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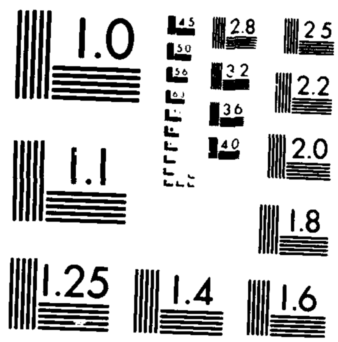

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INTERPRETING CLIMATIC INFORMATION FOR DESIGNING MILITARY EQUIPMENT

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Abstract

The design of most military equipment must reflect the potential for combat almost anywhere in the world. Climatic presentations for this purpose have been developed for the recently completed Military Standard 210C (MIL-STD-210C), "Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment." This document contains data for many meteorological elements and combinations encompassing the worldwide surface environment, regional surface environments including the maritime environment, and the worldwide air environment up to 80 km. This paper addresses the development and interpretation of these climatic presentations and provides guidance on how they should be used to establish design and test requirements.

Introduction

To fulfill its intended purpose, military equipment must be designed and tested for the extremes of the natural environment to which it will be exposed. A tri-service committee headed by the Air Force Geophysics Laboratory revised MIL-STD-210B, "Climatic Extremes for Military Equipment" to provide a document that would better promote the use of climatic data to define this environment.

MIL-STD-210C, "Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment," has been expanded to include regional climatic data in addition to worldwide data. Included are background information describing where and how the values were obtained, data to facilitate tradeoff analyses, and a bibliography of sources from which the information was obtained. Guidelines for applying the data have been changed to promote determination of the appropriate environments for the design and testing of each system or item under development.

The new standard contains climatic data on worldwide extremes, regional presentations, and values aloft up to 80 km. This information is intended to provide natural environment starting points for the sequence of engineering analyses to derive design criteria for materiel. It is also a source of data for deriving climatic test values for MIL-STD-810.

Each system or item of equipment under development should be designed to function in and survive only those environments that it will be exposed to. This is in keeping with current DoD policy on "tailoring" design requirements for each system. This term implies that design and test requirements should not be the same for all items, but should be based on the anticipated life cycle, performance and safety requirements, and economic considerations for each item.

Climatic Information in MIL-STD-210C

The standard provides climatic data for the worldwide surface environment (excluding Antarctica), regional surface environments, and the worldwide air environment up to 80 km. Climatic information for each element (or combination of elements) represents conditions in the most severe non-anomalous area in the world (or region) for that element (or combination).

The climatic data are generally presented in the form of frequencies-of-occurrence. For both worldwide and regional applications, the frequency of occurrence of climatic elements (e.g. temperature) is based on hourly data wherever possible. From hourly data, it is possible to determine the total number of hours a specific value of a climatic element is equalled or exceeded. For example, if a temperature occurs or is exceeded for an average of 7 hours in a 31-day month (744 hours), it has occurred roughly 1 percent of the hours in that month. If it occurs, or is exceeded, an average of 74 hours in the month, then it has a frequency-of-occurrence of 10 percent, etc. The value that is equalled or exceeded 1 percent of the time is referred to as the 1-percent value. The climatic values specified in the standard are for the worst month but they may occur less frequently in other months.

Data on long-term climatic extremes are also provided for most climatic elements. These are values that are expected to occur at least once, for a short duration (< 3 hours), during approximately 10, 30, and 60 years of exposure. Therefore, they are rarer climatic events than the percentile values that represent average conditions in the worst month. The most extreme value ever recorded is also provided for each element.

Regional Surface Environments

For determining climatic design criteria for materiel not intended for worldwide use, the land and sea surface areas of the world are divided into 5 regional types of climate. The four regional types that represent the land environments are partitioned on the basis of temperature during the worst month in the most severe part of the region. The four land regional types (Figure 1) and their defining temperatures are:

(1) Basic Regional Type - One percent hot and

cold temperatures of -31.7°C(-25°F) and 43.3°C(110°F) during the worst month in the coldest and hottest parts of the regional type, respectively.

(2) Hot Regional Type - Hotter than Basic Type with a 1 percent temperature of 49°C(120°F) in the hottest parts.

(3) Cold regional Type - Colder than Basic Type with a 1 percent temperture of -45.6°C(-50°F) in the coldest parts.

(4)Severe Cold Regional Type - Colder than the Cold Type with a 20 percent temperature of -51°C(-60°F) in the coldest parts.

The manner of presentation of climatic data for the 4 land regional types is different than for the ocean/coastal regional type, the worldwide surface environment, and the worldwide air environment. These provide climatic information for a wide range of climatic elements, whereas climatic values for each of the land types are presented in the form of daily weather cycles associated with 1 percent hot and cold temperature values that define each regional type (20 percent for severe cold type) and 1 percent humidity values. The basic regional type, which encompasses by far the largest land area of the 4 types, comprises 5 different daily weather cycles; the hot type has 2 cycles; and the cold and severe cold types require only 1 cycle each to define their conditions.

Worldwide Air Environment

The worldwide air environment to 80 km contains climatic information for use in designing airborne and air projected systems and equipment on a worldwide basis; these data are also applicable to ground equipment which is airborne (external to pressurized cargo compartments) or projected through the atmosphere. Values in this section represent "free air" conditions and not aerodynamically-induced conditions (e.g., aerodynamic heating). Values for altitudes of 2, 4, 6 etc. km are not applicable to surface locations existing at these altitudes (such extremes up to 4573 m are provided for the worldwide surface environment).

Climatic information for the worldwide air environment is presented in terms of envelopes of climatic values, and profiles of temperature, density, and rainfall rate/water concentration.

Atmospheric Envelopes

Climatic data in the form of vertical envelopes are values of extremes at each altitude regardless of the location or month in which they occurred. Therefore, the values provided for each altitude do not generally occur at the same time and place for layers greater than a few kilometers, and are not at all representative of the influence of the total atmosphere on a vertically rising or decending vehicle. These envelopes are most applicable for determining conditions at specific altitudes of concern for vehicles horizontally traversing the atmosphere, or for determining which altitude may present the most severe adverse effect for each climatic element.

For each climatic element, information is provided for the recorded extreme (up to 30 km), and for the frequency of occurrence during the most severe month in the worst part of the world (excluding areas south of 60°S) for that element. Values with a 1, 5, 10, and 20 percent frequency of occurrence are presented.

Atmospheric Profiles

These climatic data are presented as realistic profiles associated with extremes at specified levels. They are primarily intended for use in the design of vehicles that are vertically traversing the atmosphere, or other considerations for which the total influence of the atmosphere is needed.

The temperature and density profiles, from the surface to 80 km, are based on 1 and 10 percent warm and cold temperatures and 1 and 10 percent high and low densities at 5, 10, 20, 30, and 40 km at the worst locations in the world (except Antarctica) during the worst month. The temperature profiles include associated densities, and the density profiles include associated temperatures. Each of the forty profiles should be considered individually to determine which are the most appropriate for a given application.

The rainfall rate/water concentration profiles aloft are related to surface rates. The profiles aloft include precipitation rate and associated drop size distributions, precipitation liquid water content (or solid equivalent), and cloud water content. Profiles are provided for the world record 1 and 42 min surface rates, and for the 0.01, 0.1, and 0.5 percent worst location/month rates.

Rationale for the Climatic Presentations

Let us now examine why climatic statistics representing the most severe area during worst month were deemed most appropriate for MIL-STD-210C. It is often said that the strength of a chain is determined by its weakest link. For equipment, limitations are determined by its ability to perform its intended function in the harshest anticipated environment to which it may be exposed.

Suppose for example, the military would like to develop a piece of hardware for use at locations throughout the contiguous United States. The item is temperature sensitive, and will operate only within the high and low temperature limits of the natural environment chosen for its design.

For simplicity, our region for this example is the contiguous U.S.; however, the U.S. is not a region in MIL-STD-210C. I determined the high and low temperature distributions (from hourly data) for the following 8 locations:

Fargo	Miami
Yuma	Boston
San Francisco	San Diego
Seattle	Dayton

These locations were subjectively chosen as being a representative cross-section of U.S. climate. The resulting statistics from the combined data base are:

1% of YEAR HI TEMP > 100°F (37.8°C)
0.5% of YEAR HI TEMP > 104°F (40°C)

1% of YEAR LO TEMP < -4°F (-20°C)
0.5% of YEAR LO TEMP < -8°F (-22.2°C)

The above frequencies may seem reasonably low for equipment non-availability. However, equipment located in the coldest general area of the U.S., represented here by Fargo, N.D., would see temperatures ≤ -8°F 4% of the year and 25% of January. It is colder than the 1% annual low temperature for the U.S. (-4°F) 34% of the time in January in much of the north central U.S. Conversely, the 0.5% annual U.S. high temperature is exceeded 5% of the year and 15% of July at Yuma, AZ which represents the hottest area of the U.S. In this area, it is warmer than the U.S. 1% high temperature of 100°F 27% of the time in July.

The above example points out the danger of combining data for diverse climates and seasons. To get a true ambient temperature for, say, a 1% equipment non-availability, the 1% worst month temperatures of -27°F (-32.8°C) and 112°F (44.4°C) for Fargo and Yuma respectively would be the appropriate design inputs.

Data Application

To use the climatic information in MIL-STD-210C:

a. The areas of the world that an item could encounter during its life cycle must be known.

This includes:

(1) Geographical location through which it may be transported

(2) Where it may be stored

(3) Where it may be deployed

(4) How it will be transported

(5) Circumstances when it will be protected from the environment.

This information is needed to determine the applicable portions of 210C or if 210C is indeed applicable. The above should be clearly specified by the procuring agency.

Once the areas that an item might encounter are known, the applicable environments from 210C can be determined. If it can be stated with a high degree of certainty that an item would be limited to one or more (but not all) of the regional climatic types, then design to these environments are appropriate. Otherwise the worldwide surface environment should be designed for.

Use of the worldwide air environment may be applicable to ground equipment which is airborne. However, one must not lose sight of the fact that the environments specified in 210C are ambient, or "free air" conditions. Items in any way shielded from the full brunt of exposure should be designed accordingly. For example, an item which is airborne but external to pressurized compartments may be exposed to low pressure values at altitude, but not the low ambient temperatures due to the modified environment within the aircraft.

b. Operational Requirements Must Be Known

It is ordinarily costly or technologically impossible to design equipment to operate under the most extreme conceivable conditions. Therefore, military planners accept equipment designed to operate for all but a certain small percentage of the time. The procuring agency is responsible for determining the operational requirements of the item or system. These requirements should then be used to determine the acceptable frequency of occurrence of a climatic element.

Values associated with several frequency levels (frequency of occurrence during the most extreme month of the year) are provided for most climatic elements or combinations. For almost all of these the 1 percent frequency (the value equalled or exceeded 1 percent of the time in the month, or about 7 hrs) is recommended for initial consideration. If these values prove unacceptable because of technical or cost considerations, the other values are provided to facilitate trade-off analyses. The use of less extreme value associated with higher frequencies of occurrence (and reduced operational capability) must be weighed by the procuring agency.

c. Safety Considerations and Equipment Survivability Must Be Known

For some materiel, one-time exposure to a climatic extreme can render it permanently inoperable or dangerous (e.g., ordnance). For such materiel, long-term climatic extremes would be more appropriate for design of equipment that is not protected from the environment. Depending on the degree of the hazard, the use of the most extreme recorded value may be required. The use of these more extreme values, instead of those occurring for a percent of the time during the most severe month each year, shall be determined by the agency or department responsible for development.

Record extremes, and values expected to occur at least once for a short duration (≤ 3 hrs) in 10, 30, and 60 years of exposure are provided for the worldwide surface environment and the coastal/ocean regional type. Record extremes are also provided for the worldwide air environment (up to 30 km). Materiel that would become inoperable or dangerous due to one-time exposure to climatic conditions in any of the land regional types should be designed for appropriate worldwide climatic conditions.

Platform Characteristics

The climatic values in 210C represent free air (ambient) conditions. The conditions that an item will see depend on how the natural environment is modified by the platform on or within which the item is expected to function. Design requirements and test procedures can be established only after the platform characteristics are identified and the platform environment is defined. The platform itself can take many forms. For a rifle, the platform is a soldier; for an engine, it is a plane or truck or other vehicle, etc.

Defining the platform environment is probably the most difficult step toward establishing design and test requirements. A great amount of thought is necessary to determine all the pertinent forcing functions acting on the item being developed. Then, calculations or estimates on the impact of these forcing functions have to be made. The following are some common questions that should be addressed:

(a) Will the platform reduce the severity of the ambient conditions or add to it?

(b) How long must ambient conditions persist before the item is affected?

(c) Will the item need to function only at specific times of the day or year when climatic conditions are less severe?

The platform environment is not necessarily constant. That is, an item may be shipped or stored prior to its installation. Potential climatic conditions during this part of an item's life cycle need to be specified for each climatic element. For example, an item being shipped which is airborne but external to pressurized compartments may be exposed to low pressure values at altitude, but not the low ambient temperatures due to the modified environment within the aircraft.

Trade-Offs

Once the platform environment(s) is(are) defined, problems in designing for any of the climatic conditions will surface if they have not already done so. If design to one or more of the initially derived ambient climatic conditions proves unacceptable due to technical or cost considerations, alternatives need to be considered. Although the procuring agency establishes the requirements, the ramifications as to cost or achievability can only be evaluated after these have been factored into the design by the contractor. The procuring agency should be made aware of the problems and potential solutions. The use of alternatives, such as less extreme values associated with higher frequencies of occurrence (and reduced operational capability), must be weighed by the procuring agency.

MIL-STD-210C contains data for many climatic elements. For most elements, less severe values that occur with greater frequency than those recommended for initial consideration are provided. These are intended for use in making cost and performance trade-offs. Background information and supplementary data provided in 210C can be used to assess the ramifications of backing-off to less severe conditions. This information is in the form of discussion as to where and when extreme climatic conditions occur, their areal extent, diurnal variations, durations, etc. References to sources from which the data were taken or where more information can be found is also provided.

Concluding Remarks

MIL-STD-210C contains considerable climatic information for use in engineering analyses to derive environmental design and test criteria for military materiel. To select appropriate climatic conditions it will be necessary to establish the life-cycle of the item. This includes how it will be transported, stored, and protected. It will then be necessary to determine the acceptable frequency of climatic conditions based on operational requirements, safety and trade-offs due to technical or cost considerations.

MIL-STD-210C requires considerable thought before the appropriate climatic conditions can be determined. I believe this effort will result in logical and cost effective design and test requirements.

Acknowledgment:

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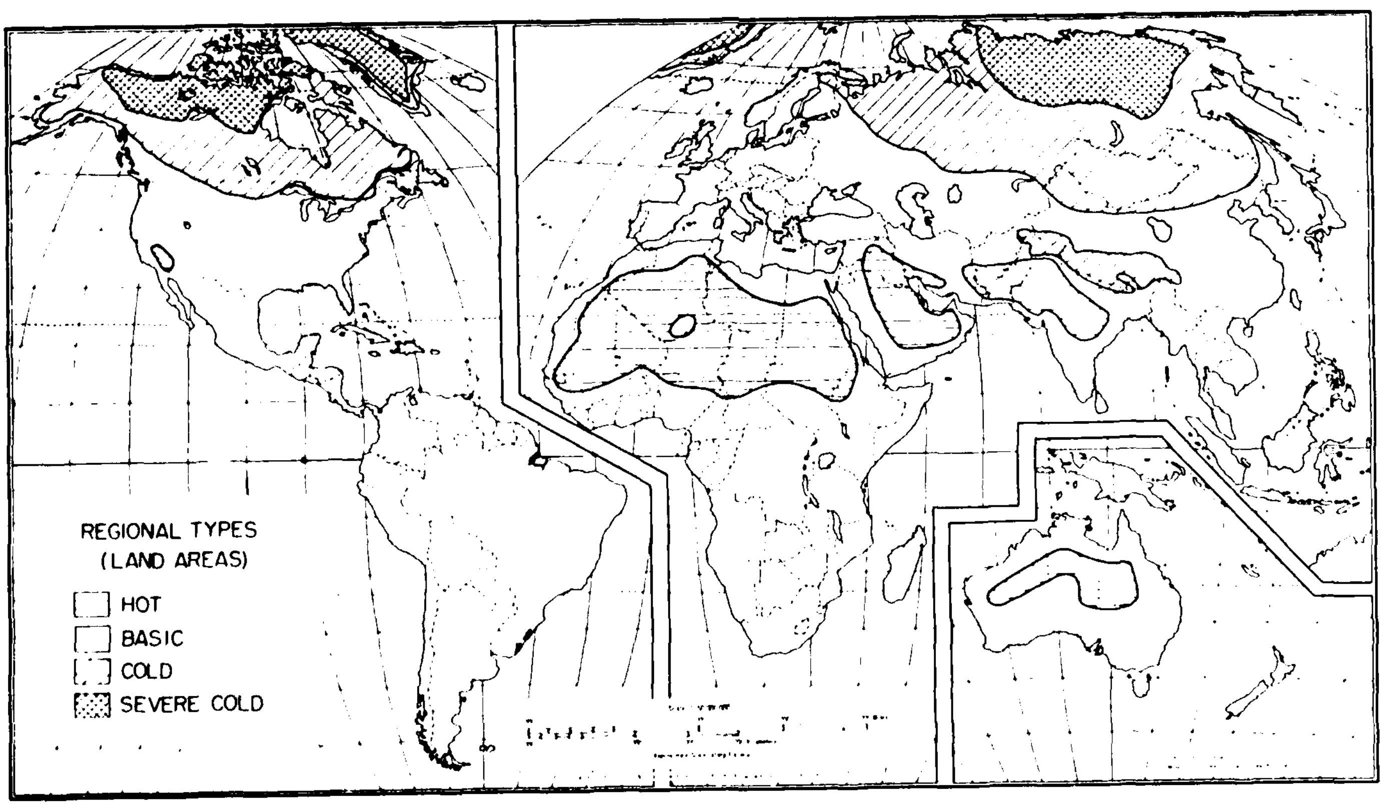

Figure I Area of occurrence of the climatic Regional Types for the Land Areas of the world

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