material is governed primarily by the thermal conductivity. The temperature distribution throughout the thickness of the material can be approximated by dividing into several slices each Δy metres thick and then applying the criterion:

$$(T_b)_{2,y} - (T_b)_{1,y+\Delta y} = \frac{\Delta t}{(\Delta y)^2} a\left[(T_b)_{1,y+\Delta y} + (T_b)_{1,y-\Delta y} - 2(T_b)_{1,y}\right]$$

Where Δt is the time interval in seconds and subscripts y, y + Δy, and y - Δy refer to the temperatures at these respective positions in the material.

The above formula gives only the distribution of temperature within the insulation material. Surface conditions can be applied by equating the flow of heat transferred from the boundary layer to the amount of heat being absorbed by the material. This results in the following condition for the surface temperature T_s, any instant:

$$T_s = (1 - X)T_r + X(T_b)_{(s-\Delta y)}$$

Where $X = \left(\frac{N}{1+N}\right)$ and $N = \left(\frac{k}{h\Delta y}\right)$ and subscript (s - Δy) refers to the temperature at a distance Δy meters inside the material.

The formulae given above to calculate the temperature gradients through the skin are based upon a one-dimensional finite difference approximation through the material. In many situations, it will be necessary to consider two-dimensional temperature distributions (e.g., the nose region of a flight platform). In these cases, the finite difference method can be extended to two directions, but it is usually more efficient to use the more recently developed finite element technique. The above formulae use a simple stepping method in order to proceed from the conditions at Time 1 to Time 2. In large-scale calculations, it would be more common to use a better stepping process such as the Crank-Nicholson method.

A.7. Computer Programs

The formulae given above for estimating temperatures induced by aerodynamic heating are simplified cases of the conditions found in practice. It would be normal to use a computer programme to obtain temperature distributions except in very simple cases. Many computer programs are tailored to the special requirements of individual cases and no suitable guidance can be given in such situations. Some general-purpose programs are available.

SECTION 2310
LEAFLET 2310/1
VALIDATION OF TEST SEVERITIES

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SECTION 2310
LEAFLET 2310/1
VALIDATION OF TEST SEVERITIES

1. SCOPE

1.1. Purpose

The main objectives of these instructions are to:

a. Outline methods for calculating valid test procedures.

b. To provide Environmental Engineering Specialists on how to collect and analyse real field data for the purposes of thermal and chemical age estimation.

1.2. Application

This leaflet outlines induced environments and presents methods for predicting these induced environments from recorded data. They are applicable to materiel that will be exposed to the extremes of climate and have a known degradation mechanism that can be associated with the environments.

1.3. Limitations

These methods should not be applied where there is only limited data available or where the integrity of the data cannot be verified. As a general rule it is not recommended that induced environments be calculated where less than five years of recorded data are available, and should not be calculated if less than one year of data are available.

2. DEFINITION OF STORAGE AND TRANSIT TYPES

The following list identifies the various storage and transportation types and associated categories as defined in para. 2.5.

2.1. Long-Term Storage Types

Air Conditioned	(Category 1)
Mounded Building/Underground	(Category 2)
Permanent Building	(Category 2)
Semi-Permanent Structures	(Category 3)

2.2. Temporary Storage Types

Container	(Category 3)
Bunker	(Category 3)
“Hut”/“Igloo”	(Category 3)

"Tent"	(Category 4)
No Cover	(Category 5)

2.3. Shipboard Storage Types

Container	(Category 3)
Hold/RFA	(Category 1)
Purpose Built Covered Weapons Bay	(Category 2)
Deck Cargo	(Category 5)

2.4. Transportation Types

Container (all vehicles)	(Category 3)
Packaged Materials:	
Wheeled Vehicle, Soft-Skinned	(Category 4)
Wheeled Vehicle, Hard-Skinned	(Category 3 or 4)
Armoured Vehicle (Internal Hull)	(Category 1 or 2)
Armoured Vehicle (External)	(Category 5)
Rotary-Wing Aircraft	(Category 3)
Fixed-Wing Aircraft	(Category 3)
Rail Carriage (Modern Transport)	Category 3)
Rail Carriage (General)	(Category 5)
Man-Portable	(Category 5)
Unpackaged Materials:	
Wheeled Vehicle, Soft-Skinned	(Category 4)
Wheeled Vehicle, Hard-Skinned	(Category 4)
Armoured Vehicle (Internal Hull)	(Category 1 or 2)
Armoured Vehicle (External)	(Category 5)
Rotary-Wing Aircraft	(Category 3)
Fixed-Wing Aircraft	(Category 3)

Rail Carriage (Modern Transport)	(Category 3)
Rail Carriage (General)	(Category 5)
Man-Portable	(Category 5)

2.5. Categories of Storage and Transportation

The following categories are defined in terms of environmental conditions that effect materiel and are not intended to specify storage design types.

a. Category 1: Special Storage. Environmental conditions are controlled (for example air conditioned). The temperature and humidity range should be maintained within the limits of the materiel where the rate of chemical deterioration is known to be stable. Humidity in the surrounding environment is controlled to match the humidity (measured as Total Volatile Materiel) of the materiel, and to prevent the transfer of moisture between the materiel and its surroundings.

b. Category 2: Standard (Long-Term) Storage. Temperature is controlled and humidity does not reach extremes. It may not be air conditioned, but the temperature will not reach the extremes of the outside ambient temperature. Either the surrounding humidity is moderate, or there is sufficient protection to keep the materiel humidity within acceptable limits.

c. Category 3: Ventilated Storage. There is sufficient protection afforded to the materiel such that the surrounding air temperature and relative humidity are no worse than the meteorological conditions. The outer surface of the storage will dissipate direct solar radiation and while providing ventilation during hot periods, will still prevent wind and driving rain affecting the materiel.

d. Category 4: Temporary Cover. Affords the materiel some protection from the elements, but will not prevent some convection from raising or lowering the temperature of the materiel at a different rate from the meteorological levels. Protection from actual rainfall will be given, but humidity levels will depend more upon the environment, protective cover, and materiel packaging.

e. Category 5: Poor or No Cover. Materiel can be affected by both convection and conduction giving extreme induced temperature conditions. Direct rainfall and ground water may affect the materiel, and humidity levels will depend heavily on the environment and protection offered to the materiel by its packaging.

3. REQUIREMENTS FOR SUCCESSFUL LIFE ESTIMATION

3.1. Data to be Collected

Induced conditions can be determined by laboratory or field experimentation. Laboratory experimentation is useful for gathering data on the difference made by mitigation factors (such as paint colour), but cannot wholly simulate real conditions. Field experiments do reflect real situations but can only be “snapshots” of the final environment which may miss typical, but infrequent, events such as storms, or local differences such as a difference in humidity between the leeward and windward sides of a range of hills. Ideally, induced conditions should be derived by monitoring actual climatic events as they occur.

3.2. Guidance for Asset Managers

a. An Asset Manager can be considered as that authority ultimately responsible for the whole life (cradle to grave) of the materiel, or asset, in question. That responsibility will very likely transfer through several different groups during the life of the materiel. Ideally, the initial (procurement) agency should take the main responsibility for implementing data gathering programmes and defining the life assessment procedures, but this is not always the case.

b. Temperature and Humidity can be monitored by the use of small electronic recorders. By gathering daily data continuously over the life of the materiel, the asset manager can gain a very precise picture of the thermal stressing placed upon it. If supported by a full life assessment programme, this also allows for a relatively accurate estimation of the remaining life of the asset to be made at any point in time.

c. There are two basic formats for automatic data recorders as stated below. Both types can also be used to uniquely identify (tag) a pallet, container, or individual item. In addition, the information could be integrated into a wider asset control system.

(1) Simple and compact recording devices are available off the shelf. These devices are relatively inexpensive and come as a sealed unit that has been demonstrated to be safe for use in most types of explosive magazines. The asset manager must decide where to place the recorders and how many to use for any given batch of materiel. These recorders can be introduced at any time during the materials life but are most effective if introduced early and kept with the same material throughout its life. However, these recorders can also be used for monitoring climatic conditions within a particular storehouse or type of transportation.

(2) For expensive, larger, assets an integrated logging system could be more effective. Integrated recorders should be considered at the design stage of the item, and will be placed to record the temperature and/or humidity at the actual point(s) that the design authority has determined will be most affected by climatic variations and, therefore, most likely to limit the life of the material. For a recorder to be integrated successfully, the design authority and asset manager would need to agree upon procedures for battery replacement/use, and the setting up and interrogation of the recorder.

d. Recorders can be supplied with a variety of interfaces such as Infrared (IR), Contact (Serial Port) or Radio (RF). Before introducing recorders the asset manager will need to consult the appropriate National Storage and Transport Authority (NS&TA), and NSA as to which is the most appropriate interface. In some cases where there are a variety of NS&TA involved (e.g., Navy, Army, and Air Force), there may be a need for more than one type of interface. Various aspects such as asset tracking requirements, access to stores, frequency of interrogation, and impact of RF interference will need to be considered in conjunction with the NS&TA and NSA who will be the representatives of the end user for the recording devices and their associated readers.

e. It may also be necessary for the asset manager to monitor the meteorological data for the region(s) in which the monitoring is being conducted. This is needed to determine how packaging and the various forms of storage and transportation are mitigating (or augmenting) the effects of the surrounding environment. Actual meteorological (local Stevenson screen) data should also be available and compared against the cycles in Leaflet 2311/2.

f. Assuming that the environmental data are gathered correctly through continuous monitoring, the asset manager will also need to know the mechanism(s) by which the materiel deteriorates in response to the various levels of temperature and humidity, if they wish to derive a predicted life for a materiel. The ageing mechanisms can be measured using predictive testing: either as a full-scale simulation of the Manufacture to Target or Disposal Sequence (MTDS) on a complete store; and/or at laboratory level by experimentation with critical components of the store. Some of these tests should be repeated at various stages during the predicted life cycle (i.e., in a surveillance programme) so that predictions can be verified and if necessary revised.

4. METHODS FOR RATIONALISING DATA

4.1. Methods for Determining Induced Levels

a. When meteorological data are collected, it can be sorted into representative diurnal cycles and yearly thresholds for predetermined climatic categories, the details of which are given in Leaflet 2311/1. In order to be consistent, a similar method for analysing the actual materiel data can be adopted.

b. The existing values, given at the end of this section, are based upon a statistical method which determines a figure from a given sample which will only be exceeded by 1 percent of the overall population, assuming that the population is normal. This method can be described as follows:

(1) Take a sample of measured data for a given month. We know, for this sample, the maximum temperature ever recorded (b), and the maximum temperature recorded each day. If it is assumed that the mean of the maximum temperatures recorded each day is the mean of a normal distribution (μ), the standard deviation (sd) for that distribution can be derived as follows:

W = the complete range of values $\Rightarrow$ number of sd's in the complete range (k) x sd $\Rightarrow$ 2 x (b-μ)

$$\therefore \text{sd} = 2 \times (b-\mu)/k \text{.....} \quad (1)$$

(2) By assuming that the population range = sample range (W), a value for k can be taken from Normal distribution tables that estimate the number of sd in the range based upon the sample size (r). Therefore, a sd can be estimated for the population distribution using (1) above.

(3) With a known mean and sd, for any temperature T, the number of days that will exceed T for that period (month) can now be calculated as follows:

$$z = \text{the standardised normal variable} = (T-\mu)/\text{sd}$$

From this the probability (P) of exceeding T can be found from normal tables of z (in EXCEL the probability can be returned by the equation, =NORMSDIST(z)).

$\therefore$ The number of days exceeding T = P x number of days in the month (n)..... (2).

(4) By calculating (2) above for each month in the year, and summing for the entire year ($D = \sum Pn$), then D estimates the number of days exceeding T in any year. To achieve a 1 percent value, T should be varied until D = 1 percent of 365, i.e., D = 3.65.

(5) Once the maximum (or minimum) 1 percent value has been determined, the corresponding diurnal cycle also needs to be determined. The next step is to determine the opposite value in the cycle to that which has been determined (i.e., if you have the 1 percent maximum value, you need to determine the minimum value for the associated diurnal cycle). The opposite value was calculated for a <u>maximum</u> exactly as above, using equations (1) and (2), but T was chosen to be the temperature where D = 99 percent of 365 instead of 1 percent. For a minimum D, = 1 percent of 365 instead of 99 percent.

(6) Algorithms have been devised to fit a curve between the two points determined as above. An example of one of these algorithms is given in Table 1.

Table 1: Algorithm Example

Time of Day	Temperature
03:00	B + 0.10(A - B)
06:00	B
09:00	B + 0.25(A - B)
12:00	B + 0.65(A - B)
15:00	B + 0.95(A - B)
18:00	B + 0.70(A - B)
21:00	B + 0.40(A - B)
24:00	B + 0.20(A - B)

Where A = D for 1 percent maximum (or minimum for cold cycle)

and B = D for 99 percent maximum (or minimum for cold cycle)

4.2. Future Improvements

a. It is very likely that the above approach was taken due to the lack of sufficient computer power available at the time it was developed. There are improved ways of calculating the maximum diurnal cycle using modern computers to quickly analyse the data.

b. The Discrete Method: this is simply an extension of the method above but the temperatures recorded each day are discretely grouped (e.g., by hour). Using modern computers, the iterative process described above can then be carried out for each discrete time step above and the points connected to give a diurnal curve.

c. The Continuous Method: in reality, the data are not discrete, but continuous. Modern statistical and computational methods will allow for the data to be analysed as a continuous cycle using Time Series methods.

4.3. Current Induced Levels

The fallback induced conditions, for the climatic categories identified in Leaflet 2311/1, are given at Annex A. If no data exists to generate induced cycles, Annex A provides fallback induced cycles, to be employed as test conditions, for representing the most extreme field conditions, within each category in the absence of field data.

4.4. Setting Test Levels

a. When making a life assessment of a safety critical materiel, it is customary to simulate the ageing of the materiel by subjecting it to a test in a climatic chamber based upon an accelerated test.

b. Solar radiation can also be associated with hot climates and accelerated ageing tests. However, solar radiation is very likely to have been present when the raw data were collected and it is not normal to include it at the test stage unless specific effects, such as actinic effects, are anticipated.

c. The 1 percent diurnal cycles given at Annex A have long been accepted as the fallback test levels for accelerated ageing of material containing propellants and explosives. To modify these levels the method for determining levels used in paragraph 3.1 can be used, but only if there is a significant amount of supporting data. These are air temperature and humidity levels and, therefore, the materiel are packaged for the test as they would be in their service storage and transportation configuration.

d. For a full analysis of life, the test duration is determined by estimating the climate and duration the material is expected to endure in service, and applying a reduced duration of testing with an increased level of climatic excitation - either a higher temperature or an increased peak to trough difference. The Berthelot (including work by Arrhenius and Eyring) relationship for comparing two temperatures is generally used to determine the level of acceleration. The application of this acceleration method is given in AECTP-600, Leaflet 602.

e. In a lot of cases where a large item is composed of a number of age limited materials, the above testing cannot be completed cost effectively on a finished item. In these cases, the life assessment must be based upon laboratory testing of the component materials to determine the relationship between material properties, temperature and time. Care must be taken to ensure that the compatibility of materials is not an issue in determining any life limiting factors.

f. Where data are collected using recorders any estimate of service life can be continuously updated using the actual data to replace the induced data within the age determining calculations. However, an acceptable number of recorders giving consistent readings will be needed before this can take precedent. Maximum values across the sample rather than Mean values should be used when calculating a safe age.

4.5. Determining Mitigating Factors

a. Where small-scale laboratory testing is to be used, it may be necessary to assess the protection afforded the materiel by its packaging, casing, or colour. This way, over or under testing of the materiel in question can be avoided.

b. The simplest method for determining mitigating factors is to place a data recorder within the structure in question (e.g., materiel packaging), and subject the whole structure, including contents, to the expected climatic conditions for a small number of cycles. Analysis of the recorder data should then give a mitigated cycle that can be used for any further testing (without the package). It is recommended that a second recorder outside the structure is also used to act as an experimental control.

c. Where it is not possible to instrument the position within the item, which is of concern, it may be necessary to rely upon design authority understanding coupled with Finite Element modelling to determine the thermal dissipation or moisture pathways.

d. Obviously, the same methods can be used for determining mitigating factors in the field, which are afforded by storage structures. Where factors are not determined for storage structures, Category 1 can be represented by a fixed temperature and Relative Humidity. Categories 2 and 3 can be represented by the meteorological cycles in Leaflet 2311/2 and Categories 4 and 5 can be assumed to offer no protection.

ANNEX A

DEFAULT TEMPERATURE DEFINITIONS FOR CLIMATIC CATEGORIES (TABLES A1–A4 AND FIGURES A-1–A-4)

Table A1: Diurnal Cycle for Category “A” Storage and Transit Conditions

Category	A1	A2	A3
Local Time Hours	Induced Air Temperature °C	Induced Air Temperature °C	Induced Air Temperature °C
0100	35	33	31
0200	34	32	29
0300	34	32	29
0400	33	31	28
0500	33	30	28
0600	33	31	29
0700	36	34	31
0800	40	38	35
0900	44	42	40
1000	51	45	44
1100	56	51	50
1200	63	57	54
1300	69	61	56
1400	70	63	58
1500	71	63	58
1600	70	62	56
1700	67	60	53
1800	63	57	50
1900	55	50	46
2000	48	44	41
2100	41	38	37
2200	39	35	34
2300	37	34	33
2400	35	33	32

NOTES: 1. Humidities for A1, A2, and A3 storage conditions vary too widely between different situations to be represented by a single set of conditions.

2. The vapour pressure in hot, dry areas will vary according to the distance from the sea or other large expanse of water, but is likely to be within the range 3 to 12 mbar for category A1 and 12 to 25 mbar for category A2. The diurnal variation is likely to exceed 3 mbar for category A1 or 2 mbar for category A2.

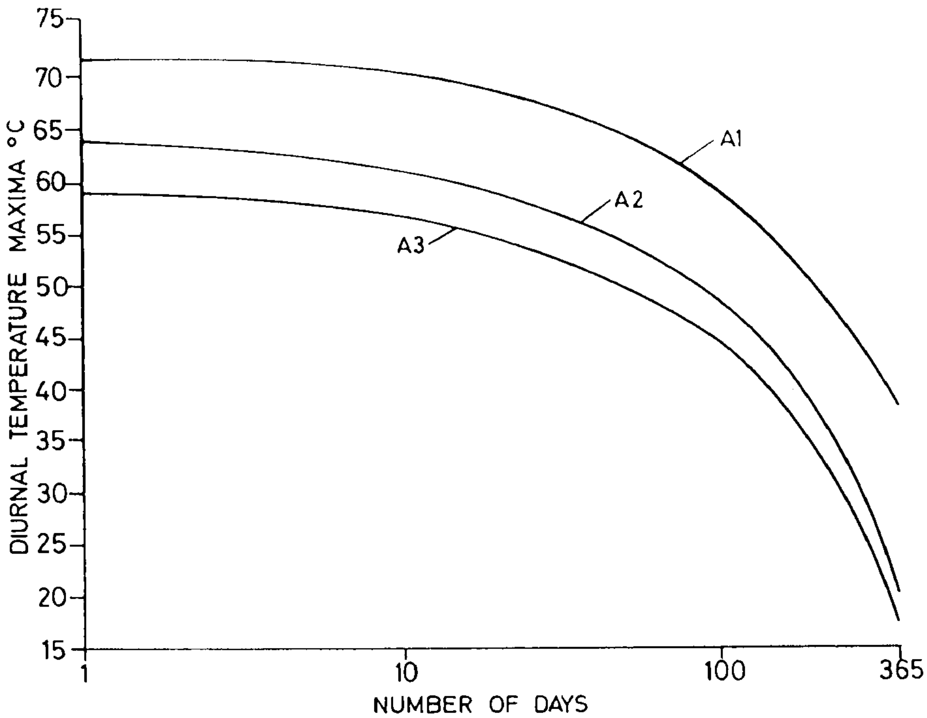

Figure A1: Distribution of the Maxima of the Diurnal Temperature Cycles for the Year for the A1, A2, and A3 Storage Conditions

Table A2: Diurnal Cycle for Category "B" Storage and Transit Conditions

Category	B1		B2		B3	
Local Time Hours	Induced Air Temperature °C	Relative Humidity %	Induced Air Temperature °C	Relative Humidity %	Induced Air Temperature °C	Relative Humidity %
0100			33	69	35	67
0200			32	70	34	72
0300	23	88	32	71	34	75
0400			31	72	34	77
0500			30	74	33	79
0600	23	88	31	75	33	80
0700			34	64	36	70
0800			38	54	40	54
0900	28	76	42	43	44	42
1000			45	36	51	31
1100			51	29	57	24
1200	31	66	57	22	62	17
1300			61	21	66	16
1400			63	20	69	15
1500	32	67	63	19	71	14
1600			62	20	69	16
1700			60	21	66	18
1800	29	75	57	22	63	21
1900			50	32	58	29
2000			44	43	50	41
2100	26	84	38	54	41	53
2200			35	59	39	58
2300			34	63	37	62
2400	24	88	33	68	35	63

NOTE: The storage and transit conditions quoted for Category B1 relates to 358 days per year. For the other 7 days, the induced air temperatures at 24 °C, relative humidity at 100 percent, and the dew point at 24 °C are nearly constant throughout the 24 hours.

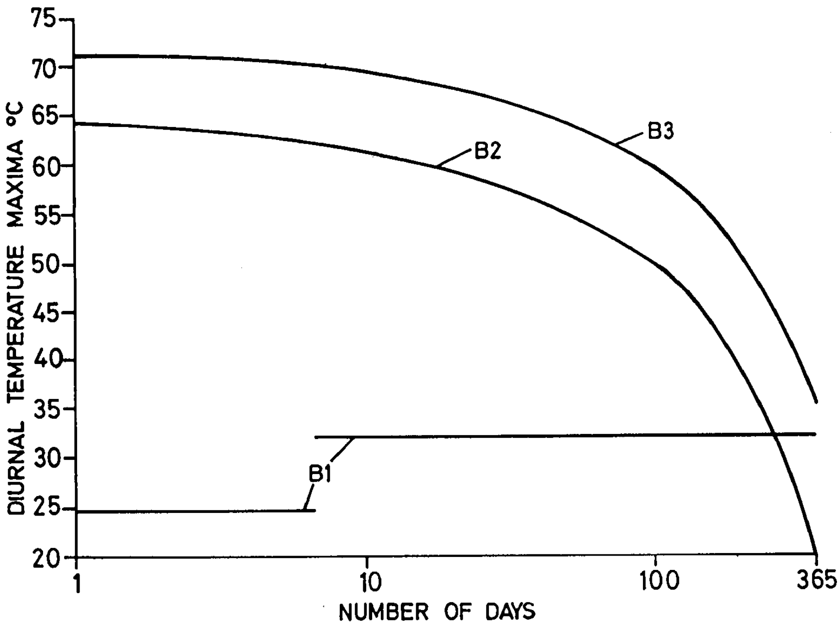

Figure A2: Distribution of the Maxima of the Diurnal Temperature Cycles for the Year, for the B1, B2, and B3 Storage Conditions

Table A3: Diurnal Cycle for Category "M" Storage and Transit Conditions

Category	M1		M2		M3
Local Time Hours	Induced Air Temperature °C	Relative Humidity %	Induced Air Temperature °C	Relative Humidity %	Induced Air Temperature °C
0100	32	52	33	71	
0200	31	56	32	73	
0300	31	56	32	70	-34
0400	30	58	31	75	
0500	30	60	30	78	
0600	30	64	31	75	-34
0700	33	56	34	63	
0800	38	42	38	51	
0900	42	31	42	40	-28
1000	48	22	45	36	
1100	53	18	51	27	
1200	61	12	57	20	-23
1300	67	9	61	16	
1400	68	8	63	13	
1500	69	8	63	13	-23
1600	68	9	62	14	
1700	65	11	60	15	
1800	61	15	57	20	-26
1900	53	20	50	26	
2000	45	32	44	36	
2100	40	39	38	51	-31
2200	36	45	35	60	
2300	34	50	34	63	
2400	33	51	33	67	-34

NOTE: The relative humidity tends to saturate at all the induced air temperatures quoted for category M3.

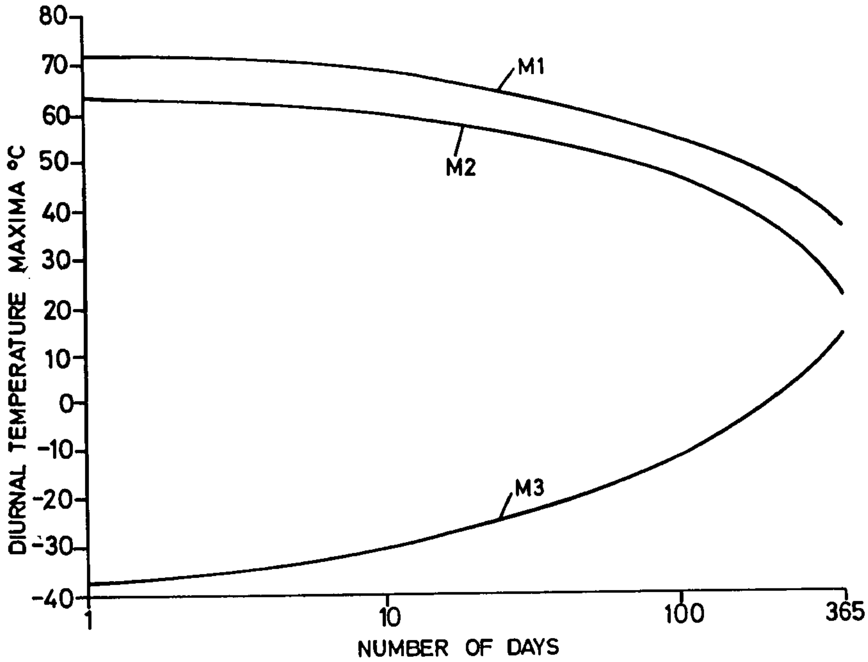

Figure A3: Distribution of the Maxima or Minima of the Diurnal Temperature Cycles for the Year, for the M1, M2, and M3 Storage Conditions

Table A4: Diurnal Cycle for Category “C” Storage and Transit Conditions

Category	C0	C1	C2
Local Time Hours	Induced Air Temperature °C	Induced Air Temperature °C	Induced Air Temperature °C
0300	-21	-33	-46
0600	-21	-33	-46
0900	-19	-33	-43
1200	-12	-28	-37
1500	-10	-25	-37
1800	-14	-29	-39
2100	-19	-32	-43
2400	-21	-33	-45

NOTES:
1. The induced air temperatures are nearly constant at -51°C for category C3 and -57°C for category C4 throughout the 24 hours.
2. The storage temperatures are slightly lower than the corresponding meteorological temperature as storage shelters are often better radiators to the night sky than either the ambient air or the ground.
3. The relative humidity tends to saturate at all the induced air temperatures quoted for categories C0 to C4.

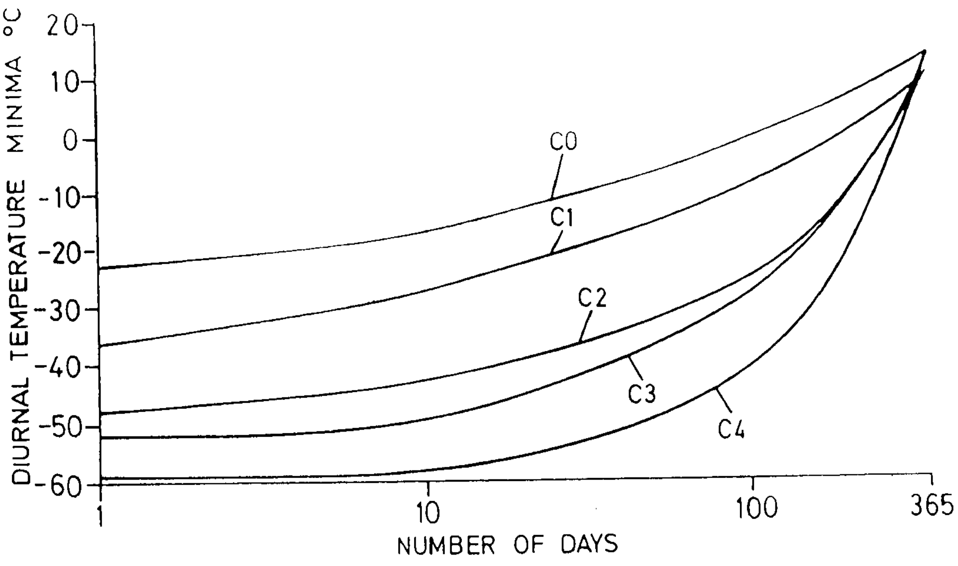

Figure A4: Distribution of the Minima of the Diurnal Temperature Cycles for the Year, for the C0, C1, C2, C3, and C4 Storage Conditions

ADDITIONAL NOTES ON ENVIRONMENTAL CATEGORIES

General Notes on "B" Categories

B1 The meteorological conditions (Leaflet 2311/2) are derived from those recorded in Singapore. As direct solar radiation is negligible, the same set of values is given for storage conditions. Trials should be based on 7 days of saturation at 24°C, and the temperature and humidity cycles of the remaining 358 days.

B2 The storage temperatures are defined as equal to those of the A2 storage condition to take into account the relatively high ambient air temperatures and direct solar radiation, which can occur when clear skies prevail.

B3 The storage temperatures are defined as equal to those of the A1 storage condition to take into account the relatively high ambient air temperatures and direct solar radiation, which can occur when clear skies prevail.

General Notes on "C" Categories

C3 As the coldest days are really long nights, the temperature is constant throughout the 24 hours. The storage cycle is the same as the meteorological conditions as there is sufficient time for temperature equilibrium to be established.

C4 As for the C3 case.

General Notes on "M" Categories

M2 Although higher temperatures and humidities are known to occur, they rarely do so simultaneously.

M3 The storage condition is the same as for the meteorological condition because in these conditions of low radiation there is sufficient time for temperature equilibrium to be established.

SECTION 2311
LEAFLET 2311
WORLDWIDE EXTREME CLIMATIC AND ENVIRONMENTAL CONDITIONS FOR DEFINING DESIGN/TEST CRITERIA

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SECTION 2311
LEAFLET 2311

0. INTRODUCTION TO LEAFLETS 2311/1, 2311/2, AND 2311/3

1. SCOPE

This document provides information on the general purpose, application, and limitations of the 2311 series of leaflets and provides additional user guidance.

1.1. Purpose

The purpose of the 2311 series of leaflets is to describe the principal climatic factors which constitute the distinctive climatic environments found throughout the world, excluding Antarctica, as follows:

a. To identify each of these distinctive climatic environments in terms of categories of temperature and humidity conditions and to state in which areas of the world each category occurs.

b. To establish standard descriptions of ambient air temperature and humidity for each of these categories in terms of diurnal and annual variations.

c. To recommend in particular, diurnal cycles of temperature, humidity, and direct solar radiation for use in determining design criteria.

d. To identify other climatic factors which are significant in each climatic category.

e. To recommend the intensities of these other climatic factors which should be considered when evaluating the total effect of climate upon the materiel.

f. To state how the value of the climatic factors varies with altitude.

g. To quote the most intense values ever reliably recorded for each climatic factor.

1.2. Application

These 2311 leaflets are intended primarily as reference material/guidance on regionalised world climate conditions for use when:

a. Compiling the climatic environmental clauses (related to the Life Cycle Environmental Profile) of requirements documents for materiel intended for use by NATO forces.

b. Evaluating the climatic environmental response, through analyses, of new and existing materiel when being considered for use by NATO forces, particularly when materiel is to be used under climatic conditions different from those for which it was designed.

1.3. Limitations

The 2311 series of leaflets do not prescribe tests or trials schedules, nor does it discuss all the possible effects of adverse climatic conditions upon materiel.

2. GUIDANCE FOR LEAFLETS 2311/1–3

2.1. User Information

Leaflets 2311/1–3 publish information on the principal climatic factors that comprise world climate in a probability of occurrence form suited to the needs of NATO forces.

a. Leaflet 2311/1 covers the climatic categories and their geographical locations (formerly STANAG 2895 Annex A).

b. Leaflet 2311/2 covers worldwide ambient air temperature and humidity conditions and levels of direct solar radiation (formerly STANAG 2895 Annex B).

c. Leaflet 2311/3 covers additional climatic environmental factors to be taken into account when considering materiel intended for use by NATO forces (formerly STANAG 2895 Annex C).

d. The climatic category maps were updated from STANAG 2895 using new data; however, the same methods were applied in defining the climatic categories therefore the geographical boundaries remained relatively constant.

e. The analysis for the "B" categories was altered slightly in order to provide relatively homogeneous boundaries.

f. The principal locations of the land surface categories are shown on the world maps (Maps 1A, 1B and 1C) in Leaflet 2311/1, and the associated diurnal cycles are in Leaflet 2311/2.

g. The sea surface categories are associated loosely with tropical, temperate and arctic waters, but no zones of demarcation are shown as it is considered that ships could enter all waters during service.

h. The temperature and accompanying humidity and solar radiation conditions which occur throughout the entire year in each of the climatic categories are presented in Leaflet 2311/2 in the form of the number of days of the year in which, on average, a specific temperature is just attained or exceeded. In addition, the total period that a specific temperature is exceeded during the entire year is also given.

i. Although the “B” categories have been specifically associated only with regions recognised as wet for at least a substantial portion of an average year, the conditions they represent can occur occasionally, for a relatively short period, in regions normally characterised by their dryness such as deserts. Thus, an appropriate high humidity climatic category should be selected or specified in requirements documents, even when it is known that the materiel will not enter any of the regions defined for the “B” categories.

j. For materiel exposed at the sea surfaces, the requirements documents should normally specify the high temperature category M1, the intermediate category M2, and the low temperature category M3, on the basis that, in general, ships enter tropical, temperate and arctic waters during service.

k. For certain materials, temperature cycling through a phase transition, such as the freezing of water, may be more severe than cycling at the temperature extremes. This should be considered and, where necessary, appropriate temperature cycles specified, based if possible on conditions for the climatic categories given in the Leaflets.

l. Temperature moderating factors are given for ground elevations substantially above sea level (Table 2 Leaflet 2311/2).

m. For explosives, propellants and pyrotechnics, it is recommended that temperature and humidity levels should be based on a probability of being exceeded for 1 percent of one month in the worst period of the year (normally 3 to 4 times a year). The diurnal cycles defined by this recommendation are included for each category in Leaflet 2311/2. The above criterion is applicable in many cases, but in other circumstances, for instance, where a temperature-induced materiel defect will not present a hazard or cause a major system malfunction, the risk situations should be assessed so that temperatures derived from related percentage values representing the optimum compromise can be adopted. Upper or lower values of temperature and humidity for such criteria may be obtained from the probability plots in Leaflet 2311/2. Care should be exercised when criteria beyond 10 percent risk (i.e. based upon a probability of being exceeded for 10 percent of one month in the worst period of the year) are being considered. These data are then used as limit values for diurnal cycles having the same amplitude as the corresponding ones in Tables 6 – 19 of Leaflet 2311/2.

n. Values of temperature and humidity at altitude are given in terms of the highest, lowest and the 1 percent high and low values in Table 2 and 3 of Leaflet 2311/2. The 1 percent values are recommended for determining design criteria for materiel, particularly explosives, propellants and pyrotechnics but, as above, less severe criteria may be applicable in certain cases. Only natural effects are given; induced effects, such as aerodynamic heating, are not considered.

o. In addition to temperature and humidity, the various other climatic factors associated with each category can be identified from Leaflet 2311/3. These factors should be stated in the requirements documents and taken into account when specifying the total climatic environment.

p. It is unlikely that the temperature and humidity conditions encountered in any given year during field trials, at a particular location will approach the extreme values defined for the climatic category of that location.

q. Guidance on the calculation of the 1 percent values can be found in Leaflet 2310/1.

2.2. Guidance on the Drafting of the Climatic Environmental Clauses of Requirements Documents

a. The climatic environmental paragraphs of the Requirements Documents (RD) for an item of materiel should give the fullest information on all aspects of the climates in which the item is required to remain safe and suitable, and/or to be capable of acceptable performance.

b. Initially the sponsor should decide in which regions of the world and for what length of time in each of these regions it is required to store and operate the item during its planned service life and embody this information in the RD in terms of one or more of the fourteen distinct climatic categories of which eleven refer to the land surfaces of the world and three to the sea surfaces, as defined at Leaflet 2311/1.

c. For materiel located on the land surfaces, the requirements documents should specify a set of conditions from the high temperature categories (A1, A2, or A3), the low temperature categories (C0, C1, C2, C3, or C4) and where high humidity is the principal consideration; one from categories (B1, B2, or B3) should also be selected.

d. When preparing the requirements documents, it should be noted that when the temperatures in the regions covered by the A1, A2, A3, M1, and M2 categories are in the vicinity of their maxima, the other climatic factors (those found in Leaflet 2311/3), apart from direct solar radiation and atmospheric pressure, are unlikely to approach their levels of maximum intensity.

e. For the bulk sea surface, it is expected that all three “M” categories will be specified as ships may enter tropical, temperate and arctic waters during service. For coastal waters it is more appropriate to specify the corresponding land service category.

f. Consideration of the effects of combined environments to which the item will be exposed are of principal importance when preparing Requirements Documents.

g. For any particular item of materiel, the requirements documents should state, for design purposes, acceptable probabilities of occurrence of temperature and humidity. These probabilities of occurrence can be derived from the appropriate tables in Leaflet 2311/2, to produce temperature and humidity levels for the climatic categories in which it is intended to operate the materiel.

h. The probabilities of particular temperatures being attained or exceeded in the regions of the respective climatic categories are given in Leaflet 2311/2 in terms of both the number of days a year they are likely to occur and the total time per year for which they persist.

i. For explosives, propellants and pyrotechnics, a probability of occurrence of one percent of one month during the hottest, or coldest, period of the year, as appropriate, is recommended. For convenience, the diurnal cycles corresponding to this probability of occurrence are given in both graphical and tabular form for each climatic category.

j. For all other forms of materiel, the sponsor should decide the optimum value for the probability of occurrence, taking into account all relevant factors including its cost, difficulties of design and production, and modes of deployment. The values selected should be stated in the Requirements Documents.

k. The Requirements Documents should state whether exposure at altitude is to be taken into account.

l. For exposure at altitude, the 1 percent values given in Tables 3 to 5 of Leaflet 2311/2 are recommended unless overriding considerations dictate to the contrary.

m. The other climatic factors which should be taken into account in the RDs are listed in Leaflet 2311/3 and their highest and/or lowest values ever reliably recorded are quoted in the respective sections of the Leaflet.

n. In general, extreme values for pressure are often used as design criteria. However, for many other climatic factors the extreme values are not always used.

o. If the Requirements Documents call for a particular item of materiel to be safe and capable of acceptable performance when exposed to intensity levels different from those recommended in Leaflet 2311/1, Leaflet 2311/2, and Leaflet 2311/3, then any departure should be justified.

p. Materiel designed to be safe and capable of acceptable performance under the conditions specified for one category should not be expected necessarily to do so under the conditions specified for another category.

q. It is rarely required that materiel be necessarily safe and/or capable of acceptable performance when exposed to the highest and lowest temperatures ever reliably recorded in the regions of the particular categories specified for the materiel.

3. TERMS AND DEFINITIONS

The following terms and definitions are used for the purpose of these leaflets:

a. Climatic Category: a classification of the climate in each area of the world in terms of a set of temperature and humidity conditions.

b. Materiel: the generic term for all equipment, stores, packaging, and supplies used by NATO forces.

c. Meteorological Temperature: the ambient air temperature measured under standard conditions of ventilation and radiation shielding in a meteorological screen at a height of 1.2 to 2m above the ground.

d. Dew Point: the temperature at which the air is saturated with water vapour. The dew point is the temperature at which the vapour begins to condense as droplets of water when the temperature falls.

e. Solar Radiation: the combination of infra-red, visible and ultra-violet radiation from the sun. The spectral energy distribution of solar radiation at midday at sea level when the sun is directly overhead is given in Table 1.

f. Effects of Solar Radiation: the two main effects of solar radiation are (i) heat and (ii) actinic effects on materials. The thermal response of materiel to this radiation will depend to an appreciable extent upon its heat capacity and surface finish but typically a rise of 20^0C can result at its surface under clear skies on days when the direct solar radiation attains or exceeds 1000 W/m^2. For more precise values, field trials or accurate simulation become essential. For materiel directly exposed to solar radiation or to high levels of reflected radiation, the degradation effect of the ultra-violet and blue/green components on plastics, rubbers, paints, etc., must also be considered. More advice on solar radiation can be found in Method 305, Annex A.

Table 1: Spectral Energy Distribution of Solar Radiation at Sea Level

Spectral Region	Bandwidth (nm)	Natural Radiation (% of total)	Tolerance (% of total)		Irradiance (W/m^2)	Spectral Region Irradiance (W/m^2)
			Min	Max		
Ultraviolet - B	280-320	0.5	0.3	0.7	5.6	5.6
Ultraviolet - A	320-360	2.4	1.8	3	26.9	62.7
	360-400	3.2	2.4	4.4	35.8	
Visible	400-520	17.9	16.1	19.7	200.5	580.2
	520-640	16.6	14.9	18.3	185.9	
	640-800	17.3	12.8	19	193.8	
Infrared	800-3000	42.1	33.7	50.5	471.5	471.5
				Totals	1120	1120

Note: The values of demarcation between the ultraviolet, visible, and infrared quoted in some reference documents differ slightly from those in the above table.

ANNEX A

REFERENCES AND BIBLIOGRAPHY

A.1. DATA SOURCES

1. STANAG 2831: Climatic Environmental Conditions Affecting The Design Of Materiel For Use By NATO Forces Operating In A Ground Role (Cancelled).

2. US AFCRL-TR-74-0052: Synopsis of Background Material for Mil. Std 210B, Climatic Extremes for Military Equipment (1974).

3. US MIL-HDBK-310 Global Climatic Data for Developing Military Products (1997).

4. UK Met 0.617: Tables of Temperature, Relative Humidity and Precipitation for the World (1965).

5. UK Met O 856 Tables of Temperature, Relative Humidity, Precipitation, and Sunshine for the World. Part 1 N. America (1980), Part 3 Europe (1973) and Part 4 Africa (1983).

6. UK IMI Summerfield T.R. No 70/10: Application of Simulated Real-Life Climatic Cycles Derived from Available Meteorological Data (1970).

7. GAM EG 13, Annex Environmental Data.

A.2. REFERENCE DOCUMENTS

1. STANAG 2805A: Minimum Fordability Requirements for Tactical Vehicles and Guns, and Minimum Immersion Requirements for Combat Equipment Normally Installed or Carried in Open Vehicles or Trailers.

2. STANAG 4044: Adoption of a Standard Atmosphere.

3. STANAG 4194: Standardised Wave and Wind Environments and Shipboard Reporting of Sea Conditions.

4. UK Def Stan 00-35 Environmental Handbook for Defence Materiel, Part 4 Natural Environments, Issue 3, 07 May 1999.

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SECTION 2311
LEAFLET 2311/1
CLIMATIC CATEGORIES AND THEIR GEOGRAPHICAL LOCATION

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SECTION 2311
LEAFLET 2311/1
CLIMATIC CATEGORIES AND THEIR GEOGRAPHICAL LOCATION

1. SCOPE

This leaflet provides information on the general purpose, application and limitations of Leaflet 2311/1 and provides additional user guidance.

1.1. Purpose

To facilitate the discussion of ambient air temperatures and humidities, eleven climatic categories have been chosen to represent the distinctive types of climate to be found at the land surfaces of the world, and a further three have been selected to describe the conditions at the sea surface.

1.2. Application

a. For materiel located on the land surfaces, the requirements documents should specify a set of conditions from the high temperature categories (A1, A2, or A3), the low temperature categories (C0, C1, C2, C3, or C4) and where high humidity is the principal consideration; one from categories (B1, B2, or B3) should also be selected.

b. If real data are not available for the materiel when exposed to solar radiation, it is more appropriate to use Leaflet 2310/1 for induced Climatic Environments rather than natural meteorological temperature.

c. For the bulk sea surface, it is common for all three “M” categories to be specified as ships may enter tropical, temperate and arctic waters during service. For coastal waters it is more appropriate to specify the corresponding land service category.

d. Consideration should be given to the combination of ambient temperatures and their associated humidity to which the materiel will be exposed.

1.3. Limitations

a. The geographical areas in Maps 1–3 in this leaflet are not intended to indicate that the climate at each and every location complies exactly with the annual distributions and diurnal cycles given in Leaflet 2311/2.

b. These maps are supplied for use as a guide only in the engineering and logistic decision-making processes for a particular item of materiel to determine its required climatic design and performance criteria. If data applicable only to particular parts of an area are required, relevant meteorological authorities should be consulted. To avoid limitations in deployment, this approach should be used as infrequently as possible.

c. Use of this document is intended for initial design criteria. Once the materiel is in service, it is preferable to monitor actual conditions.

d. It is considered impractical to attribute categories to specific sea areas, but as a general guide, M1 and M2 apply to regions that experience tropical or temperate conditions, while M3 is representative of arctic conditions.

1.4. User Information

a. Eight of the categories pertaining to the land surface (termed A1, A2, A3, C0, C1, C2, C3, and C4 respectively) are defined with temperature as the principal consideration while the remaining three (termed B1, B2, and B3 respectively) represent climates in which high humidity is accompanied by warm temperatures as the critical characteristic.

b. The locations to which these categories apply are shown in Maps 1–3.

c. For the sea surface, two categories (termed M1 and M3 respectively) are defined with temperature as the principal consideration while the third (termed M2) represents sea climates in which a warm temperature is accompanied by high humidity.

d. The upper and lower values of the cycles detailed in Leaflet 2311/2 are summarised in Table 2.

e. The “B” categories are defined in Table 1 using humidity (dew point) as well as temperature. The values available for a large number of stations were as follows: T99 (99 percent temperature in the hottest month), T01 (1 percent temperature in the coldest month) and TDT 99 (the 99 percent dew point in the hottest month). TDT 99 has been used as it was thought to be the best single discriminant for the B category humidity and it has the advantage that it can be calculated in the same way as T99 and applies to the same month. The table shows the criteria that were used to produce the area of each B climatic category.

f. In certain cases, it may be necessary to consider another value TD99 (which is the 99 percent dew point for the wettest month).

g. Efforts should be made to use measured environmental data, especially for temperature and humidity when there is likely to be a temperature or humidity-based failure mode.

Table 1: Definitions for the Humid Climatic Categories

Climatic Category	T99 (99% air temperature of hottest month °C)	T01 (1% air temperature of coldest month °C)	TDT 99 (99% dew point temperature in hottest month °C)
B1 (jungle)	31 to 35	>17	>24.5
B2 (savannah with hot, dry season)	35 to 39.5	-	>25.5
B3 (Persian Gulf, Aden)	>39.5	-	>29

Notes:

1. These definitions are based on 3 or 6 hourly data from 1983–2001 for several thousand World Met Office (WMO) synoptic land stations worldwide.

2. B1 definition: the criterion T01>17°C is necessary to restrict the area to the wet tropics. The “jungle” areas are covered quite well by Met stations such as the Congo and the Amazon Basin, although there is a lack of good stations in West and Central Africa and parts of Amazonia. Most small tropical islands are covered by T99, as it will be below 35°C where there is a sea breeze.

3. B2 definition: difficult to define as it is not obvious whether to emphasise the temperature or humidity and these may maximise in different months. Many tropical highlands particularly in Africa are not covered by the B categories. B2 stations were typically savannah areas surrounding the jungle regions and approached the A2 areas. This category may still need to be adjusted.

4. B3 definition: the exact position of the station relative to the desert interior and the warm sea is critical. The land side is either A1 or A2, while small islands in the Persian Gulf may only be A3 or B2, e.g., Bahrain is A2. The Gulfs of Oman and Aden are B3 as well as the Persian Gulf and southern Red Sea littorals. The B3 areas are coastal and do not extend out into the sea regions.

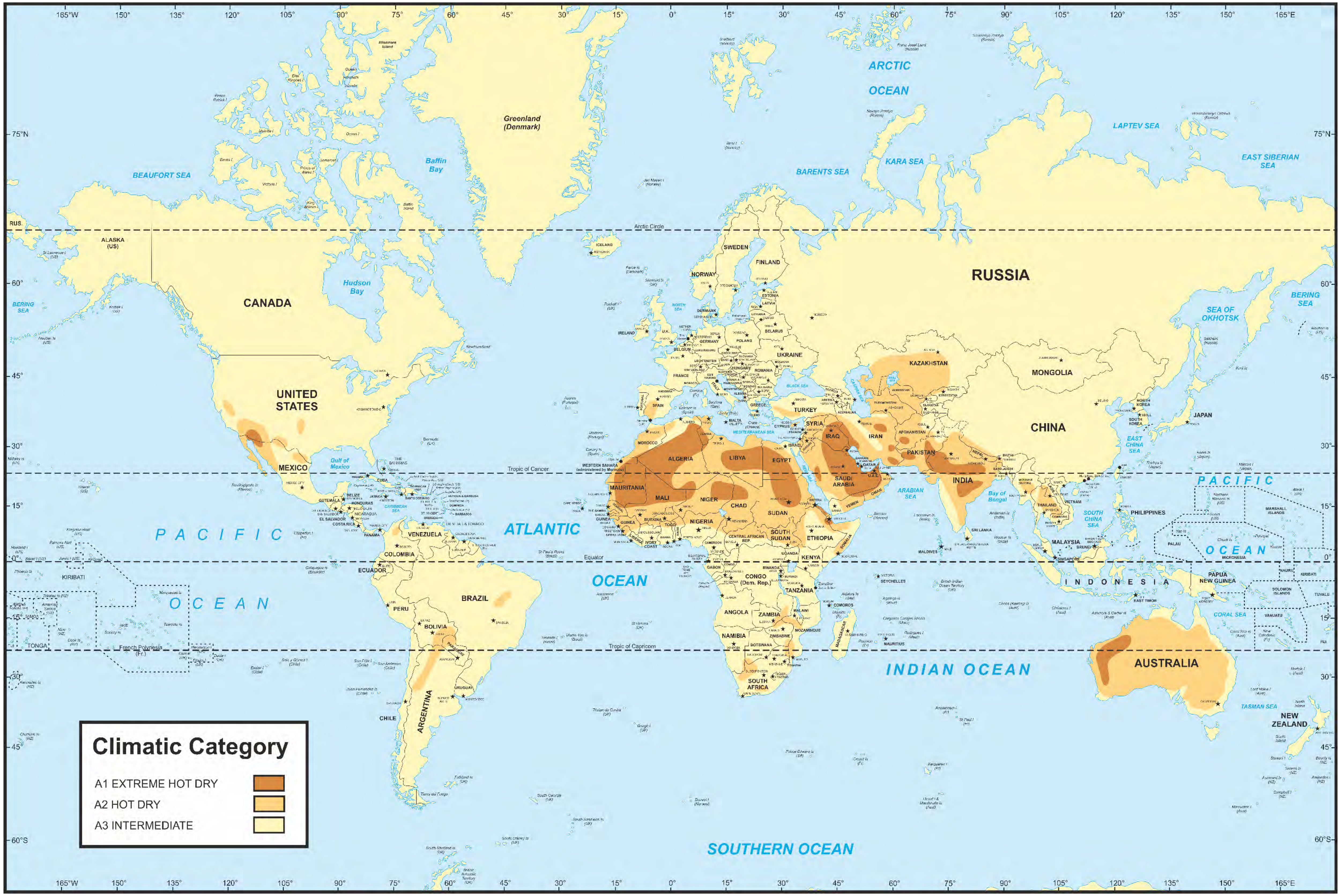
Table 2: Summarised Temperature and Humidity Cycles Worldwide

Cycle	Meteorological	
	Temperature (°C)	Relative Humidity (%)
A1	32 to 49	8 to 3
A2	30 to 44	44 to 14
A3	28 to 39	78 to 43
B1 - 7 days	24	100
B1 - 358 days	23 to 32	88 to 66
B2	26 to 35	100 to 74
B3	31 to 41	88 to 59
C0	-6 to -19	Tending to saturation
C1	-21 to -32	
C2	-37 to -46	
C3	-51	
C4	-57	
M1	29 to 48	67 to 21
M2	25.5 to 35	100 to 53
M3	-23 to -34	Tending to saturation

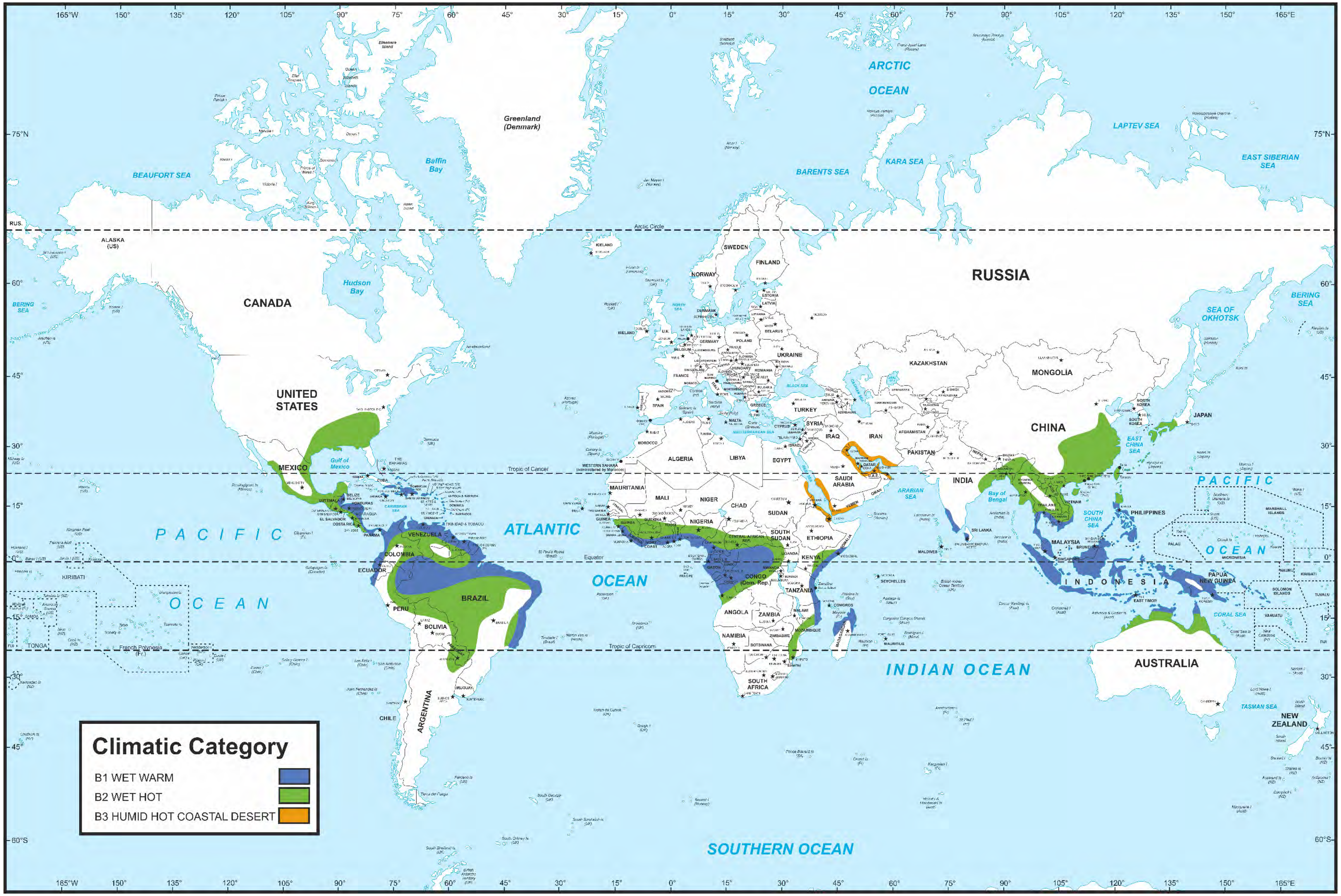
2. CLIMATIC CATEGORY LOCATION MAPS

The climate location maps are shown over the following pages. Note that these only give an approximate indication of the climate zone boundaries and are there is no definite demarcation between the climate zones.

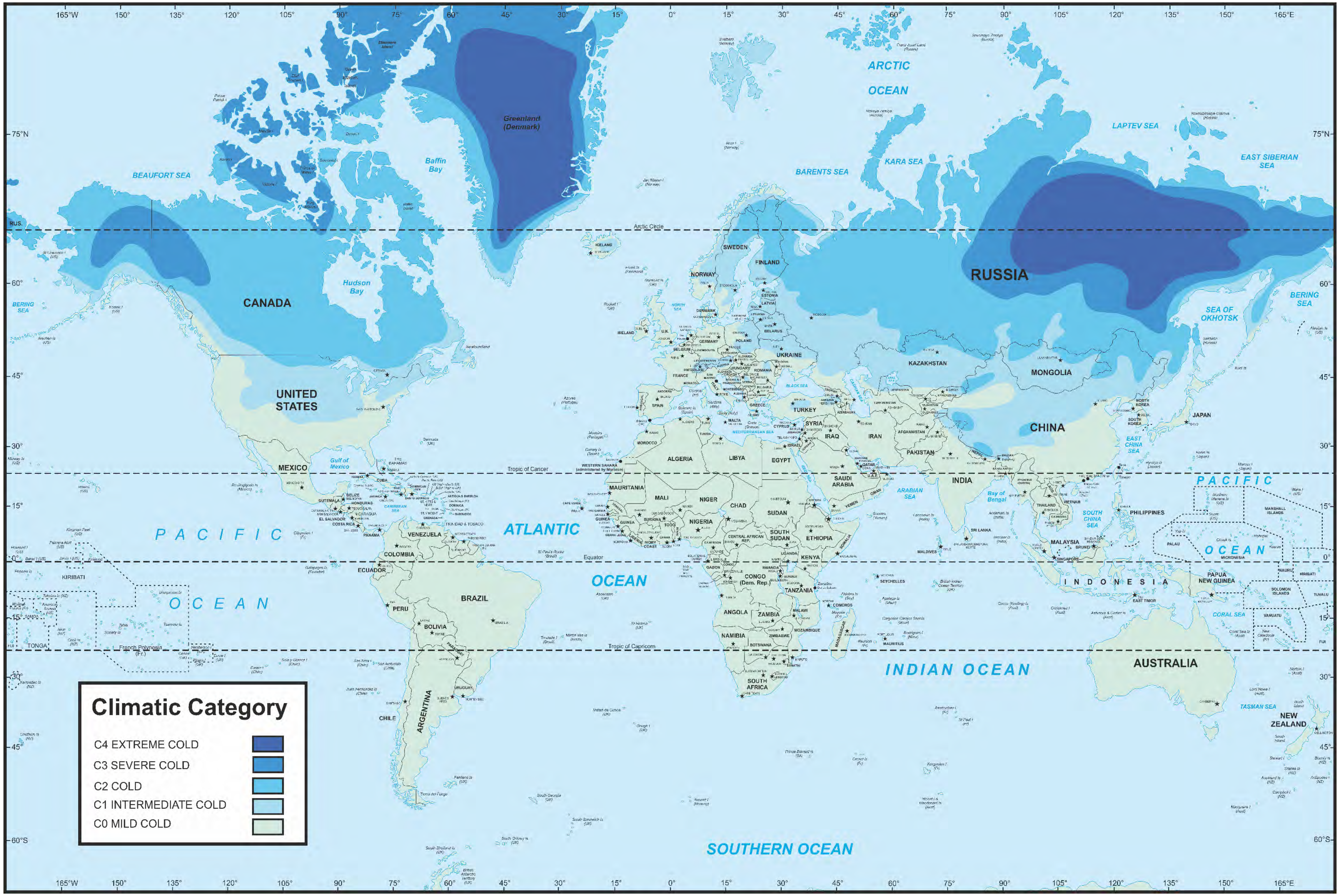
2.1. Map 1 Climatic Categories: Extreme Hot Dry A1, Hot Dry A2, and Intermediate A3



2.2. Map 2 Climatic Categories: Wet Warm B1, Wet Hot B2, and Humid Hot Coastal Desert B3



2.3. Map 3 Climatic Categories: Mild Cold C0, Intermediate Cold C1, Severe Cold C3, and Extreme Cold C4



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SECTION 2311
LEAFLET 2311/2
WORLDWIDE AMBIENT AIR TEMPERATURE AND HUMIDITY CONDITIONS AND LEVELS OF DIRECT SOLAR RADIATION

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SECTION 2311
LEAFLET 2311/2
WORLDWIDE AMBIENT AIR TEMPERATURE AND HUMIDITY CONDITIONS AND LEVELS OF DIRECT SOLAR RADIATION

1. SCOPE

1.1. Purpose

This Leaflet provides information about the ambient (meteorological) temperature, solar radiation, and humidity conditions found over the land at or near sea level and the sea surfaces of the various climatic categories identified in Leaflet 2311/1.

These land and sea surface conditions comprise the following:

a. A plot of the number of days of the year on which, on average, a given temperature is just attained or exceeded in the 5–10 percent climatically least hospitable regions of each category.

b. A plot of the relative humidity associated with the temperature.

c. The diurnal meteorological temperature cycle representative of conditions on days when extreme or near-extreme temperatures occur.

d. A plot of the total number of days and hours in the year that a given temperature is just attained or exceeded.

1.2. Application

a. These diurnal cycles are recommended for use in determining design criteria for NATO forces materiel.

b. For elevated ground, the appropriate correction factor is given in Table 2 of this Leaflet. For meteorological conditions at altitude, reference should be made to Tables 3–5.

c. The approximate boundaries for these categories are shown in Maps 1, 2, and 3 (Leaflet 2311/1). The description of some of the more important land surface regions of each category accompanies the diurnal cycles of temperature and humidity given in this Leaflet 2311/2. For the sea surface, two categories (termed M1 and M3 respectively) are defined with temperature as the principal consideration while the remaining category (termed M2) represents sea climates in which a warm temperature is accompanied by high humidity.

d. The upper and lower values of the cycles detailed in Leaflet 2311/2 are summarised in Table 1.

Table 1: Summarised Temperature and Humidity Cycles Worldwide

Cycle	Meteorological	
	Temperature (^oC)	Relative Humidity (%)
A1	32 to 49	8 to 3
A2	30 to 44	44 to 14
A3	28 to 39	78 to 43
B1 - 7 days	24	100
B1 - 358 days	23 to 32	88 to 66
B2	26 to 35	100 to 74
B3	31 to 41	88 to 59
C0	-6 to -19	Tending to saturation
C1	-21 to -32	
C2	-37 to -46	
C3	-51	
C4	-57	
M1	29 to 48	67 to 21
M2	25.5 to 35	100 to 53
M3	-23 to -34	Tending to saturation

1.3. Limitations

It is impractical to attribute categories to specific sea areas, but as a general guide, M1 and M2 apply to regions that experience tropical or temperate conditions, while M3 is representative of arctic conditions.

2. MODERATING FACTORS FOR CLIMATIC ENVIRONMENTAL CONDITIONS

2.1. Temperature Moderating Factors for Elevated Ground

The temperature quoted for Categories A1, A2, and A3 relate to ground elevations from sea level to 900 m. For ground elevations greater than 900 m, the moderating factor given in Table 2 should be applied. Similarly, the data for Categories B1, B2, and B3 relate to ground elevations from sea level to 1200 m, and for higher elevations the appropriate moderating factors quoted in Table 2 should be applied.

Table 2: Temperature Moderating Factors for Elevated Ground

Climatic category	Ground elevations above MSL	Moderating factors
A1, A2, A3	900 m	-1 ^{o}C per 100 m
B1	1200 m	-2 ^{o}C per 300 m
B2, B3	1200 m	-1 ^{o}C per 100 m

2.2. Temperature and Humidity at Altitude

2.2.1. Ambient Air Temperature at Altitude: Worldwide

The temperatures of the ambient air which, on a worldwide basis are estimated to be attained or exceeded for 7.4 hours (i.e., 1 percent of a month) of the hottest period of the year and for all but 7.4 hours of the coldest period of an average year are quoted for a range of altitudes in Table 3. The temperatures at other altitudes in the range can be calculated by linear interpolation between the two nearest values quoted. The highest and lowest temperatures ever reliably recorded at these altitudes are also given.

Table 3: Ambient Air Temperature at Altitude: Worldwide

Altitude km	Altitude kft	Highest temperature ever recorded °C	Value of 1% high temperature occurrence level °C	Value of 1% low temperature occurrence level °C	Lowest temperature ever recorded °C
0	0	58	49	-61	-68
1	3.28	41	40	-53	-54
2	6.56	32	30	-41	-47
4	13.1	19	17	-48	-53
6	19.7	8	6	-57	-61
8	26.2	-4	-5	-66	-68
10	32.8	-13	-13	-74	-75
12	39.4	-22	-22	-73	-80
14	45.9	-30	-30	-75	-77
16	52.5	-35	-37	-86	-87
18	59.1	-35	-37	-86	-88
20	65.6	-31	-32	-86	-87
22	72.2	-39	-30	-84	-85
24	78.7	-33	-33	-85	-86
26	85.3	-27	-28	-84	-84
28	91.9	-22	-23	-83	-84
30	98.4	-17	-18	-83	-85
35	115		3	-81	
40	131		25	-71	
45	148		30	-70	
50	164		37	-70	

Note: It should be noted that not all these highest (or lowest) temperatures at various altitudes occurred simultaneously nor necessarily at the same location and the set of values given in Table 3 do not represent a specific temperature-altitude profile.

2.2.2. Ambient Air Temperature at Altitude: Over Open Seas

The range of ambient air temperatures over open seas at any altitude below 16 km (52.5 kft) is significantly less than the range over land masses. The high and low values over open seas, calculated in a similar manner as those for the worldwide condition, are given in Table 4. Values of air temperature above 16 km (52.5 kft) are the same as those for worldwide.

Table 4: Ambient Air Temperature at Altitude: Over Open Seas

Altitude km	Altitude kft	Highest temperature ever recorded ºC	Value of 1% high temperature occurrence level ºC	Value of 1% low temperature occurrence level ºC	Lowest temperature ever recorded ºC
0	0	51	48	-34	-39
1	3.28	34	33	-29	-31
2	6.56	26	25	-31	-32
4	13.1	16	14	-39	-40
6	19.7	2	1	-46	-47
8	26.2	-8	-9	-56	-58
10	32.8	-20	-21	-69	-70
12	39.4	-36	-39	-74	-75
14	45.9	-35	-37	-75	-76
16	52.5	-35	-37	-86	-87

Notes:

1. It should be noted that not all these highest (or lowest) temperatures at various altitudes occur simultaneously nor necessarily at the same location and the set of values given in Table 4 do not represent a specific temperature-altitude profile.

2. The surface values are based on Abadam and Anchorage, Alaska.

2.2.3. Humidity at Altitude: Worldwide

The humidities, expressed in terms of dew points, which, in an average year, are exceeded for a total of 7.4 hours during the wettest month at various altitudes up to 8 km (26 kft) are listed in Table 5, together with the highest values ever recorded.

Table 5: Humidity at Altitude

Altitude km	Altitude kft	1% high humidity occurrence level of dew point ºC	Highest recorded dew point ºC
0	0	31	34
1	3.28	29	30
2	6.56	24	26
4	13.1	16	18
6	19.7	3	3
8	26.2	-8	-7

2.3.4. Direct Solar Radiation at Altitude

Although the thermal effect of direct solar radiation at altitude is somewhat greater than at sea level, for the purpose of this leaflet the values that apply at sea level, defined in the various appendices of this leaflet, are also taken at altitude. The degrading effect of the ultraviolet component of solar radiation on some materials (see Section 2311 – General Introduction, Paragraph 3.f) increases significantly with altitude. No figures are quoted since the effect is wavelength dependent and varies considerably from one material to another. For additional information on solar radiation at altitude see Method 305, Annex A.

3. AMBIENT AIR TEMPERATURE, HUMIDITY, AND DIRECT SOLAR RADIATION CONDITIONS OVER LAND AND NEAR SEA LEVEL.

3.1. A1: Extreme Hot Dry

a. Category A1 applies to areas which experience very high temperatures namely, hot, dry deserts of North Africa, parts of the Middle East, northern India and southwestern USA.

b. The general data for the meteorological conditions are given in Figures 1–3.

c. In addition, the cycle of maximum temperature and associated humidity, recommended as design criteria for materiel exposed to the A1 meteorological conditions is given in Table 6. The highest temperature of this cycle is that air temperature which is attained or exceeded at the hotter locations in the category, on average, for a total time of approximately 7.4 hours (i.e., 1 percent of one month) during the hottest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

d. The highest temperature ever reliably recorded for the A1 meteorological condition is 58ºC.

Table 6: Diurnal Cycle for the A1 Climatic Category

Local Time	Meteorological Conditions		
	Ambient Air Temperature	Relative Humidity	Solar Radiation
Hours	°C	%	W/m^2
0100	35	6	0
0200	34	7	0
0300	34	7	0
0400	33	8	0
0500	33	8	0
0600	32	8	55
0700	33	8	270
0800	35	6	505
0900	38	6	730
1000	41	5	915
1100	43	4	1040
1200	44	4	1120
1300	47	3	1120
1400	48	3	1040
1500	48	3	915
1600	49	3	730
1700	48	3	505
1800	48	3	270
1900	46	3	55
2000	42	4	0
2100	41	5	0
2200	39	6	0
2300	38	6	0
2400	37	6	0

Note: The vapour pressure in extreme hot, dry areas will vary according to the distance from the sea or other large expanses of water but is likely to be within the range 3 to 12 millibar. The diurnal variation is unlikely to exceed 3 millibar.

3.2. A2: Hot Dry

a. Category A2 applies to areas which experience high temperatures accompanied by moderately low humidities, namely, the most southerly parts of Europe, most of the Australian continent, south central Asia, northern and eastern Africa, coastal regions of North Africa, southern parts of USA and most of Mexico.

b. The general data for the meteorological conditions are given in Figures 1–3.

c. In addition, the cycle of maximum temperature and associated humidity, recommended as design criteria for materiel exposed to the A2 meteorological condition is given in Table 7. The highest temperature of this cycle is that air temperature which is attained or exceeded at the hotter locations in the category, on average, for a total time of approximately 7.4 hours (i.e. 1 percent of one month) during the hottest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

d. The highest temperature ever reliably recorded for the A2 meteorological condition is 53 °C.

Table 7: Diurnal Cycle for the A2 Climatic Category

Local Time Hours	Meteorological Conditions		
	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0100	33	36	0
0200	32	38	0
0300	32	43	0
0400	31	44	0
0500	30	44	0
0600	30	44	55
0700	31	41	270
0800	34	34	505
0900	37	29	730
1000	39	24	915
1100	41	21	1040
1200	42	18	1120
1300	43	16	1120
1400	44	15	1040
1500	44	14	915
1600	44	14	730
1700	43	14	505
1800	42	15	270
1900	40	17	55
2000	38	20	0
2100	36	22	0
2200	35	25	0
2300	34	28	0
2400	33	33	0

Note: The vapour pressure in hot, dry areas will vary according to the distance from the sea or other large expanses of water but is likely to be within the range 12 to 25 millibar. The diurnal variation is unlikely to exceed 2 millibar.

3.3. A3: Intermediate

a. In strict terms, Category A3 applies only to those areas that experience moderately high temperatures and moderately low humidities for at least part of the year. It is particularly representative of conditions in Europe except the most southern parts, Canada, the northern United States, and the southern part of the Australian continent.

b. However, for the purposes of this Agreement, Category A3 is considered to apply to all land masses except those designated as Category A1 or A2 areas in Map 1.

c. The general data for the meteorological conditions are given in Figures 1–3.

d. In addition, the cycle of maximum temperature and associated humidity, recommended as design criteria for materiel exposed to A3 meteorological conditions is given in Table 8. The highest temperature of this cycle is that air temperature which is attained or exceeded at the hotter locations in the category, on average, for a total time of approximately 7.4 hours (i.e. 1 percent of one month) during the hottest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

e. The highest temperature ever reliably recorded for the A3 meteorological condition is 42 ^{o}C.

Table 8: Diurnal Cycle for the A3 Climatic Category

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature ^{o}C	Relative Humidity %	Solar Radiation W/m^2
0100	30	69	0
0200	29	72	0
0300	29	74	0
0400	28	76	0
0500	28	78	0
0600	28	78	45
0700	29	74	170
0800	30	67	500
0900	31	59	800
1000	34	51	960
1100	36	47	1020
1200	37	45	1060
1300	38	44	1020
1400	38	43	915
1500	39	43	660
1600	39	44	250
1700	38	46	70
1800	37	48	15
1900	35	50	0
2000	34	53	0
2100	34	56	0
2200	32	59	0
2300	32	63	0
2400	31	66	0

3.4. General Data for the "A" Category Meteorological Conditions

Figures 1–3 for A1, A2, and A3 show the number of days in a year on which, on average a given temperature is exceeded, together with the corresponding dew points. The associated diurnal temperature cycles are in Tables 6–8.

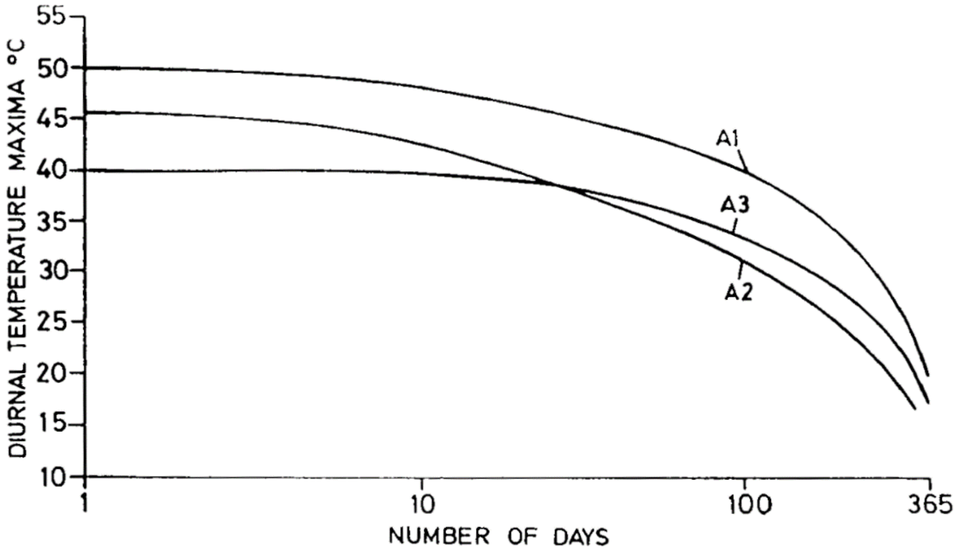


Figure 1: Diurnal Temperature Maxima

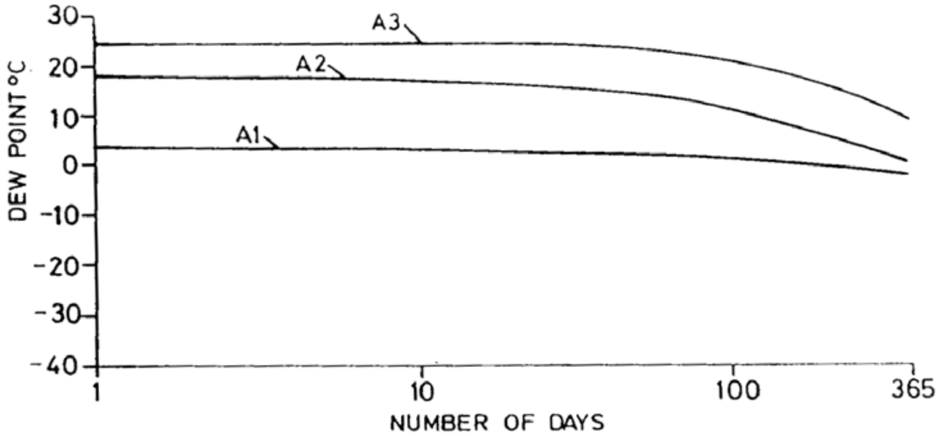


Figure 2: Dew Point

The number of hours in each year for which the air temperature just reaches or goes above a given value in the A1, A2, and A3 meteorological conditions. Computed from the information supplied in Figure 1 and Tables 6–8.

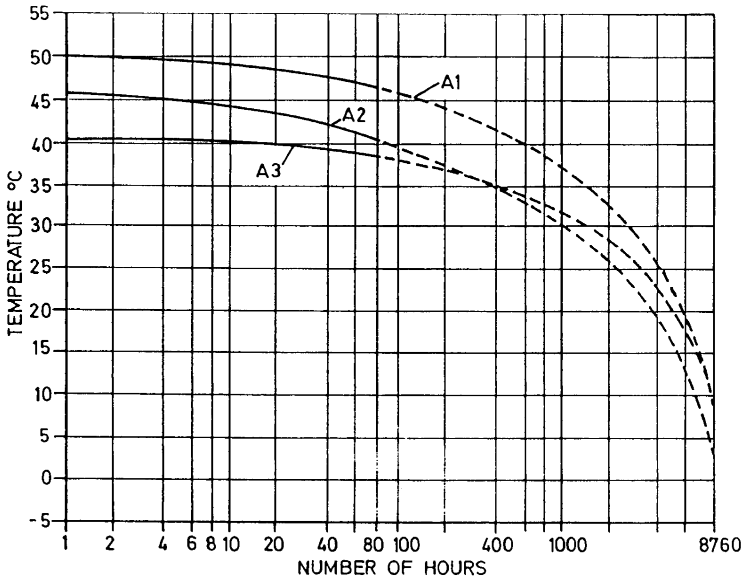


Figure 3: Temperature

3.5. B1: Wet Warm

a. Category B1 applies to those areas that experience moderately high temperatures accompanied by continuous very high relative humidity. These conditions are found in rain forests and other tropical regions during periods of continuous cloud cover, where direct solar radiation is not a significant factor. Geographical regions covered include the Zaire and Amazon basins, southeast Asia including the East Indies, the northeast coast of Madagascar and the Caribbean Islands.

b. The meteorological condition is derived from conditions recorded in Singapore.

c. The general data for the meteorological conditions are given in Figures 4–5

d. For materiel, it is recommended that trials be based on both the 7 days of saturation at 24°C and the temperature and humidity diurnal cycles, which are representative of conditions for the remainder of the year.

e. These data are given in Table 9.

Table 9: Diurnal Cycle for the B1 Climatic Category

Local Time Hours	Meteorological Conditions			
	Ambient Air Temperature °C	Relative Humidity %	Dew Point °C	Solar Radiation W/m^2
7 days per year 0300 0600 0900 1200 1500 1800 2100 2400	Nearly constant at 24°C throughout the 24 h	Nearly constant at 95–100% throughout the 24 h	Nearly constant at 24°C throughout the 24 h	Negligible on days when the accompanying temperatures and humidities occur
358 days per year 0300 0600 0900 1200 1500 1800 2100 2400	 23 23 28 31 32 29 26 24	 88 88 76 66 67 75 84 88	 21 21 23 24 25 24 23 22	Negligible on days when the accompanying temperatures and humidities occur

3.6. B2: Wet Hot

a. Category B2 applies to those areas which experience moderately high temperatures accompanied by high humidity and high direct solar radiation. These conditions occur in exposed areas of the wet tropical regions.

b. The meteorological condition is derived from observations made at the Gulf of Mexico coastal stations and subsequently confirmed by observations in other tropical areas.

c. The general data for the meteorological conditions are given in Figures 4–5.

d. In addition, the diurnal cycles of maximum temperature and humidity, recommended as design criteria for materiel exposed to the B2 meteorological conditions are given in Table 10. Although both higher temperatures and higher humidities are known to occur in regions of the B2 category, they rarely do so simultaneously at the same location.

Table 10: Diurnal Cycle for the B2 Climatic Category

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m²
0100	27	100	0
0200	26	100	0
0300	26	100	0
0400	26	100	0
0500	26	100	0
0600	26	100	45
0700	27	94	230
0800	29	88	460
0900	31	82	630
1000	32	70	800
1100	33	77	900
1200	34	75	970
1300	34	74	990
1400	35	74	915
1500	35	74	795
1600	34	76	630
1700	33	79	410
1800	32	82	230
1900	31	86	45
2000	29	91	0
2100	28	95	0
2200	28	96	0
2300	27	100	0
2400	27	100	0

3.7. B3: Humid Hot Coastal Desert

a. Category B3 applies to those areas which experience moderately high temperatures accompanied by high water vapour content of the air near the ground in addition to high levels of solar radiation. These conditions occur in hot areas near large expanses of water such as the Persian Gulf and the Red Sea.

b. The meteorological condition is derived from observations made at Dhahran and other hot, humid stations.

c. The general data for the meteorological conditions are given in Figures 4–5.

d. In addition, the diurnal cycles of maximum temperature and humidity, recommended as design criteria for materiel exposed to the B3 meteorological conditions are given in Table 11. Although both higher temperatures and higher humidities are known to occur in regions of the B3 category, they rarely occur simultaneously at the same location.

e. The meteorological conditions reported here are seasonal in nature and occur only during the summer months. In winter months the conditions are less severe, but for materiel requiring worldwide clearance for operational deployment the worst-case meteorological conditions must be assumed.

Table 11: Diurnal Cycle for the B3 Climatic Categories

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0100	31	88	0
0200	31	88	0
0300	31	88	0
0400	31	88	0
0500	31	88	0
0600	32	85	45
0700	34	80	315
0800	36	76	560
0900	37	73	790
1000	38	69	920
1100	39	65	1040
1200	40	63	1080
1300	41	59	1000
1400	41	59	885
1500	41	59	710
1600	41	59	460
1700	39	65	210
1800	37	69	15
1900	36	73	0
2000	34	79	0
2100	33	85	0
2200	32	85	0
2300	32	88	0
2400	31	88	0

3.8. General Data for the "B" Category Meteorological Conditions

Figure 4 for B1, B2, and B3 shows the number of days of the year on which, on average, a given temperature is just attained or exceeded, for the B1, B2, and B3 meteorological conditions. The associated diurnal temperature cycles and corresponding dew points or relative humidities are obtained from Tables 9–11.

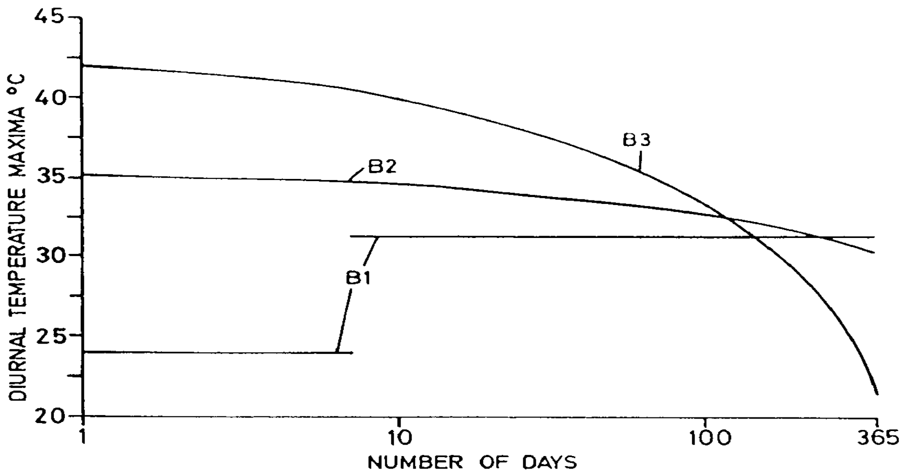


Figure 4: Diurnal Temperature Maxima

Figure 5 shows the number of hours in each year for which the air temperature just reaches or goes above a given value in the B1, B2, and B3 meteorological conditions. This is computed from the information supplied at Figure 4 and Tables 9–11.

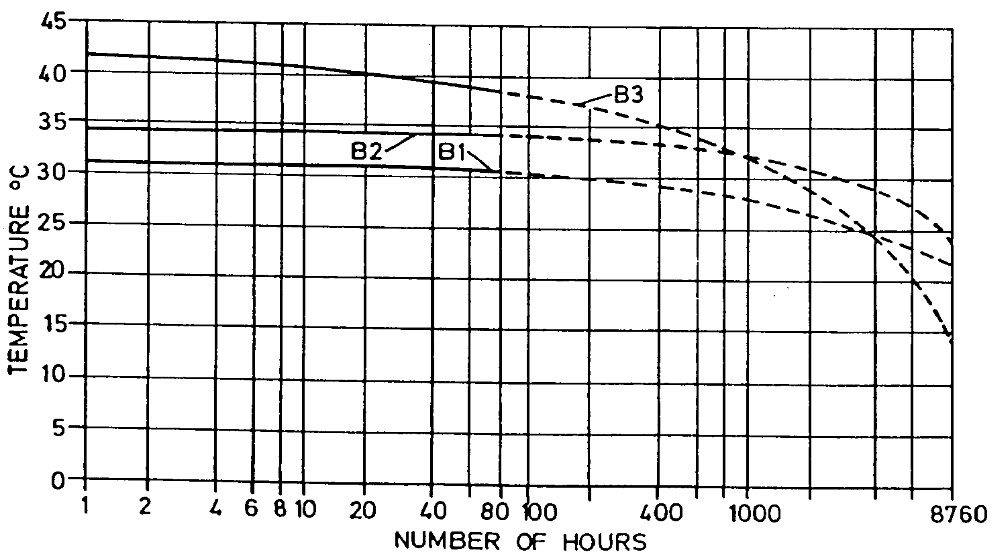


Figure 5: Temperature

3.9. C0: Mild Cold

a. In strict terms, Category C0 applies only to those areas which experience mildly low temperatures such as the coastal areas of Western Europe under prevailing maritime influence, southeast Australia and the lowlands of New Zealand.

b. However, for the purposes of this Agreement, Category C0 is considered to apply to all land masses except those designated as Category C1, C2, C3, or C4 in Map 3. This applies even to areas such as the Sahara or Persian Gulf.

c. The general data for the meteorological conditions are given in Figures 6–8.

d. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the C0 meteorological condition is derived from observations made at the coldest 5–10 percent European locations of this category are given in Table 12. The lowest temperature of this cycle is that air temperature which, on average, is attained or exceeded for all but approximately 7.4 hours (i.e. 1 percent of a month) during the coldest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

e. The lowest temperature ever reliably recorded for the C0 meteorological condition is -24 °C.

Table 12: Diurnal Cycle for the C0 Climatic Category

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m²
0300	-19	Tending to saturation	Negligible on days when accompanying temperatures occur
0600	-19		
0900	-15		
1200	-8		
1500	-6		
1800	-10		
2100	-17		
2400	-19		

3.10. C1: Intermediate Cold

a. Category C1 applies to those areas that experience moderately low temperatures such as central Europe, Japan, and the central USA.

b. The general data for the meteorological conditions are given in Figures 6–8.

c. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the C1 meteorological condition is given in Table 13. The lowest temperature of this cycle is that air temperature which, on average, is attained or exceeded for all but approximately 7.4 hours (i.e. 1 percent of a month) during the coldest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

d. The lowest temperature ever reliably recorded for condition is -42 °C.

Table 13: Diurnal Cycle for the C1 Climatic Category

Local Time Hours	Meteorological Conditions		
	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0300	-32	Tending to saturation	Negligible on days when accompanying temperatures occur
0600	-32		
0900	-26		
1200	-21		
1500	-21		
1800	-25		
2100	-28		
2400	-32		

3.11. C2: Cold

a. Category C2 applies to the colder areas, which include northern Norway, the prairie provinces of Canada, Tibet, and much of the Russian Federation.

b. The general data for the meteorological conditions are given in Figures 6–8.

c. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the C2 meteorological condition is given in Table 14. The lowest temperature of this cycle is that air temperature which, on average, is attained or exceeded for all but approximately 7.4 hours (i.e. 1 percent of a month) during the coldest period of the year at several of the colder locations in Canada. The profile of this cycle is typical of those for days when this temperature is just attained.

d. The lowest temperature ever reliably recorded for the C2 meteorological condition is -56°C.

Table 14: Diurnal Cycle for the C2 Climatic Category

Local Time Hours	Meteorological Conditions		
	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0300	-46	Tending to saturation	Negligible on days when accompanying temperatures occur
0600	-46		
0900	-43		
1200	-37		
1500	-37		
1800	-39		
2100	-43		
2400	-45		

3.12. C3: Severe Cold

a. Category C3 applies to the coldest area of the North American continent and the areas surrounding the coldest parts (C4) of Siberia and Greenland.

b. The general data for the meteorological conditions are given in Figures 6–8.

c. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the C3 meteorological condition is given in Table 15. It should be noted that, as the coldest days are in reality prolonged nights, the temperature is constant throughout the 24 hours.

Table 15: Diurnal Cycle for the C3 Climatic Category

Local Time Hours	Meteorological Conditions		
	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0300 0600 0900 1200 1500 1800 2100 2400	Nearly constant at -51°C throughout the 24 h	Tending to saturation	Negligible on days when accompanying temperatures occur

3.13. C4: Extreme Cold

a. Category C4 applies to the coldest areas of Greenland and Siberia.

b. The general data for both the meteorological and storage conditions are given in Figures 6–8.

c. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the C4 meteorological condition is given in Table 16. It should be noted that, as the coldest days are in reality prolonged nights, the temperature is constant throughout the 24 hours.

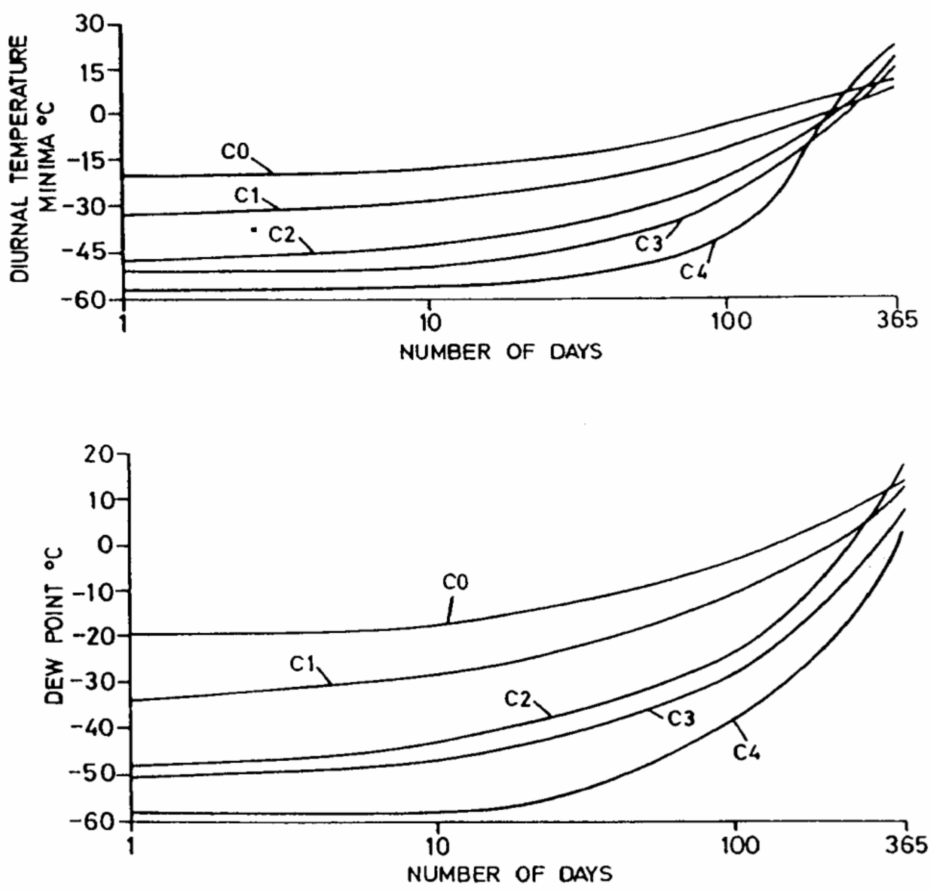
d. The lowest temperature ever reliably recorded for the C4 meteorological condition is -68°C.

Table 16: Diurnal Cycle for the C4 Climatic Category

Local Time Hours	Meteorological Conditions		
	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0300 0600 0900 1200 1500 1800 2100 2400	Nearly constant at -57°C throughout the 24 h	Tending to saturation	Negligible on days when accompanying temperatures occur

3.14. General Data for the “C” Category Meteorological Conditions

Figures 6 and 7 for C0, C1, C2, C3, and C4 show the number of days in a year on which, on average a given temperature is exceeded, together with the corresponding dew points. The associated diurnal temperature cycles are in Tables 12–16.



Figures 6 and 7: Diurnal Temperature Maxima and Dew Point

The number of hours in each year for which the air temperature just reaches or goes below a given value in the C0, C1, C2, C3, and C4 meteorological conditions. This is computed from the information supplied at Figure 6 and Tables 12–16.

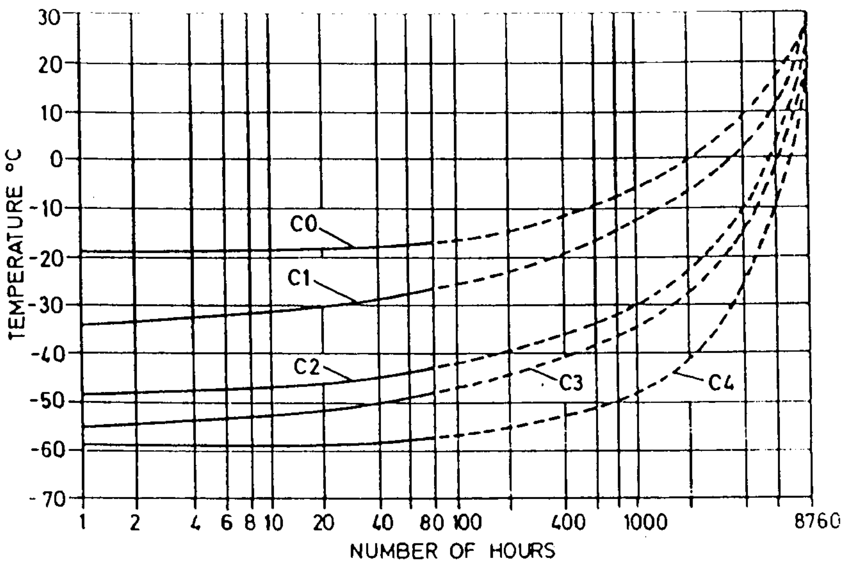


Figure 8: Temperature

3.15. M1: Marine Hot

a. Category M1 applies to tropical bulk sea areas where high ambient air temperature is the predominant climatic characteristic.

b. The general data for the meteorological and conditions is given in Figures 9–11.

c. In addition, the cycle of maximum temperature and associated humidity, recommended as design criteria for materiel exposed to the M1 meteorological condition is given in Table 17. The highest temperature of this cycle is that air temperature which is attained or exceeded at the hottest locations in the category, on average, for a total time of approximately 7.4 hours (i.e. 1 percent of one month) during the hottest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

d. The highest temperature ever reliably recorded for the M1 meteorological condition is 51 °C.

Table 17: Diurnal Cycle for the M1 Climatic Category

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0100	32.5	51	0
0200	31.5	53	0
0300	31	55	0
0400	29.5	60	0
0500	29	64	0
0600	29	67	55
0700	31.5	61	270
0800	34.5	51	505
0900	38	38	730
1000	40.5	32	915
1100	43	28	1040
1200	45	25	1120
1300	46.5	22	1120
1400	48	21	1040
1500	48	21	915
1600	47.5	23	730
1700	46.5	27	505
1800	45	33	270
1900	42.5	37	55
2000	40.5	41	0
2100	38	43	0
2200	36.5	45	0
2300	35	47	0
2400	34	49	0

3.16. M2: Marine Intermediate

a. Category M2 applies to the warmer, mid-latitude regions of the seas, particularly to temperate sea areas where high humidity combined with moderately high temperatures are the principal climatic characteristics.

b. The general data for the meteorological conditions is given in Figures 9–11.

c. In addition, the diurnal cycles of maximum temperature and humidity, recommended as design criteria for materiel exposed to the M2 meteorological conditions are given in Table 18. Although both higher temperatures and higher humidities are known to occur in regions of the M2 category, they rarely do so simultaneously at the same location.

Table 18: Diurnal Cycle for the M2 Climatic Category

Local Time	Meteorological Conditions		
	Ambient Air Temperature	Relative Humidity	Solar Radiation
Hours	°C	%	W/m²
0100	26.5	100	0
0200	26.5	100	0
0300	26	100	0
0400	26	100	0
0500	25.5	100	0
0600	26	100	45
0700	28	90	170
0800	29.5	82	470
0900	31	74	790
1000	32.5	70	920
1100	33.5	67	1040
1200	34	63	1080
1300	35	58	1040
1400	35	55	930
1500	35	54	710
1600	34	57	470
1700	33	62	190
1800	32	71	15
1900	30	77	0
2000	29	82	0
2100	28	88	0
2200	27.5	90	0
2300	27.5	92	0
2400	27	94	0

3.17. M3: Marine Cold

a. Category M3 applies to the colder regions of the seas, particularly the Arctic zone where low ambient air temperature is the predominant climatic characteristic.

b. The general data for the meteorological conditions is given in Figures 9–11.

c. In addition, the minimum temperature cycle recommended as a design criterion for materiel exposed to the M3 meteorological condition is given in Table 19. The lowest temperature of this cycle is that air temperature which, on average, is attained or exceeded in the colder regions for all but approximately 7.4 hours (i.e. 1 percent of a month) during the coldest period of the year. The profile of this cycle is typical of those for days when this temperature is just attained.

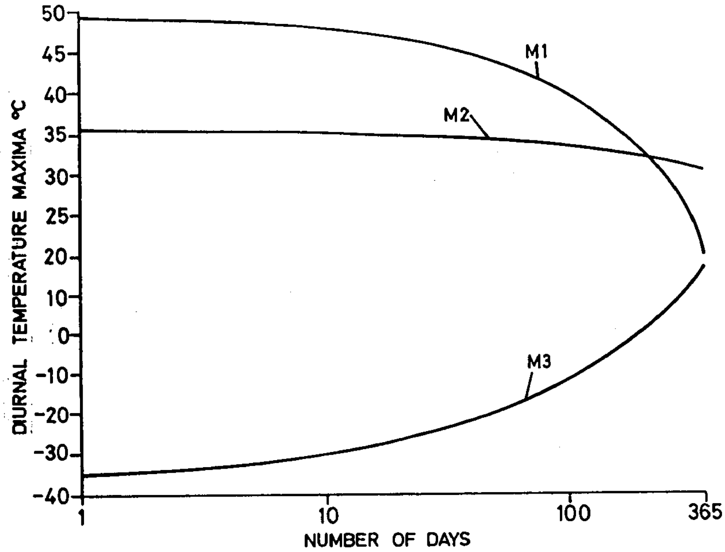
d. The lowest temperature ever reliably recorded for the M3 meteorological condition is -38 °C.

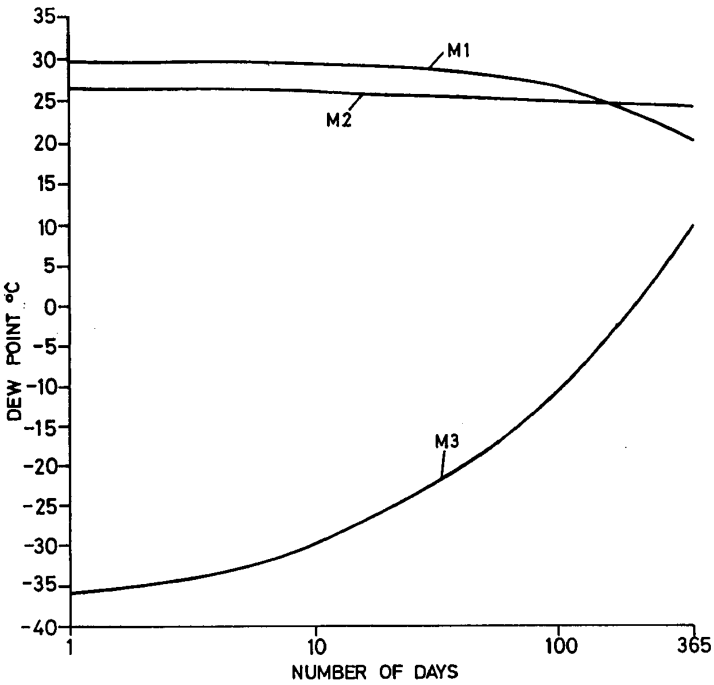
Table 19: Diurnal Cycle for the M3 Climatic Category

Local Time	Meteorological Conditions		
Hours	Ambient Air Temperature °C	Relative Humidity %	Solar Radiation W/m^2
0300	-34	Tending to saturation	Negligible on days when accompanying temperatures occur
0600	-34		
0900	-28		
1200	-23		
1500	-23		
1800	-26		
2100	-31		
2400	-34		

3.18. General Data for the "M" Category Meteorological Conditions

Figures 9 and 10 show the number of days of the year on which, on average, a given temperature is just attained or exceeded or in the case of Category M3 a given minimum temperature is not exceeded, together with the corresponding dew points, for the M1, M2, and M3 meteorological conditions. The associated diurnal temperature cycles are obtained from Tables 17–19.





Figures 9 and 10: Diurnal Temperature Maxima and Dew Point

The number of hours in each year for which the air temperature just reaches or goes above a given value, or in the case of Category M3 a minimum temperature is not exceeded, in the M1, M2, and M3 meteorological conditions as shown in Figure 11. This is computed from the information supplied at Figure 9 and Tables 17–19.

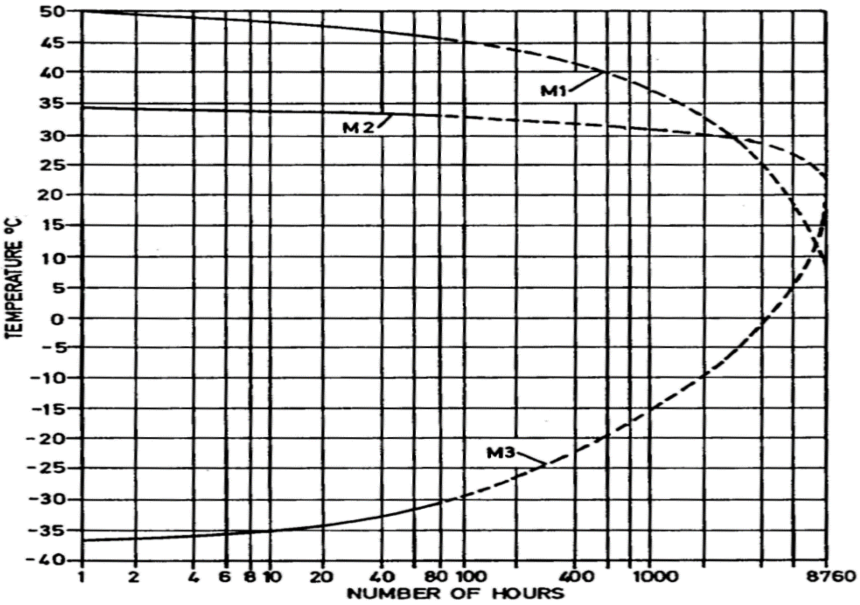


Figure 11: Temperature

SECTION 2311
LEAFLET 2311/3
ADDITIONAL CLIMATIC ENVIRONMENTAL FACTORS

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SECTION 2311
LEAFLET 2311/3
ADDITIONAL CLIMATIC ENVIRONMENTAL FACTORS

1. SCOPE

1.1. Purpose

This leaflet briefly discusses these additional factors and, where possible, recommends intensity levels which should be used in appropriate circumstances, as design and test criteria for materiel intended for use by NATO Forces. In addition, the highest and/or lowest intensity levels ever reliably recorded under natural conditions are quoted.

1.2. Application

Although temperature, humidity and solar radiation are primary considerations when preparing statements on the climatic environment of materiel, the additional factors covered by this document should also be taken into account.

1.3. Limitations

Some of the additional climatic environmental extremes may not be applicable depending upon the user requirements and/or the predicted manufacture to target or disposal sequence (lifecycle).

2. ADDITIONAL CLIMATIC ENVIRONMENTAL FACTORS

2.1. Atmospheric Pressure

a. Materiel should remain safe and be capable of acceptable performance at all values of atmospheric pressure from the highest to the lowest recorded for each environment to which the materiel will be exposed.

b. The highest value of atmospheric pressure recorded at sea level is 1084 mbar. The lowest value recorded at the sea surface is 870 mbar, and the lowest value for the highest ground elevation contemplated for the operation, storage, and transportation of materiel of NATO forces is 503 mbar.

c. The highest and lowest values of atmospheric pressure estimated for a range of altitudes up to 30 km (98.4 kft) are given in Table 1.

d. The frequency of occurrence (99 percent and 1 percent) values of atmospheric pressure up to 80km are reported in Table 1 below are taken from Mil Hdbk-310.

Table 1: Atmospheric Pressures at Altitude [1 mbar = 0.1kPa = 1hPa = 100Pa]

Altitude	Altitude	Highest Recorded Atmospheric Pressure	99% Atmospheric Pressure	1% Atmospheric Pressure	Lowest Recorded Atmospheric Pressure
km	kft	mbar	mbar	mbar	mbar
0	0	1084	-	-	870
1	3.28	930	920	847	842
2	6.56	821	817	742	736
4	13.1	643	642	550	548
6	19.7	501	499	408	406
8	26.2	385	384	299	296
10	32.8	294	293	218	215
12	39.4	226	226	157	154
14	45.9	168	167	111	111
16	52.5	123	123	79	79
18	59.1	88	88	56	56
20	65.6	65	65	41	40
22	72.2	45	45	29	28
24	78.7	35	34	21	20
26	85.3	26	25	15	14
28	91.9	20	19	11	10
30	98.4	15	15	9	7
35	114.8	-	7.6	3.1	-
40	131.2	-	4.1	1.5	-
45	147.6	-	2.2	0.67	-
50	164.0	-	1.2	0.31	-
55	180.4	-	0.71	0.15	-
60	196.9	-	0.39	0.074	-
65	213.3	-	0.19	0.035	-
70	229.7	-	0.086	0.017	-
75	246.1	-	0.037	0.0080	-
80	262.5	-	0.015	0.0035	-

Note: The reported pressures at the various altitudes do not necessarily occur simultaneously nor necessarily at the same location and the set of values given in Table 1 does not represent a specific pressure altitude profile.

2.2. Ozone Concentrations

If the requirements documents require exposure to ozone to be taken into consideration when designing particular items of materiel, the 1 percent concentrations given in Table 2 should be taken as representing the meteorological conditions at altitudes from 0 (sea level) to 30 km (98.4 kft).

Table 2: Ozone Concentration at Altitude for the Meteorological Condition

Altitude km	Altitude kft	Ozone concentration for Meteorological Condition $\mu g/m^3$
0	0	220
1	3.28	205
2	6.56	190
4	13.1	170
6	19.7	170
8	26.2	460
10	32.8	735
12	39.4	865
14	45.9	975
16	52.5	1100
18	59.1	1075
20	65.6	845
22	72.2	730
24	78.7	650
26	85.3	505
28	91.9	430
30	98.4	330

Note: The greatest concentration of ozone ever recorded in the open at sea level due to natural conditions is 980 $\mu g/m^3$.

2.3. Wind

Wind is subject to fluctuations on a variety of scales, with periods ranging from a fraction of a second to several minutes. Fluctuations about the mean speed comprise the gustiness of the wind. Large variations can occur between places a short distance apart, and it is not possible to indicate all the special problems which arise. This chapter attempts to provide data relating to mean winds and gustiness.

2.3.1. Mean Wind Speed

a. Variation of wind speed with height:

In the lowest levels of the atmosphere friction with the earth's surface is the dominant feature so that, in general, the mean wind speed increases with increasing height above ground up to about 600 meters, above which the variation becomes primarily dependent on factors other than friction. Since the measured wind depends on height above ground all values given have been reduced to their equivalents at the World Meteorological Organisation (WMO) standard height of 10 m.

b. Frequency of very strong winds:

Figures 1 and 2 show the percentage frequency in the average year when the mean wind speed (measured over an interval of 5 to 10 minutes), equals or exceeds 14 ms^{-1} and 25ms^{-1} respectively. The charts are to some extent subjective and they refer to the standard height of 10 meters over the sea or fairly open and low-lying ground; they should not therefore be used to infer probabilities in mountainous areas or when special problems of aspect or exposure arise.

2.3.2. Gustiness

Gustiness results mainly from roughness of the earth's surface and is accentuated when the air flows over trees, buildings and other obstacles. However, it is also a feature of the eddies developed by convective currents and such currents form most readily when temperature near the surface falls off rapidly with height, i.e., usually during the hottest part of the day. Gustiness over land is, therefore, usually more pronounced by day than by night, whilst over the sea where frictional effects and the diurnal temperature range are both small, gustiness is relatively slight at any time of day and is usually associated with convection, which develops when cold air flows over warmer sea.

a. Period of measurement:

The gust recorded by an instrument depends on the sensitivity of that instrument. For this reason it may be assumed that a speed averaged over about 3 seconds has been used for the data concerning extreme gust speeds, etc., quoted below.

b. Extreme gust speeds:

Figure 3 is a world map showing the maximum gust likely to be experienced once in 10 years, based on analyses as outlined in Reference 3 and various building design codes of practice. The estimates are for the standard height of 10 m over the sea or fairly level country and they are not applicable to mountainous regions or to places that have local peculiarities of exposure or topography. Exceptionally high gusts, which may occur in tropical storms, are also excluded.

c. Gust ratios:

(1) The ratio of the maximum speed of a gust to the mean wind speed is known as the "gust ratio" and provides a measure of gustiness of the wind.

(2) For level sites in open country Table 3 gives the ratio of the probable, maximum gust averaged over time (t) to the mean hourly wind speed. These factors are probably too high for open coastal exposures but will be too low for city and urban situations and may be rather low for open but not level, rural exposures. The ratios given in Table 4 have therefore been proposed for estimating maximum speeds over 1 minute, 30 seconds, and 10 seconds respectively, using a known mean hourly wind speed.

(3) Since the gust ratio is largely determined by roughness of the terrain, an indication of this roughness can be obtained from the ratio of the maximum gust measured over 3 seconds to the mean hourly wind speed, both determined from many years of data. Knowing this ratio it is possible to calculate the maximum

speed for any time intervals up to 1 hour, using the factors shown in Table 5. Owing to the dependence of gust ratios on terrain there may be some slight differences between Tables 3 and 4.

Table 3: Probable Maximum Gust for Level Sites in Open Country

time (t)	1 hour	10 min	1 min	30 sec	20 sec	10 sec	5 sec	2 sec	1 sec	0.5 sec
gust ratio	1.00	1.06	1.24	1.32	1.36	1.43	1.48	1.54	1.57	1.60

Note: Ratio of probable maximum mean speed averaged over time (t) to the mean hourly speed.

Table 4: Suggested Ratios for Estimating Maximum Mean Speeds Over Short Periods from a Known Mean Hourly Speed

	1 minute	30 seconds	10seconds
Open rural exposures	1.25	1.33	1.45
Urban and City exposures	1.45	1.60	1.80

Table 5: Factors for Calculating Maximum Wind Speed for Various Intervals Using the Mean Speed Measured Over the Hour

RATIO	CONVERSION FACTORS					
maximum mean speed/mean hourly speed	10 min	1 min	30 sec	15 sec	10 sec	3 sec
1.4	1.05	1.17	1.22	1.27	1.30	1.40
1.5	1.05	1.20	1.26	1.33	1.37	1.50
1.6	1.06	1.23	1.30	1.38	1.43	1.60
1.7	1.06	1.25	1.34	1.44	1.50	1.70
1.8	1.06	1.27	1.37	1.48	1.55	1.80
1.9	1.06	1.28	1.39	1.52	1.60	1.90
2.0	1.06	1.29	1.42	1.56	1.66	2.00
2.1	1.06	1.30	1.44	1.60	1.71	2.10

2.3.3. Extreme Winds

The general term “cyclone” describes an area where atmospheric pressure is lower than in surrounding areas and the general flow of air is anticlockwise north of the equator but clockwise in the southern hemisphere. Low-pressure systems that cause strong wind conditions may be classified but the definitions are not always exclusive and names vary from region to region.

a. Depressions or lows:

These terms are applied to cyclones of middle and high latitudes or weak tropical cyclones. These features range in size from a few hundred to around 2000 km diameter and usually move west to east. Widespread and sustained strong winds are possible especially over the North Atlantic, the southern oceans south of about 40 °S, and exposed coastal regions. In these regions winds may exceed 14 m/s (27 kt) for 10–25 percent of the year, however steady winds are usually less than 31 m/s (60 kt) although gusts may exceed 51 m/s (100 kt) about once in 10 years.

b. Tropical storms or tropical cyclones:

Cyclones generated over warm tropical oceans, commonly 500 – 1000 km diameter, usually move east to west but tend to curve away from the equator. Wind speeds are normally 17 – 32 m/s (34 – 63 kt) i.e., more than gale force but less than hurricane force.

c. Hurricanes:

By definition, a tropical storm becomes a hurricane (or typhoon, cyclone, etc.) if wind speeds are 33 m/s (64 kt) or more; the upper limit is unknown but speeds around 103 m/s (200 kt) have been reliably reported. Hurricanes often travel at 15–30 km/h (8–16 kt) but can exceed 50 km/h (27 kt) especially in higher latitudes, and may last from 2 days to 2 weeks. An indication of the areas affected and the probabilities is included in Figure 4.

d. Whirlwinds:

(1) These narrow revolving windstorms occur commonly over most of the world. Many are small, innocuous, transient features but some are devastatingly destructive owing to the combined effects of wind strength, twisting and suction. The extreme phenomena, usually called tornadoes, are often associated with thunderstorms and may occur as a group or family of storm cells. The area most frequently affected by tornadoes is the USA where 700–1200 are reported each year. As in other parts of the world the most common type of tornado lasts only a minute or two and causes little damage. The path of destructive tornadoes is often 100–700 m wide and the track length less than 25 km and the duration perhaps 30 minutes. The most devastating tornadoes (perhaps 2 percent of total) may be 1.5–2 km wide along a track up to 450 km long and lasting 2–4 hours. The upper limit of wind speeds is unknown but recent estimates suggest a figure around 125 m/s (250 kt).

(2) The chance of a single location of 2.59 km^2 (one square mile) being affected by a tornado in any year is less than 1 in 1000, even in the *most* vulnerable parts of the USA, and the chance of a location in NW Europe being affected is estimated at less than 1 in 10,000, a return period of one in at least 20,000 years.

(3) Whirlwinds that occur on a small scale in many parts of the world may also be vigorous enough to raise dust or even water to be visible as a dust devil or a waterspout.

e. Non-rotating phenomena:

Violent winds may also occur over Polar regions where the katabatic outflow from ice plateaux, enhanced by the topography can reach speeds around 75 m/s (150 kt). Elsewhere in the world, squalls associated with a downburst of air from a thunderstorm may locally generate winds of 50 m/s (100 kt) at the surface.

f. Scale of wind systems:

Figure 5 is a schematic diagram illustrating the relative scale and strength of meteorological wind systems.

g. Design criteria:

Unless overriding considerations dictate to the contrary, requirements documents should require materiel to remain safe when exposed to the conditions described in Figure 3. The materiel should be capable of acceptable performance when exposed to winds and gusts having speeds up to the maximum respective values given in Table 6.

Table 6: Wind and Gust Speeds at Heights of 3m Above Ground Recommended as Design Criteria

1-minute steady speed (m/s)	Gust speed(m/s) for shortest horizontal dimension of materiel					
	0.7m	1.5m	3m	8m	15m	30m
22	34	31	30	28	27	26
Note: data are based on the 99 percent steady 1-minute 3m wind speed at Stornoway in December (22m/s) with the associated gust speeds.						

2.4. Precipitation

a. Precipitation is defined as all forms of hydrometeors, both liquid and solid, which are free in the atmosphere and which reach the Earth's surface. It embraces rain, snow, and hail, each of which is discussed under the appropriate heading.

b. Precipitation intensity is defined in this Agreement as the rate at which precipitation falls. Although the values in Table 6 may be considered as instantaneous rates, in practice they are averages taken over periods of one minute or longer.

c. Unlike air temperatures which, at any particular time, are often substantially the same (±5°C) over relatively large regions, a value of precipitation intensity is peculiar to the highly localised area where the measurement is made and, at a relatively short distance away, the intensity may differ by a factor of two or more. Thus, it is impracticable in this Agreement to relate precipitation intensity to specific areas of the world with adequate detail so, apart from a European rain condition, only data on a worldwide basis are given.

d. At altitudes below the freezing level, 4.5 km (14.8 kft) in the tropics, precipitation may occur as liquid or solid particles but above this level snow or hail will predominate.

e. For the general meteorological condition on a worldwide basis, materiel should remain safe and be capable of acceptable performance when exposed to precipitation whose intensity is attained or exceeded for only a specified small portion of the wettest month of the year. Normally, this small portion is taken to be 0.5 percent but in some circumstances where a higher intensity may need to be specified, the value for 0.1 percent is recommended.

f. The precipitation intensities on a worldwide basis associated with these proportions of time are given in Table 7 for a range of altitudes up to 20 km. However, for materiel destined only for Europe, the intensities at 0 m (sea level) may be relaxed to the values given for the European rain condition in Table 8.

Table 7: Precipitation Intensities: Worldwide

Altitude		Intensity exceeded for 0.5% of wettest month	Intensity exceeded for 0.1% of wettest month	Estimated greatest ever precipitation
km	kft	mm/min	mm/min	mm/min
0	0	0.80	3.13	31
1	3.28	0.87	3.40	34
2	6.56	0.93	3.60	36
4	13.1	1.00	4.10	41
6	19.7	1.10	4.20	42
8	26.2	0.77	3.00	30
10	32.8	0.51	2.00	20
12	39.4	0.35	1.40	14
14	45.9	0.22	0.84	9
16	52.5	0.11	0.40	4
18	59.1	0.02	0.09	1
20	65.6	0	0	0

2.4.1. Rainfall

a. The data are based on observations in Southeast Asia that is recognised as the wettest region of the world.

b. Thus, in the region selected, materiel should remain safe and be capable of acceptable performance in rainfall whose intensity is attained or exceeded for only a specified small portion of the wettest month of the year.

c. For the general meteorological condition, this small portion should be 0.5 percent. However, in some circumstances where a higher intensity is considered necessary, the value which is exceeded for 0.1 percent of the time is recommended. The intensities associated with these time values are given in Table 7.

d. The intensities shown in Table 7 will seldom persist for more than a few consecutive minutes. During a rainstorm the rain intensity varies widely in an unpredictable manner and, at least on some occasions, the highest intensities experienced during the wet seasons will exceed those for the 0.1 percent level by factors of two or more. The highest values ever recorded on a worldwide basis for three durations are quoted in Table 8.

e. Flooding is a possible consequence of heavy rainfall and may lead to materiel being immersed in water (see Immersion 2.4.3).

Table 8: Worldwide Rainfall Intensities (Sea Level)

Region	Intensities exceeded for 0.5% of wettest month	Intensity exceeded for 0.1% of wettest month
Worldwide	0.80 mm/min	3.13 mm/min
European	0.58 mm/min	0.80 mm/min

Table 9: Greatest Rainfall Intensities at Sea Level

Period	Average rate of rainfall mm/min
1 min	31.0
42 min	7.3
12 h	1.9
24 h	1.31

2.4.2. Drip Hazard

a. When moist air comes into contact with materiel having a surface temperature below the dew point of the ambient air, condensation occurs. If, as a result sufficient water accumulates on the surface of the materiel, it will tend to form globules, which, on reaching a sufficient size, will run down gradients or drip from overhanging surfaces. Condensation will be most pronounced where the surface materials are good thermal conductors, such as metals or glass. In cold climates, a further hazard could arise from expansion of drips upon freezing.

b. In addition, unsealed items having an internal atmosphere may draw in air when subjected to cooling. Where the moisture content of the air is sufficient, condensation will occur within the item and the resulting water may not be completely expelled on a subsequent rise in temperature. Repeated cycles of this environment could cause progressive increase of liquid water inside the item. Again, freezing constitutes a further hazard in these circumstances.

2.4.3. Immersion

Immersion is defined as the total or partial covering by water for a limited or specified period. The effects of immersion upon items of materiel are principally determined by depth and duration of immersion, both of which are affected by factors other than the climate. It is agreed, therefore, that unless operational requirements specifically state to the contrary, depths for test purposes can be taken as lying between 150 mm and 4 m, with a standard time of immersion of two hours. It should be noted that when a relatively warm item of materiel is partially or totally immersed in cooler water, a reduction in air pressure within the item might result, which in turn, could cause or aggravate the ingress of moisture.

2.4.4. Hail

In those regions of the world where hail is most intense, there are, on average, two hailstorms during the most severe month for hail in each year. The average duration of each storm is about ten minutes. In view of the briefness of these periods, hail is not an essential consideration in the design of most materiel for use by NATO forces. Possible exceptions are where hail could endanger life or essential equipment. Although hailstones up to 140 mm diameter have been reported, very few exceed 25 mm diameter. The estimated 0.001 percent and 0.01 percent hailstone diameters at the most severe location during the most severe month are 50 mm and 20 mm, respectively.

2.4.5. Ice Accumulation

The accumulation of ice on items of materiel should be taken into consideration in its design if the requirements documents indicate that it could enter the regions of the M3 and C categories. The principal sources of this ice are frosting, freezing rain, refreezing of thawing snow, and freezing of condensation. The thickness of the ice will depend upon the period of exposure, the contours of the item of materiel and the heat dissipation of the materiel if operating.

2.4.6. Snowload and Snow Crystal Sizes

a. The effects of the structural load imposed by the accumulation of snow should be taken into account for materiel such as buildings, shelters, vehicles and other relatively large items that are exposed to snow in the regions of the M3 and C categories.

b. For the purposes of the Agreement, “Snowload” is defined as the weight per unit area of snow accumulation on the ground and items of materiel are considered to experience the same snowload as the adjacent ground though, in practice, it is usually somewhat less.

c. The frequency of snow clearance is a principal factor determining the snowload on materiel. It is therefore appropriate that the specific levels of snowload defined in this document are derived from those observed on three classes of materiel, semi-permanently installed, temporarily installed and portable, each having a distinctly different frequency of snow clearance during deployment in service:

(1) Semi-Permanently Installed Materiel. This group applies principally to semi-permanent installations, which, although demountable, are not very mobile. In general, snow would not be removed between snowfalls and therefore the loading is due to the whole season’s accumulation.

(2) Temporarily Installed Materiel. This group applies to large items such as portable hangars upon which snow collects. The snow is cleared between storms and the snow loading is therefore the amount resulting from any single snowstorm.

(3) Portable Materiel. This applies to items such as tents, which may be moved daily. Distortion arising from snowloading will make daily clearing essential and consequently, accumulations of snow will not exceed those resulting from a 24-hour snowfall.

d. The snowloads, associated with each of these groups of materiel are given in Table 10 and are those that, on average, are equalled or exceeded once in any ten consecutive years. The highest values of snowload are also quoted.

e. Snowloads on materiel at sea are generally not sufficient to present a hazard. However, if snowloads are to be taken into consideration in this environment for a particular item of materiel, then the value given in Table 10 for portable materiel should be used as it assumes snow will be removed regularly.

f. Snowloading is not applicable to the in-flight environment.

g The sizes of freshly falling snow crystals, accompanied by no more than light winds, range from 0.05 to 20 mm diameter with a median range 0.1 to 1.0 mm when ambient air temperatures are lower than -33 °C and a median range tending to 2.0 to 5.0 mm at higher air temperatures, the largest sizes occurring when the air temperature is just below freezing point.

h. When snow crystals are blown by winds in the region of 18 ms^{-1} or more, they become broken and abraded into grains having rounded or sub-angular corners. The diameters of these grains range from 0.02–0.2 mm.

Table 10: Specified Limit and Highest Recorded Snowloads

Type of materiel	Period of snow accumulation	Specified limit of snowload kg/m^2	Highest recorded snowload kg/m^2
Semi-permanently installed	Whole season	240	586
Temporarily installed	Single snowstorm	100	191
Portable	24 h	50	113

2.5. Blowing Sand and Dust

a. "Sand" and "dust" are terms for solid non-cohesive particulate matter, usually of mineral origin, found on the surface of the earth or suspended in the atmosphere. The range of particle diameters of sand and dust together extends from about 0.1 to 200 μm, the latter value being the lower limit for very fine pebbles. Although sand and dust are normally differentiated on the basis of particle diameters, no universally accepted demarcation value exists.

b. In this Agreement, a classification based on their different aerodynamic behaviour is adopted. Particles of less than 75 μm diameter can remain suspended in the atmosphere by natural turbulence of the air for very long periods, even years. These are termed “dust” by most authorities. Conversely, those greater than 150 μm diameter are unable to remain airborne unless continually subjected to strong natural winds, powerful airflows or the turbulence that may be caused, for example, by aircraft, helicopter or convoys of land vehicles. These particles are termed “sand.” Over the intermediate range of diameters from 75 to 150 μm, there is a gradual transition in settling times and the particles are variously referred to as “dust” or “sand” in different documents.

c. For the purposes of laboratory simulation, the recommended demarcation value for distinguishing sand from dust is 149 μm.

2.5.1. Distribution and Hardness of Sand

a. Sand is distributed widely over the earth’s surface. There are vast sandy regions in the Sahara and in Saudi Arabia as well as significant areas in most of the world’s deserts. All the continents have sandy beaches of various widths and there are large deposits at or near the surface in many inland areas formerly covered by water. On account of this widespread occurrence of sand, it should be assumed that most forms of materiel for use by NATO forces would be exposed to sandy conditions during their service life.

b. Hardness and angularity are usually the most important characteristics of sand grains. On a worldwide basis, the majority of sands are composed of quartz (SiO_2), which, in its most common form, has a hardness of 7 on the Mohs scale. Other minerals which may be found in sand range from hardness 2 for white gypsum to hardness 9 for those containing corundum.

c. Although in time, grains of sand become rounded by mutual abrasion, those having angular shape are found in substantial proportion in most samples of sand. The latter arise from the tendency of some rock—forming minerals, particularly quartz, to fracture along cleavage planes through impact action.

d. In general, the movement of sand by wind pressure is confined to the air layer within the first meter above the ground. Even within this layer, about half the sand grains (by weight) move within the first 10 mm above the surface and most of the remainder are within the first 100 mm. As a consequence of the low elevation at which the majority of sand grains move, most abrasion damage caused by sand outside high wind periods is at or near ground level.

2.5.2. Distribution and Concentration of Dust

a. In contrast to sand, dust particles, on account of their low terminal velocity, can remain suspended in air indefinitely and may settle on surfaces anywhere.

b. In dry conditions, soils with more than 9 percent by weight of dust particles become at least moderately dusty and those with 14 percent or more are potentially very dusty. Thus, as over 40 percent of the land surface of the world, excluding Antarctica, is classified as moisture deficient and a further 40 percent is seasonally dry, dust must be expected to be present over most of the land surface of the world for substantial parts of the year. Even in regions and seasons of heavy rainfall, dust continues to create problems where the protective cover has been broken. Many moist areas are so well drained that most unprotected soil becomes dust in a remarkably short time after heavy rain.

c. There is evidence that dust problems are aggravated by higher atmospheric temperatures, by relative humidity below 30 percent, and by the drying action of winds, though to what extent is not known quantitatively.

d. Probably the most effective dust production agent is man himself, especially when he is equipped with machinery to increase his speed and mobility. Tanks, trucks, bulldozers, artillery, aircraft, and marching troops are effective in the destruction of protective cover and the consequent generation of small particles to such an extent that dust problems must be expected nearly everywhere these activities take place. Possible exceptions are those locations that are under permanent snow, ice, or water cover, and where precipitation is so frequent that the surface never dries out.

e. Dust concentrations from three distinctly different scenarios are given in Table 11. Materiel should remain safe and be capable of acceptable performance when exposed to dust concentrations given for those scenarios most representative of its locations and modes of deployment.

Table 11: Concentration of Dust in Atmosphere

Dust Concentration	Scenario
180 mg/m^3	Typical of dust picked up and transported by gale force winds (typically 18 ms at 3m) in locations remote from normal military activities.
1.0 g/m^3	Occurs where there is a military presence. Though considerably greater than for natural dust storms, it is a realistic level for military activities on a worldwide basis.
2.0 g/m^3	Representative of the most arduous conditions associated with aircraft (particularly helicopter) operations. In addition to dust, the rotor down-wash of helicopters is strong enough to raise sand grains to considerable heights.

2.6. Temperature of Surface Sea Water

a. Items of materiel which might be floated on or immersed in sea water should remain safe and be capable of acceptable performance compatible with its operational role when immersed in water at any temperature from 36 °C to -2°C. Seawater of average salinity freezes at -2°C.

b. The upper value is the surface sea water temperature which is exceeded for only 7.4 hours of the month of the year in which sea temperatures are at their highest. Similarly, the lower value is the surface sea water temperature which is exceeded for all but 7.4 hours of the month of the year in which sea temperatures are at their lowest.

c. The highest and lowest surface seawater temperatures ever reliably recorded are 38 °C and -6 °C respectively.

ANNEX A

REFERENCES

A.1. REFERENCES

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4. “Extreme Wind Speeds over the United Kingdom for Period Ending 1963.” H.C. Shellard, London Meteorological Office Climatological Memorandum No 50, 1968.

5. “Extreme Wind Speeds over the United Kingdom for Period Ending 1971.” Carol E. Hardman, N.C. Helliwell and J.S. Hopkins, London Meteorological Office Climatological Memorandum No 50A, 1973.

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ANNEX B

CHARACTERISTICS OF WIND

The charts shown in Figures B1 and B2 give the percentage frequency in the average year when the mean wind speed, (measured over an interval of 5 to 10 minutes) equals or exceeds 14m/s and 25m/s. The charts refer to the standard height of 10 meters over fairly open and low-lying ground and therefore should not be used to infer probabilities in mountainous areas nor when special problems of aspect or exposure arise.

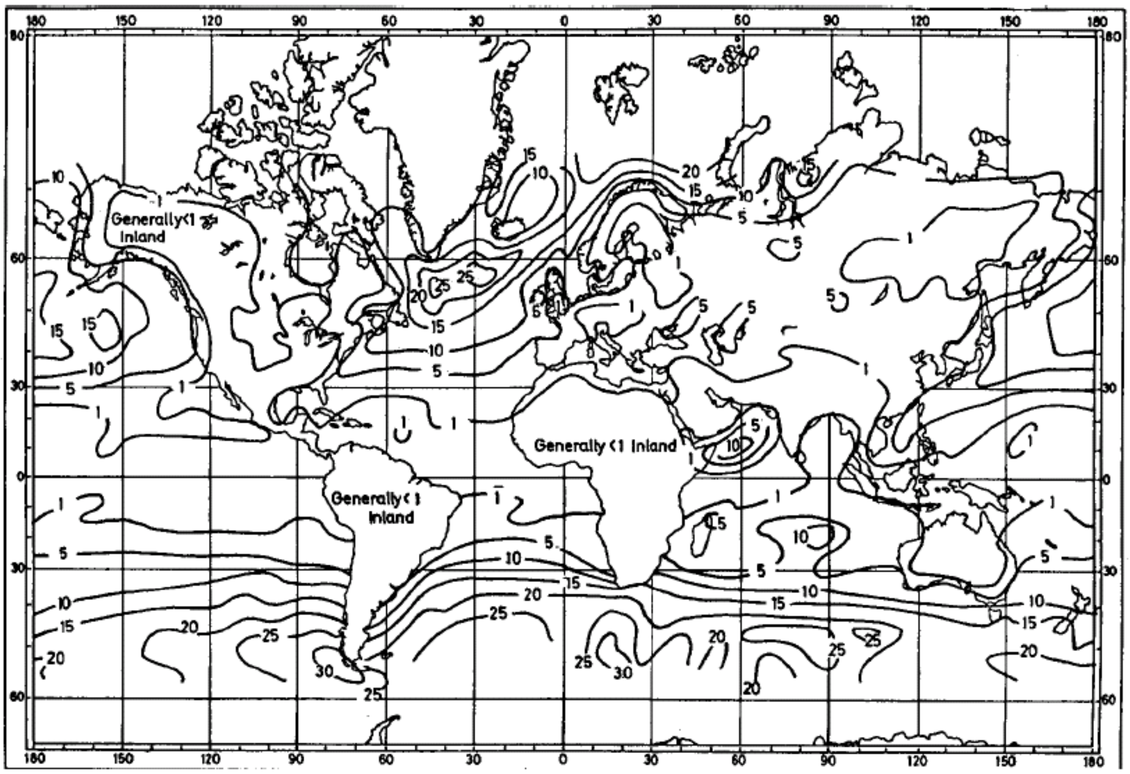

Figure B1: Percentage Frequency of Winds ≥ 14m/s

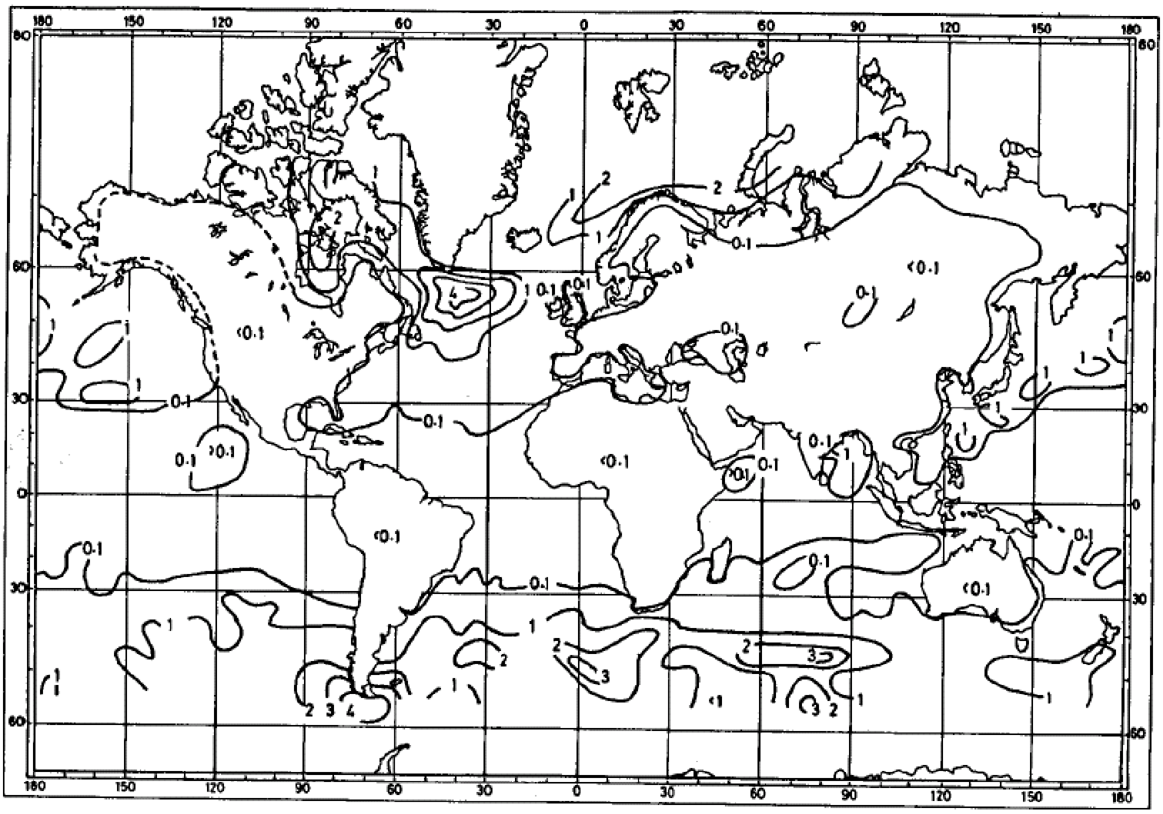

Figure B2: Percentage Frequency of Winds ≥ 25m/s

The chart in Figure B3 shows the maximum gust likely to be experienced once in 10 years, based on the analyses as outlined in reference 3 and various building design codes of practice. The estimates are for the standard height of 10 meters over fairly level country and they are not applicable to mountainous regions nor to places that have local peculiarities of exposure or topography. Exceptionally high gusts, which may occur in tropical storms, are also excluded.

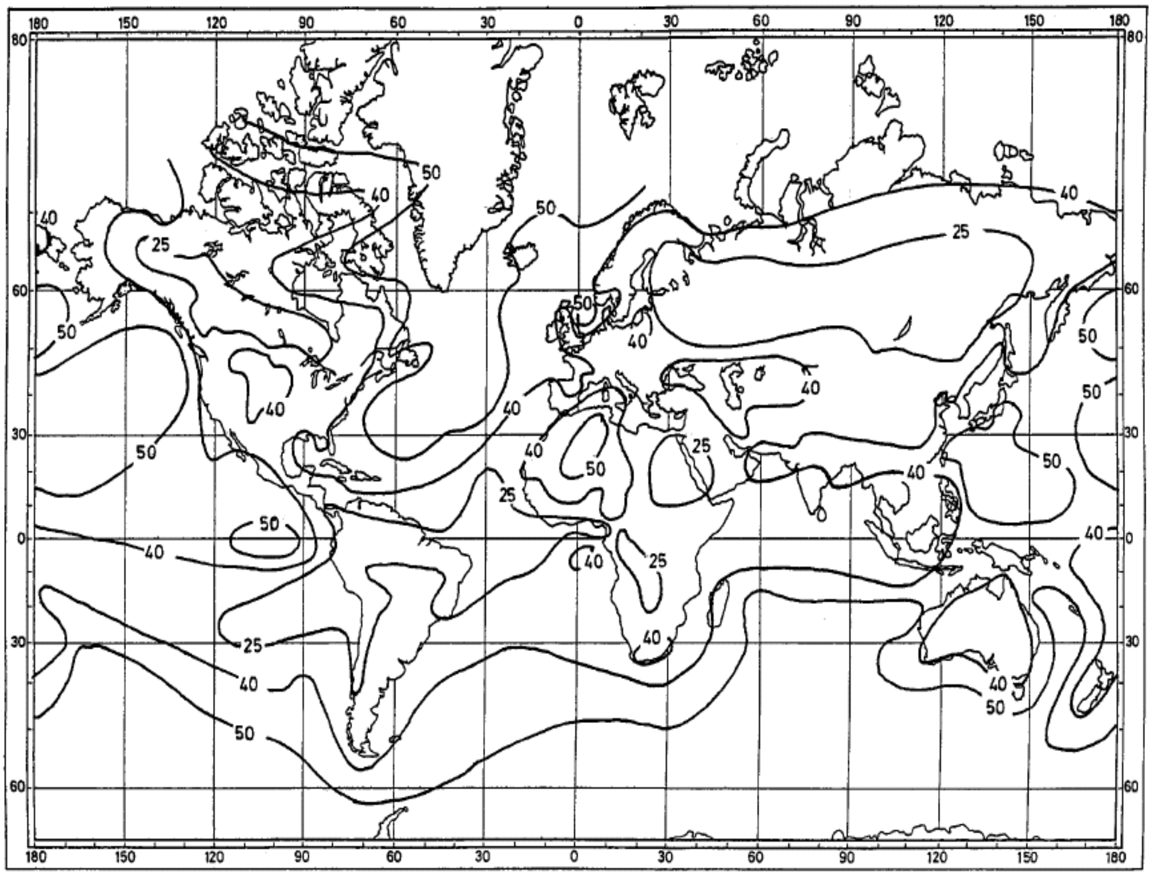

Figure B3: Maximum Gust (m/s) at 10m Above Open-Level Terrain, Likely to be Exceeded Once in 10 Years on Average (Excluding Tornadoes)

By definition a tropical storm becomes a hurricane (or typhoon, cyclone, etc.) if wind speeds are 33m/s (64kt) or more; the upper limit is unknown but speeds around 103m/s (200kt) have been reliable reported. Hurricanes often travel at 15–30 km/h (8–16kt) but can exceed 50km/h (27kt) especially at higher latitudes and may last from 2 days to 2 weeks. Figure B4 gives an indication of the areas affected and the probabilities are included.

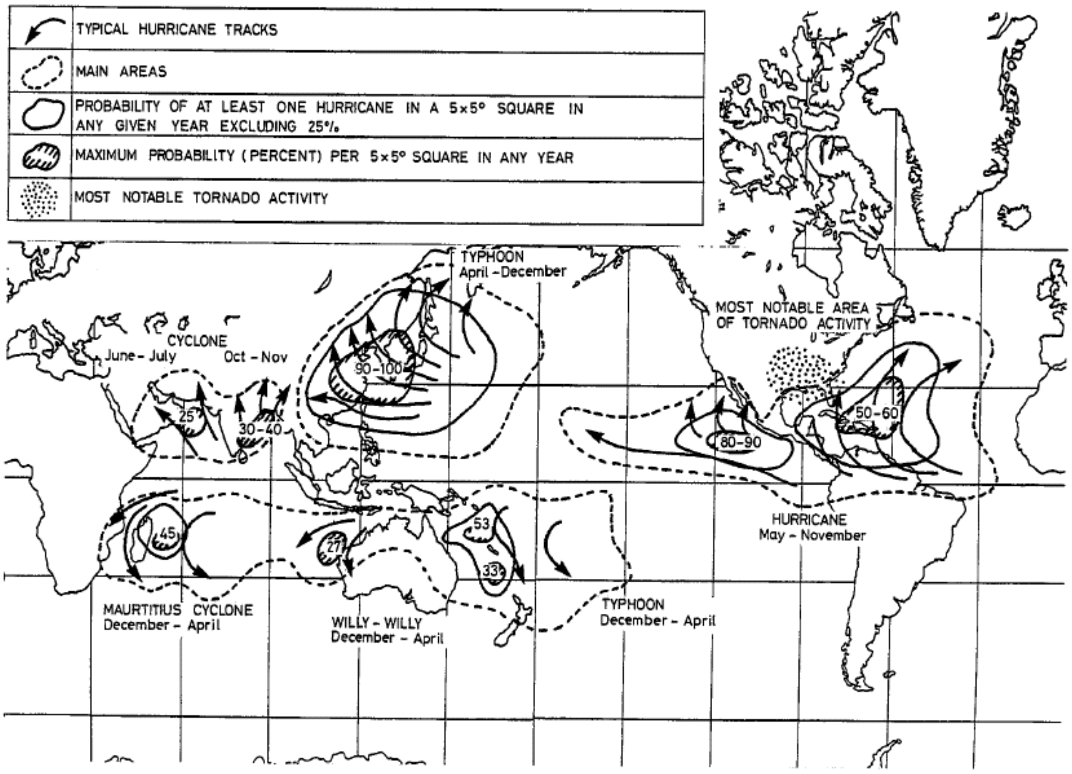

Figure B4: Areas Affected by Tropical Storms of Hurricane Force

Figure B5 is a schematic diagram illustrating the relative scale and strength of meteorological wind systems. The approximate maxima of identifiable systems are 250 hours life and a diameter of 2500km. The broken lines indicate commonly accepted limits; however, gusts within larger strong wind systems are often within the range 100–200m/s.

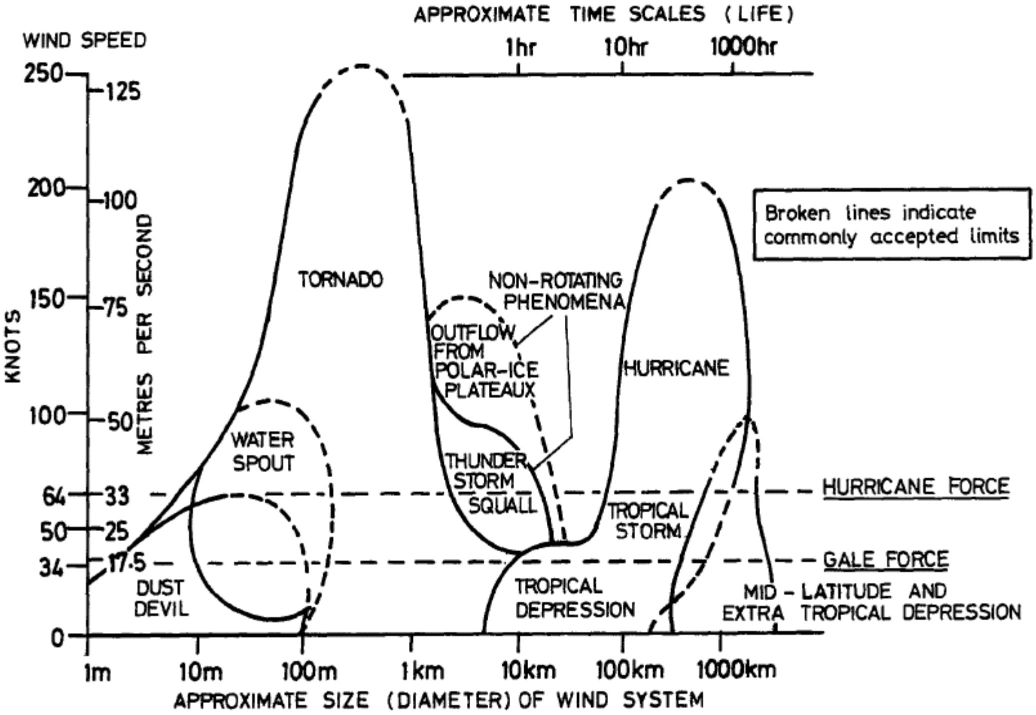

Figure B5: Characteristic Wind Speed Size and Time Scale of Meteorological Wind Systems