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SUPERSEDING
MIL-STD-210
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DEPARTMENT OF DEFENSE HANDBOOK

GLOBAL CLIMATIC DATA FOR DEVELOPING MILITARY PRODUCTS

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AMSC N/A

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FOREWORD

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

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving the document should be addressed to AFRL/VSBE, 29 Randolph Rd., Hanscom AFB, MA 0173 1-3010 by using the self-addressed Standardization Document Improvement Proposal (DOD Form 1426) appearing at the end of this document or by letter.

FOREWORD

MIL-HDBK-310 has been expanded to include regional climatic data in addition to the worldwide data presented in previous editions. The narrative has been expanded to include: background information describing where and how the values were obtained, data to facilitate tradeoff analyses, and a bibliography of sources from which the information in this standard was obtained. Furthermore, 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. Noteworthy changes from MIL-STD-210B/C in content and concept are as follows:

a. Climatic data in this standard are not design or test criteria. Rather, they are to be used to derive design and test criteria for each item based on the response of the item to both the natural environment and to the forcing functions induced by the platform on or within which the item is located.

b. The data are presented in terms of their frequency of occurrence during the most severe month, as in MIL-STD-210B. However, in this revision they are no longer referred to as operational extremes, and the acceptable frequency of occurrence must be determined by the procuring activity.

c. Long-term climatic extremes presented in this revision are values that are expected to occur at least once, for a short duration, during 10, 30, or 60 years of exposure. These replace withstanding extremes in MIL-STD-210B/C.

d. The land areas of the world are divided into 4 regional types of climate based on temperature differences. Climatic values representative of extreme conditions in each of the types are presented in the form of daily weather cycles.

e. Consistent vertical profiles of temperature and density up to 80 km based on extremes at 5, 10, 20, 30 and 40 km have been added to the worldwide air environment.

f. Separate climatic data for the naval air environment are no longer included.

g. Basic background information is presented along with supplementary data to promote a better understanding of the data presented and to facilitate tradeoff analyses.

h. Values for various climatic elements have been added or updated where appropriate.

i. This document implements NATO STANAG 2895 (see paragraph 6). It should be used *for* all appropriate NATO-related applications.

CONTENTS

CONTENTS – Continued

Page

CONTENTS - Continued.

Page

CONTENTS - Continued

Page

CONTENTS - Continued.

Page

CONTENTS - Continued.

Page

CONTENTS - Continued.

TABLES Page

CONTENTS - Continued.

TABLES Page

FIGURES

CONTENTS - Continued.

1. SCOPE - This handbook provides climatic data primarily for use in engineering analyses to develop and test military equipment and materiel.

1.1 Purpose. The data provided are intended to serve as natural environmental starting points for the sequence of engineering analyses to derive environmental design criteria for materiel. The climatic data are also intended to provide guidance in the development of environmental tests of materiel.

1.2 Application. (a) This handbook provides climatic information for land, sea, and air environments in which military materiel may be required to operate. These data represent free air (ambient) conditions, and are not to be confused with the response of materiel, either to these conditions, or to those of a platform on or within which the materiel might be located.

(b) Selection of specific climatic values in this handbook should be made only after determining: (1) the area of geographic deployment; (2) handling and logistics requirements; and (3) the operational requirements of the materiel being developed (see 4.3.3).

1.3 Limitations (a) Climatic data for the region south of 60°S latitude are excluded from consideration in this document.

(b) The climatic data in this handbook should not be used in the development of materiel for a specific geographic location or an anomalous site such as a mountain top. This type of climatic support may be obtained through the Office of Primary Responsibility (OPR) for each military service (see 4.6).

(c) The possible adverse effects of climatic conditions upon materiel are not discussed in this handbook.

(d) This handbook does not include induced environments such as may be encountered in storage or transit, or caused by a platform on or within which the materiel might be located.

(e) Unless otherwise indicated, information provided for a climatic element does not occur at the same time and/or place as information provided for another climatic element.

(f) The climatic data in this handbook should not be used directly as test values without consulting MIL-STD-810 or other appropriate environmental test documentation.

2. APPLICABLE DOCUMENTS

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

2.2 Government Documents. MILITARY STANDARDS MIL-STD-1165 - Glossary of Environmental Engineering Terms and MIL-STD-810 - Environmental Test Methods and Engineering Guidelines (Unless otherwise indicated, copies of the above standards are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094).

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplements thereto, cited in the solicitation. When this standard is used by acquisition, the applicable issue of the DoDISS must be cited in the solicitation.

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. TERMS AND ABBREVIATIONS

3.1 Terms. Definitions for the scientific and meteorological terms used herein can be found in Mil-Std-1165.

3.2 Abbreviations. The following abbreviations are used in this handbook:

(a) Bph - British thermal units per square foot per hour

(b) fps - Feet per second

(c) LST - local standard time
(d) MIX. RAT. - Mixing ratio
(e) mps - Meter per second
(f) ppm - Parts by weight of water vapor per million parts of dry air
(g) RH - Relative humidity
(h) SOL. RAD. - Solar radiation

4. GENERAL INFORMATION

4.1 General. Climatic data in this handbook are generally presented in the form of frequencies-of-occurrence. Specific examples are as follows:

(a) 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 equaled 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 equaled or exceeded 1 percent of the time is referred to as the 1-percent value.

(b) 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 ($\leq$ 3 hours), during approximately 10, 30, and 60 years of exposure. Therefore, they are rarer climatic events than those in 4.1(a). The most extreme value ever recorded is also provided for each element.

(c) Worldwide climatic information for each element (or combination of elements) represents conditions in the most severe non-anomalous area in the world for that element (or combination).

(d) Regional climatic information for each element (or combination) represents conditions in the most severe non-anomalous part of the region (see 4.2).

(e) Values occurring for specified frequencies-of-occurrence during the worst month may also occur in other months, but with a lower frequency-of-occurrence.

4.2 Regional Information. Regional information is as follows:

(a) The land and sea surface areas of the world are divided into five types of climate, subsequently referred to as 'regional types." Four regional types represent land environments and one represents sea surface and coastal areas. Each regional type represents climatic conditions in one or more areas. Data for these regional types apply in cases where surface-based (land or sea) equipment is not intended for worldwide use, but will be used in one or more (but not all) of the regions. However, potentially dangerous items, or materiel that would become permanently inoperable due to one-time exposure to climatic conditions in any of the land regional types, should be designed for the appropriate worldwide climatic conditions.

(b) The land areas of the world are partitioned into four regional types based on temperature characteristics. Regions represented by the regional types for the land areas of the world are shown in Figure 1 (page 101). Climatic information for these regional types is presented as daily cycles of coincident temperature, humidity, and solar radiation. Additional environmental elements or combinations of elements that could occur and cause problems are specified for each regional type.

(c) The coastal/ocean regional type includes all coastal ports and open seas that could involve naval operations. This does not include conditions encountered by ships involved in icebreaking operations or ports when they are closed due to ice.

4.3 User Guidance

4.3.1 Presentation of the Data. Data is presented as follows:

(a) Climatic information for each element (or combination) in section 5 generally includes the recorded extreme, the frequency of occurrence during the most severe month of the year, and long-term climatic extremes. Data on diurnal cycles are presented where appropriate. Interpolation will provide intermediate values of elements between specified frequencies. Extrapolation should not be used to make estimates outside the range of values in section 5.

(b) Upper-air climatic data as a function of altitude are presented in tables of the 1-, 5-, 10-, and 20-percent frequencies-of-occurrence, and recorded extremes, for each element. These are envelopes of extreme conditions at each altitude and do not represent internally consistent profiles, since values for each altitude would not occur simultaneously at any one location or region. Consistent upper-air profiles of temperature, density, and rainfall rate/water concentration versus altitude that occur at the same time and place are also presented. For temperature and density, these are based on specified percentiles at selected altitudes. Precipitation-rate profiles are based on specified surface extremes.

4.3.2 Additional Information. Appendix A provides additional information for the climatic elements, regional climatic types, or upper air environments discussed in section 5. References to scientific reports and journal articles from which the data were taken, and other sources of information are also provided.

4.3.3 Data Application. Specific data application is as follows:

(a) To use the climatic information in this handbook, the areas of the world that equipment could encounter during its life cycle must be known. This includes the geographical locations through which an item may be transported, where it may be stored, and where it may be deployed. It is also necessary to know how it will be transported and under what circumstances it will be protected from the environment.

(b) It would often be costly or technologically impossible to design materiel to operate under the most extreme environmental conditions ever recorded. Therefore, military planners accept equipment designed to operate under environmental stresses for all but a certain small percentage of the time. The agency or department responsible for the development of materiel shall determine 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. Frequencies-of-occurrence that are recommended for initial consideration are discussed in section 5.1 for the Worldwide Surface Environment, 5.2.5 for the Coastal/Ocean Regional Type, and sections 5.3.1 and 5.3.2 for the Worldwide Air Environment. These recommended frequencies were taken from inputs to MIL-STD-210B by the Joint Chiefs of Staff, Memorandum for the Secretary of Defense, JCSM-502-69, 12 August 1969.

(c) 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, or the record extreme, would be more appropriate for design of equipment that is not protected from the environment. (It should be noted that highest/lowest recorded extremes depend upon the period-of-record and should not be construed as "all time" extremes). 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.

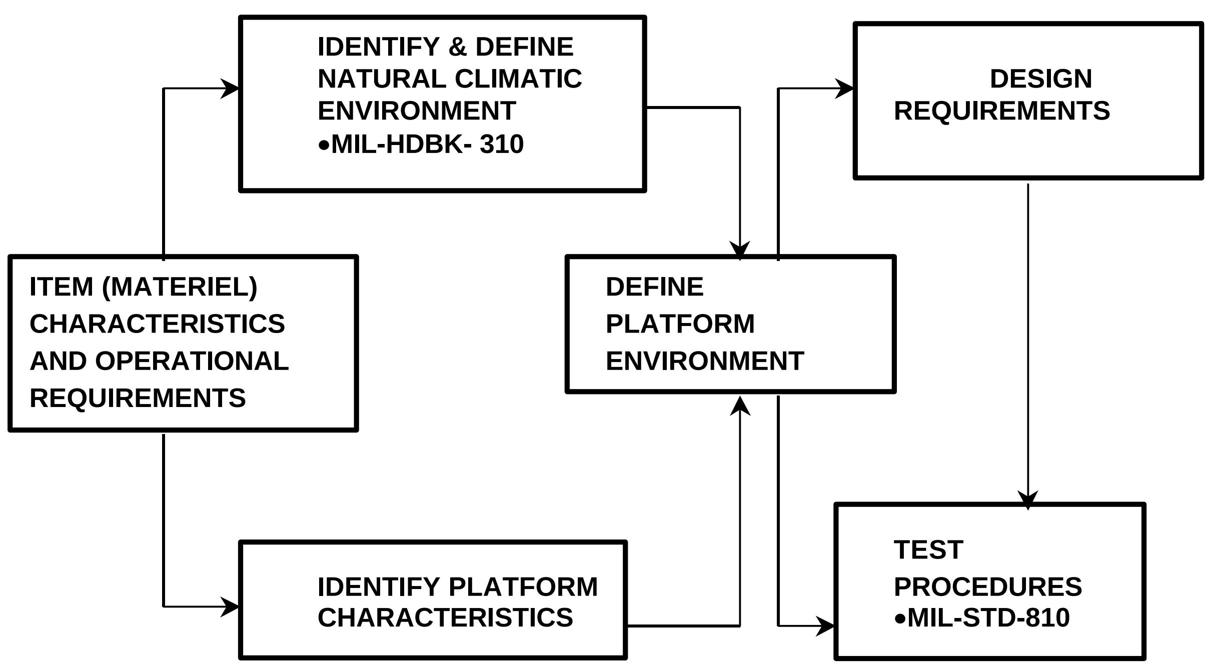
4.3.4 Engineering Analyses and Trade-Offs. The natural environmental values selected from this handbook are to be used as inputs to the engineering analyses of materiel responses to the ambient environment. If the initially selected values prove unacceptable because of technical or cost considerations, the additional climatic information presented in Appendix A may be helpful in conducting trade-off analyses.

4.4 Organization and Contents. Section 5 is subdivided into three major parts that are further subdivided as follows:

(a) 5.1 Worldwide Surface Environment
(b) 5.2 Regional Surface Environments
  5.2.1 Basic Regional Type
  5.2.2 Hot Regional Type
  5.2.3 Cold Regional Type
  5.2.4 Severe Cold Regional Type
  5.2.5 Coastal/Ocean Regional Type
(c) 5.3 Worldwide Air Environment to 80 km
  5.3.1 Atmospheric Envelopes
  5.3.2 Atmospheric Profiles

Each of the subdivisions above provide discussion of the climatic information contained in that subdivision, their applicability, and values recommended for initial consideration. Each of these is further broken down into data presentations for individual climatic elements or combinations of elements.

4.5 Relationship with MIL-STD-810. MIL-HDBK-310 is a source of information that should be used to derive climatic test values required by MIL-STD-810. The relationship between the two standards is shown in the following diagram:



4.6 Scientific Consultation: Consultation is encouraged with environmental scientists in order to guard against misinterpretation of this document.

(a). Air Force:
HQ AFMC/DOW
WPAFB, OH 45433
Phone: commercial: (937) 257-5364 (Dsn prefix: 787-)
Fascimile: (937) 656-1246 (Dsn prefix: 986-)
Web: http://www.afmc.wpafb.af.mil/organizations/HQ-AFMC/DO/dow/index.htm

(b). Army:

(c). Navy:

5. DETAILED REQUIREMENTS AND GUIDELINES

The climatic information presented in this section is divided into three major subdivisions. Section 5.1 provides data for materiel intended for worldwide use (see 1.3). Section 5.2 provides data that represent specified regions. Since regions representing a specific type of weather are not generally contiguous, the climatic data are said to apply to "regional types. The world is divided into five regional types, of which four cover the land areas. The fifth regional type covers the coastal/ocean environment (see 4.2). Section 5.3 provides data on the worldwide air environment up to an altitude of 80 km for airborne and air-projected equipment.

5.1 Worldwide Surface Environment. The data in this section are based on surface weather observations over land areas. Information for each climatic element is generally divided into three subsections. The first provides the most extreme value ever recorded. The second subsection presents values that occur for specified frequencies-of-occurrence during the most severe month (see 4.1(a)). The third subsection presents long-term climatic extremes that would be equalled or exceeded at least once during 10, 30 or 60 years of exposure (see 4.1(b)).

In general, equipment should be designed to operate during all but a certain small percentage of the time (see 4.3.3(b)). Once an acceptable frequency of occurrence of a climatic element has been determined, the corresponding climatic value can be ascertained from the data in the second subsection for each element. It is recommended that a 1-percent frequency be initially considered for all climatic elements except cold temperature, for which a 20-percent frequency is recommended, and rainfall, for which a 0.5-percent frequency is recommended. Values corresponding to several frequencies of occurrence are provided for most climatic elements. These and other data in Appendix A are for trade-off analyses (see 4.3.4).

More extreme climatic values should be considered for equipment whose failure to operate is life-threatening, or for materiel that could be rendered useless or dangerous after a one-time exposure (see 4.3.3(c)). An option for such materiel would be protection from exposure to these extremes.

5.1.1 High Temperature. Temperatures discussed in this section were observed in standard meteorological instrument shelters. They represent temperatures of the free air in the shade about 1.5 m above the ground. These high temperatures will normally be encountered only during strong sunshine and fairly light winds. The ground surface will attain temperatures 15 to 30°C higher than that of the free air, depending upon radiation, conduction, wind, and turbulence. Air layers very close to the surface will be only slightly cooler than the ground, but the decrease with height above the surface is exponential so that temperatures at 1 m will be only slightly warmer than that observed in an instrument shelter.

The temperature attained by military equipment exposed to high temperatures will vary greatly with the physical properties of the equipment affecting heat transfer and capacity, and with the type of exposure. (Probably the worst exposure is that of equipment placed on the ground in the direct sunshine.) The heat load from a realistic diurnal air temperature and solar radiation cycle (data that can be provided from meteorological records) make up only a part of the heat transferred to the equipment. The equipment temperature will also be dependent on solar radiation reflected to it from the ground, long wave radiation from the heated ground, long wave radiation to the cold sky, scattered solar radiation from the sky and nearby clouds, the vertical temperature distribution in the free air surrounding the equipment, and total ventilation from wind and turbulence.

5.1.1.1 Highest Recorded. The world[1]s highest recorded temperature, 58°C (136°F), occurred at El Azizia, Libya on 13 September 1922. El Azizia is located in the northern Sahara at 32°32′N, 13°01′E, elevation 112m. At least 30 years of observations are available for this station. Besides the 58°C reported, maximum temperatures of 56°C (133°F) and 53°C (127°F) for August and June have also been observed.

5.1.1.2 Frequency of Occurrence. There were insufficient hourly data to determine the distributions of high temperatures versus frequency of occurrence on a global basis. Therefore, a statistical technique was used to estimate percentile temperatures for thousands of locations worldwide. Atlases containing the high temperature analyses were used to determine areas of the world with the highest 1-, 5-, and 10-percent temperatures during the worst month.

The hottest area of the world lies in the interior of northern Africa eastward to India. The hottest part of this area is the Sahara desert, which qualifies as the worst part of the world for high temperature. The 1-, 5-, and 10-percent temperatures are 49°C (120°F), 46°C (115°F), and 45°C (113°F), respectively.

Hot extremes are part of a well pronounced diurnal cycle. The daily maximum lasts only a couple of hours. However, it is accompanied by intense solar radiation that causes equipment to attain temperatures considerably higher than free-air values. Therefore, a realistic diurnal cycle including solar radiation should be considered with the hot extreme. The cycle should also include windspeed, which serves as a limiting factor to heat intensification. The moisture content is also needed since the extremely low relative humidities that can be present during the hottest situations may present special design problems.

If military materiel is to be designed to operate in a 1-percent temperature any place in the world during the warmest month of the year, then it must be designed for a diurnal cycle in which the air temperature attains a maximum of at least 49°C at a height of about 1.5 m above the ground. This cycle and associated solar radiation, relative humidity and windspeed is presented in Table I (page 72). Temperatures of 49°C will also be encountered during other months, and in hot deserts outside this area, but less frequently than 1 percent of the time. Diurnal cycles associated with the 5 and 10 percent temperatures can be approximated by subtracting 3°C, and 4°C, respectively, from each of the hourly temperatures in Table I. Values of other elements in the cycle would not vary significantly from those associated with the 1-percent value because lower temperatures could be caused by other meteorological conditions.

5.1.1.3 Long-term Extremes. High temperatures that would be expected to occur at least once during 10, 30, and 60 years in the hottest part of the world are 53°C (128°F), 54°C (130°F), and 55°C (131°F), respectively. These values were derived from statistical analysis of 57 years of temperature data from Death Valley, California and are considered representative of conditions in the Sahara desert. Diurnal cycles, including associated solar radiation, relative humidity, and wind-speed are provided in Table II (page 73).

5.1.2 Low Temperature. Low temperature extremes result from the optimum combination of several meteorological elements. Long absence of solar radiation, clear skies, a snow cover, and calm air are the most essential requirements, with the ultimate fall in temperature dependent upon the duration of these conditions. Since these conditions can exist for extended periods at high-latitude continental areas, there can be much longer durations of cold than high temperatures, which have a diurnal dependence.

Temperatures discussed in this section were observed in standard meteorological instrument shelters. They represent temperatures in the free air at about 1.5m above the snow surface. Temperatures within a few centimeters of the surface could be 4 to 5°C colder.

5.1.2.1 Lowest Recorded. Excluding Antarctica, the generally accepted world[1]s lowest recorded temperature is -68°C (-90°F). It was recorded at Verkhoyansk (elevation, 105 m), USSR on 5 and 7 February 1892 and at Ojmjakon (elevation, 660m), USSR on 6 February 1933.

5.1.2.2 Frequency of Occurrence. Hourly data were insufficient to determine the distributions of low temperature versus frequency of occurrence on a global basis. Therefore, a statistical technique was used to estimate percentile temperatures for thousands of locations worldwide. Atlases containing the low temperature analyses were used to determine areas of the world with the coldest temperatures occurring 1, 5, 10, and 20 percent of the time during the worst month. The 20-percent value was added for this element because the low temperatures associated with lower frequencies are limited in geographical extent.

The coldest areas of the world, excluding Antarctica, are the central part of the Greenland ice cap (approximately 2,500-3,000 m elevation) and Siberia between 62° to 68°N, and 125° to 145°E (less than 800 m elevation). The 1-, 5-, 10-, and 20-percent temperatures in these areas are -61°C (-78°F), -57°C (-70°F), -54°C (-65°F), and -51°C (-60°F), respectively. These temperatures will also be encountered during other months and in other high-latitude locations in the northern hemisphere, but less frequently. A diurnal cycle is not provided because the effect of solar radiation during these extreme conditions is minimal. Therefore, duration of very cold temperatures is an important consideration. Studies indicate that during a 24 hour period, maximum temperatures would exceed the percentile temperatures by only about 3°C.

5.1.2.3 Long-term Extremes. Low temperatures that would be expected to occur at least once during 10, 30, and 60 years in the coldest area of the world are -65°C (-86°F), -67°C (-89°F), and -69°C (-92°F), respectively. They were derived from statistical analysis of 16 years of data from Ojmjakon, USSR. The 60-year value is lower than the recorded extreme because it represents a longer period than the period of actual observations. Temperature regimes for 32 days with these temperature minima are provided in Table III (page 74).

5.1.3 High Absolute Humidity. Absolute humidity is the mass of water vapor in a specified volume of air. It may be expressed in many ways, but is generally specified as grams/m^3 or parts of water vapor per million part of dry air (ppm). The dew point, the temperature at which condensation would occur if the air was cooled at constant pressure, is the observed meteorological element used to calculate the absolute humidity. Climatic data on dew-point temperatures were used to determine extremes of absolute humidity. These extremes were converted to mixing ratios, parts by weight of water vapor per million parts of dry air (ppm). Conversion was accomplished assuming a pressure of 1000 mb. Since the amount of water vapor that the air can hold increases with temperature, areas with the highest absolute humidities are hot locations (usually at the edge of a desert) adjacent to very warm bodies of water.

5.1.3.1 Highest Recorded. The highest accepted dew point observation is 34°C (93°F), recorded in July (exact date unknown) at Sharjah, Arabia, on the shore of the Persian Gulf. This corresponds to a mixing ratio of 35 x 10^3 ppm.

5.1.3.2 Frequency of Occurrence. The highest dew points in the world were recorded along the narrow coastal deserts of the Red Sea, Gulf of Aden, and the Persian Gulf eastward to the northern Arabian Sea. In this area, Abadan, Iran was found to have the highest dew point occurring 1 percent of the time in the worst month, 31°C (88°F), mixing ratio 30 x 10^3 ppm.

Although Abadan has the highest 1-percent extreme, extremes for higher percents are found in regions where the dew points are somewhat lower but more nearly constant. The 5-, 10-, and 20-percent dew-point extremes are 30°C (86°F), 29°C (84°F) and 28°C (83°F), respectively, as determined using data from Belize City, Belize. Respective mixing ratios are: 28, 26, and 25 x 10^3 ppm.

Using the Abadan data, a synthetic cycle associated with the 1-percent dew-point extreme was constructed and is given in Table IV (page 75). It shows the 1-percent dew point of 31°C (88°F) persisting for 7 hrs, a maximum temperature of 41°C (105°F) and a dew point of 29°C (84°F) or higher for the full 24-hr cycle. Also shown in Table IV are the associated insolation and relative humidity cycles.

5.1.3.3 Long-term Extremes. The long-term extreme occurrence of dew point is about 2°C more than the 1-percent value. This may not be as detrimental to equipment as a somewhat lower dew point occurring for an extended period of time. Therefore, the usual manner of determining long-term extremes is not followed for high absolute humidity. Rather, the long-term extreme will be a repetition of a daily cycle typical of a location experiencing high absolute humidities for extended periods of time. Though this location will not experience the high 1-percent value of the coastal desert, it will experience longer periods of sustained high dew points only slightly lower than the 1-percent value.

Long periods with high absolute humidities were found at Belize City, Belize during August. Data from this location were used to synthesize the diurnal cycle in Table V (page 76). This cycle repeats daily for a month. The dew points in this cycle range between 26 and 28°C for ambient temperatures between 27 and 30°C. Such conditions are found in coastal, moist tropical locations and are approximately duplicated for a month. Adjacent months will experience only slightly less humid extremes.

5.1.4 Low Absolute Humidity. Since the amount of water vapor that can be contained in air is directly proportional to air temperature, lowest absolute humidities will be found with lowest air temperatures. For the low absolute humidity extremes, dew points (referred to as frost points when below freezing) were determined using low temperature extremes with an assumed relative humidity of 90 percent.

5.1.4.1 Lowest Recorded. The absolute humidity associated with the low temperature extreme of -68°C given in 5.1.2.1 and 90-percent relative humidity is assumed. This corresponds to a frost point of -68.4°C (-91°F).

5.1.4.2 Frequency of Occurrence. The absolute humidities associated with the low temperature extreme values in 5.1.2.2 and 90-percent relative humidity are assumed. For the 1-percent low temperature of -61°C (-78°F), this corresponds to a frost point of -62°C (-79°F)

5.1.4.3 Long-term Extremes. The absolute humidities associated with the low temperature extremes given in 5.1.2.3 and 90-percent relative humidity are assumed. For at least one occurrence in 10, 30, and 60 years this corresponds to frost points of -66.1°C (-87°F), -67.8°C (-90°F), and -69.5°C (-93°F) respectively.

5.1.5 High Temperature with High Humidity. Since very high absolute humidities can occur with even higher temperatures than those in 5.1.3, this section provides guidance on the joint occurrence of high humidities with temperatures above 41°C (105°F). These extremes occur in the coastal deserts surrounding the Persian Gulf, Gulf of Aden, and the Red Sea. Abadan, Iran was determined as representative of the world's most extreme high temperature, high-humidity environment.

5.1.5.1 Highest Recorded. A temperature of 48.3°C (119°F) with a concurrent dew point of 29.4°C (85°F) was recorded at Abadan, Iran on 24 July 1953.

5.1.5.2 Frequency of Occurrence. Seven years of data for Abadan, Iran were analyzed to determine the following joint frequencies of occurrence:

Temperature °C (°F)	Dew Point °C (°F)		
	1 percent	5 percent	10 percent
46.1 (115)	27.2 (81)	21.7 (71)	*
43.3 (110)	27.8 (82)	24.4 (76)	20 (68)

*The indicated temperature does not occur this often.

5.1.5.3 Long-term Extremes. The 7 years of data available for Abadan were insufficient for extreme value analysis to determine the long-term extremes in the same format presented for most other elements. Therefore, the 0.1-percent joint values of temperature and dew point were calculated to satisfy more stringent design requirements. Temperatures and respective dew points having a joint frequency of occurrence of 0.1 percent are: 48.9°C (120°F) with a dew point of 25.6°C (78°F), 46.1°C (115°F) with a dew point of 31.1°C (88°F), and 43.3°C (110°F) with a dew point of 31.1°C (88°F).

5.1.6 High Relative Humidity with High Temperature. Relative humidity (RH) indicates the degree of saturation of the air. It is the ratio of the actual vapor pressure of the air to the saturation vapor pressure.

The maximum RH (not including supersaturation) of 100 percent is encountered in nature at temperatures up to about 30 to 32°C (86 to 90°F) right over water surfaces adjacent to coastal deserts. Over much of the world[1]s tropical areas, 100 percent RH with temperatures up to 26°C (79°F) occurs quite frequently. RH of 100 percent is present in fog and clouds, but may also be present before fog is visible. One hundred percent RH is also closely approached in tropical jungles.

5.1.6.1 Highest Recorded. Surface relative humidities of 100 percent with fairly high temperatures are common in the moist tropics. An observed RH of 100 percent with a temperature of 30°C (86°F) at Dobochura, Papua, New Guinea has undoubtedly occurred at other locations in the moist tropics.

5.1.6.2 Frequency of Occurrence. Large open areas of the tropics have high relative humidities with high temperature. Giving the 1-percent high RH is meaningless for design, since the 5-percent value is as high as 100 percent in many areas. Therefore, only a daily cycle typical of open areas in the moist tropics is provided.

The conditions depicted in Table VI (page 77) may be found in open moist tropical areas during any month of the year. The diurnal cycle includes a temperature variation from 25.60 to 35°C (78° to 95°F), and a relative humidity variation from 74 to 100 percent. Examples of stations with such extremes are Calcutta (India), Seno (Laos), Kampot (Cambodia), Hanoi (North Vietnam), Nanking (China), Kwajalein Atoll, Paramaribo (Surinam), and Georgetown (Guyana).

5.1.6.3 Long-term Extremes. See the discussion for high absolute humidity in section 5.1.3.3. Equipment should be designed to withstand long exposure to nearly constant high relative humidity and high temperature depicted by the daily cycle given in Table VII (page 78). Such a daily cycle prevails in jungles under the canopy of tropical rainforests. The primary feature of this condition is the long duration of relative humidity at and above 95 percent. These conditions may occur on several days during any month of the year but are more prevalent during rainy seasons.

5.1.7 High Relative Humidity with low Temperature. High relative humidity in the dry arctic winter is the rule rather than the exception since the loss of heat by radiation during the long nights causes the temperature to drop to the frost point of the air.

5.1.7.1 Highest Recorded. A value of 100 percent with the low temperature extreme given in 5.1.2.1.

5.1.7.2 Frequency of Occurrence. A value of 100 percent with the temperatures given in 5.1.2.2.

5.1.7.3 Long-term Extremes. A value of 100 percent with the temperatures given in 5.1.2.3.

5.1.8 Low Relative Humidity with High Temperature. Lowest relative humidities approach zero percent in hot deserts distant from bodies of water.

5.1.8.1 Lowest Recorded. A relative humidity of 2 percent at 43.3°C (110°F) was recorded in Death Valley, California.

5.1.8.2 Frequency of Occurrence. Since the percentile values of low relative humidity vary very little, the RH cycle in Table I (page 72) is recommended.

5.1.8.3 Long-term Extremes. The relative-humidity cycle associated with the long-term high temperature extremes in Table II (page 73) is recommended.

5.1.9 Low Relative Humidity with low Temperature. Not available.

5.1.10 Wind Speed. Observations of wind speed are one of the least standardized of all meteorological elements. The exposure and height above the ground of wind-measuring equipment is far from uniform. Because windspeeds near the ground can vary significantly with height and exposure, specifying this variability is an important problem. Another problem, the interval over which wind speeds are averaged, varies from country to country. The current standard averaging period in the United States, 1 min, is considered representative of the values herein referred to as the "average or steady wind." Gusts associated with steady wind speeds must also be considered.

The gust factor is the ratio of the gust speed to the steady windspeed. Although many factors influence this ratio, one can develop approximations for the gust factor as a function of steady windspeed. Gust speeds reported in weather observations are normally considered to be about 2-sec averages, but for designing various sized equipments, other short-duration gusts are often applicable. A previous study indicates that a gust must have a duration such that its size is about eight times the downwind dimension of a structure in order to produce a force on the structure commensurate with the gust speed. For example, a structure with a 3 m downwind dimension must have a 24 m long gust to establish full dynamic pressure on the structure. Smaller structures will be sensitive to shorter-duration gusts.

The most probable gust extremes associated with the 1-min steady extremes presented in the following sections are scaled to arbitrarily chosen downwind equipment dimensions of 0.6, 1.5, 3, 8, 15, and 30 m. Because the placement of most equipment will not take into consideration the direction of the extreme windspeeds, the shortest horizontal dimension of the equipment should be considered the downwind dimension.

5.1.10.1 Highest Recorded. The recognized worldwide maximum wind speed measured at a surface station is a 5-min speed of 177 knots and a 1-sec gust of 196 knots measured at Mt. Washington Observatory, New Hampshire on 12 April 1934. The Observatory is 1915 m above MSL and the anemometer was mounted at 12 m. However, this is an anomalous location and such values should not be considered for this standard.

Tornado winds also are excluded from consideration because they are considered to be too localized. No wind measuring device has ever survived the full fury of a tornadic wind. Authorities have suggested that the winds could exceed 350 knots.

A 152 knot gust at a height of 9.2 m (corresponding to 139 knots at 3m) was recorded during a typhoon that passed over Iwo Jima AB, Volcano Islands in the Pacific Ocean in 1948. The maximum sustained wind is a 5-min speed of 131 knots measured at a height of 16.5 m (corresponding to 119 knots when corrected to a 1-min speed at 3 m) at San Juan, Puerto Rico. These two extremes should not be considered as the highest winds that have occurred over a general area or region. Certainly, higher speeds have occurred, but have not been recorded due to their devastating damage.

The highest wind speeds affecting sizable areas occur within the typhoons that pass over the islands of the western North Pacific Ocean. Of these, Typhoon Nancy, during the period 11-12 September 1961, was the most intense typhoon ever observed by the Joint Typhoon Warning Center (Inception date for the JTWC was 1945). They reported maximum surface winds to be 185 knots, estimated from air reconnaissance observations. For this standard, it is assumed that the highest sustained wind-speeds affecting a sizable area of military concern was the 185 knots (sustained for a duration of several minutes). The most probable 2-sec gust to accompany this sustained wind is estimated to be 204 knots.

5.1.10.2 Frequency of Occurrence. The location having the highest 1-percent wind is Northern Scotland. Typical of the area is Stornoway where in the windiest month (December), the 1-, 5- and 10-percent high wind speeds are 43, 36 and 33 knots, respectively (1-min speeds at a 3 m height).

The most probable gusts that can be expected to accompany these 1-, 5- and 10-percent wind speeds, based on the shortest horizontal dimension of the equipment, are given in the following table:

Associated Gust, Knots (m/s)							
Percent Extreme	1-min Steady Knots (m/s)	Shortest Horizontal Dimension of Equipment (m)					
		< 0.6	1.5	3	8	15	30
1	43(22)	62(32)	59(30)	56(29)	53(27)	50(26)	48(25)
5	36(19)	52(27)	49(25)	47(24)	44(23)	42(22)	40(21)
10	33(17)	48(25)	45(23)	43(22)	40(21)	38(20)	36(19)

The wind speeds in the table are for a height of 3 m. Speeds can be estimated for other heights by using the power law relationship

$$V_Z = V_{3m} \times \left(\frac{Z}{3m}\right)^P$$

where V_Z is the velocity at the desired height, V_{3m} is the velocity at 3m, Z is the desired height in meters, and P is an exponent that varies primarily with terrain and stability. MIL-STD-210B used P values of .125 for winds less than 50 kts and 0.08 for gusts and winds of at least 50 kts. However, this resulted in circumstances where the steady speeds exceeded the gusts. Therefore, a compromise of P = 0.10 is recommended for converting these wind speeds and gusts to other heights up to 100 m. Reference to more detailed information is provided in the appendix.

5.1.10.3 Long-term Extremes. The area having the highest winds in the world (excluding mountain peaks and tornado tracks) is in the typhoon belt of the western North Pacific Ocean. (This area ordinarily has relatively low wind speeds). Locations typical of the center of this belt are the Volcano Islands (for example, Iwo Jima) and Ryukyu Islands (for example, Okinawa). Of these locations, Naha, Okinawa (26°12′N, 122°30′E, station elevation 7 m MSL) was found to have the highest annual extremes. Based on 19 years of data, the mean of the highest annual 2-sec gusts is 84 knots with a standard deviation of 26.4 knots. Applying these statistics in the theory of extremes, the 2-sec gusts which can be expected to occur at least once during 10, 30, and 60 yrs are 134, 154, and 167 kts, respectively. The most probable 1-min steady winds associated within these 2-sec gusts are 119, 140, and 156 kts, respectively. Gusts for various shortest horizontal dimensions of equipment are presented in the following table:

Associated Gust, Knots (m/s)							
Period (yrs)	1-min Steady Speed knots (m/s)	Shortest Horizontal Dimension of Equipment (m)					
		< 0.6	1.5	3	8	15	30
10	119(61)	149(77)	144(74)	141(73)	137(71)	134(69)	132(68)
30	140(72)	169(87)	165(85)	162(83)	158(81)	155(80)	152(78)
60	156(80)	184(95)	180(93)	177(91)	173(89)	171(88)	167(86)

These wind speeds are for a height of 3 m. Speeds (and gusts) can be estimated for other heights up to 100 m by using the power law relationship in 5.1.10.2 with a value of 0.08 for P. This lower value for P is recommended because these extremely high wind speeds occur in open areas where winds decrease less rapidly with height.

5.1.11 Rainfall Rate. The highest rates of rainfall occur when there is strong convection (rising currents of air) and available moisture. Thunderstorms and tropical cyclones (including hurricanes and typhoons), are systems that most commonly have these ingredients. Thunderstorms, which are relatively small and localized, produce the heaviest rainfalls over periods of a few hours or less.

Tropical cyclones are responsible for most of the extreme amounts for a few hours to a few days. Orographic precipitation, which is the result of moist air forced to ascend over topographic features, can also be quite heavy and can continue for long periods. Windward slopes of mountain ranges in the moist tropics generally have the highest monthly and annual amounts; they are also prone to very extreme amounts when affected by tropical storms.

5.1.11.1 Highest Recorded. The world's greatest recorded 1-min rainfall is 31.2mm at Unionville, Maryland, on 4 July 1956. This extreme occurred during an afternoon of intense thunderstorms. The total precipitation during the storm was 91.4 mm. The drop size distribution associated with this rate is given in 5.1.11.2. (This 1-min rate is about twice as great as the next several candidates leading one to doubt its validity. See ref. in 40.1.11).

The greatest rainfall from readily available records for about 1 hr is 305 mm which occurred within a 42 min period (7.25 mm/min) at Holt, Mo. during a local intensification of a narrow squall line ahead of a surface cold front. The drop-size distribution associated with this rate is given in 5.1.11.2.

The world's greatest 12-hr rainfall is 135 cm on 28-29 February 1964 (average of 1.87 mm/min) at Belouve, La Reunion Island.

The world's greatest 24-hr rainfall is 188 cm on 15-16 March 1952 (average of 1.31 mm/min) at Cilaos, La Reunion Island.

The world's greatest five-day rainfall is 430 cm on 23-27 January 1980 at Commerson, La Reunion Island.

La Reunion Island is located in the Indian Ocean at approximately 21°S, 55°30′E. It is about 30 by 40 miles in extent and very mountainous, with steep slopes and narrow valleys. Sea surface temperature is highest during the tropical cyclone season, reaching 27°C (81°F) in March. The record-producing rainfalls at Cilaos and Commerson occurred during tropical cyclones as did, presumably, that at Belouve.

5.1.11.2 Frequency of Occurrence. Operation of exposed equipment is affected by the instantaneous rate of rainfall. Heaviest rainfalls have the highest expectancy in tropical areas, especially over windward coasts and slopes. Unfortunately, little data are available on 1-min rates that are used to represent instantaneous rates. Total amounts, measured every 3 hrs or more, make up most of the climatological records. In order to determine 1-min rates on a large scale, a technique for obtaining intensities from readily available precipitation data was developed.

A statistical model, in the form of regression equations for estimating 1-min precipitation intensities from available climatology, was developed using 1-min data obtained during special observation programs. Atlases of 1-min rates, based on the model, were used to determine areas in the world with the highest rates occurring 0.5, 0.1, and 0.01 percent of the time. Rainfall rates are presented for lower frequencies than other climatic elements because high rates are quite extensive in the tropics and high rates can be a problem in many months of the year.

The highest rainfall rates occurring 0.5, 0.1, and 0.01 percent of the time were estimated to be 0.6, 1.4, and 2.8 mm/min, respectively. These were based on data from 2 locations in northeast Brazil, Barro Do Corda and Teresina, and from Cherrapunji, India. These rates do not greatly exceed those occurring in many parts of the moist tropics, especially in Southeast Asia. The liquid water content for these rates is 1.6, 3.5, and 6.7 g/m^3, respectively.

Drop-size distributions for these rates, and also the world record 1-min and 42-min rates in 5.1.11.1, were estimated from a gamma-function fit to drop-size distributions observed during heavy rain in tropical cyclones.

The raindrop concentrations per cubic meter are:

Rate (mm/min)	Drop Diameter Range (mm)					
	0.5 to 1.4	1.5 to 2.4	2.5 to 3.4	3.5 to 4.4	4.5 to 5.4	5.5 to 6.4
0.6	1154	260	26	2	< 1	< 1
1.4	1608	520	77	8	< 1	< 1
2.8	2057	863	170	25	3	< 1
7.2	2779	1595	440	91	16	3
31.2	4121	3547	1514	487	135	34

5.1.11.3 Long-term Extremes. Periods of intense rainfall for 1, 12, and 24 hours that would be expected to occur at least once in 10, 30, and 60 years were derived from a statistical analysis of data from more than 200 locations around the world. This was used to develop regression equations to estimate rainfall extremes from climatic data that are widely available for most observation sites, since published data for 1, 12, and 24 hrs are limited. The highest rainfalls were found to occur in Southeast Asia, Burma, west to India, and south to Indonesia.

The rain amounts for 1, 12, and 24 hrs given in the following table often occur with the passage of a tropical cyclone. Nominal temperature and wind speed associated with these storms are 24°C (75°F) and 64 kts for the 1-hr intensity, 50 kts for the 12-hr intensity, and 40 kts for the 24-hr intensity (for anemometer heights of 3 m).

Duration (hrs)	Rainfall Rate (cm/hr)		
	Period (yrs)		
	10	30	60
1	10	12	13
12	2.3	2.8	3.0
24	1.5	1.8	1.8

5.1.12 Blowing Snow. The effects of blowing snow are primarily dependent on mass flux and the shape, size, and hardness of snow particles. Mass flux is defined as the mass of snow moving horizontally (or parallel to the ground) across a unit area per unit time; e.g., grams per square meter per second. The highest mass fluxes occur near the ground and decrease significantly with increasing height. However, substantial fluxes occur up to about 10 m. Therefore, extreme values for blowing snow are given for height intervals from 0.05 m to 10 m. Design values should be based on the height of the equipment.

When blown by strong winds, snow crystals are broken and abraded into roughly equidimensional grains with rounded or subangular corners. Particles occur in greatest numbers in the size range 20 to 400 micrometers (0.02 mm to 0.4 mm), where the size is the effective diameter, defined as (length X breadth)$^{1/2}$ in the plane of measurement. Particle size decreases rapidly with height from the surface to 0.05 m, and gradually above this level. A typical distribution of blowing snow particle sizes applicable to extremes given below is:

	EFFECTIVE DIAMETERS (micrometers)												
	23 to 34	35 to 46	47 to 58	59 to 70	71 to 82	83 to 94	95 to 106	107 to 118	119 to 130	131 to 142	143 to 154	155 to 166	167 to 178
PERCENT	0.60	1.3	5.0	15	22	21	16	9.7	4.7	2.5	1.0	0.70	0.50

Within the basic cold area (see 5.2.1.2.), temperatures during periods of blowing snow are typically -10°C to -20°C (14°F to -4°F). Within the cold and severe cold areas (see 5.2.3 and 5.2.4), blowing snow is common at temperatures between -23°C and -29°C (-10°F to -20°F). Blowing snow may occur at temperatures as low as -40°C (-40°F).

5.1.12.1 Highest Recorded. Highest recorded horizontal mass fluxes (saturation conditions) at heights ranging from 0.05 to 10 m, accompanied by a wind speed of 45 knots at the 3-m level are:

HEIGHT		MASS FLUX	
(m)	(ft)	(g/m^2 sec)	(lb/ft^2 sec)
10	33	310	63 x 10^{-3}
7.5	25	320	66
5.0	16	330	68
2.5	8.2	380	78
1.0	3.3	560	115
0.75	2.5	630	129
0.50	1.6	800	164
0.25	0.82	1600	328
0.10	0.33	3000	614
0.05	0.16	6200	1270

5.1.12.2 Frequency of Occurrence. The horizontal mass fluxes, one percent value, at heights ranging from 0.05 to 10 m, driven by wind speeds of 25 knots at the 3-m level (the 1-percent wind speed in central Canada during January) are:

HEIGHT		MASS FLUX	
(m)	(ft)	(gm/m^2 sec)	(lb/ft^2 sec)
10	33	2.2	0.45×10^{-3}
7.5	25	3.3	0.68
5.0	16	4.0	0.82
2.5	8.2	6.9	1.4
1.0	3.3	16	3.3
0.75	2.5	22	4.5
0.50	1.6	32	6.6
0.25	0.82	66	14
0.10	0.33	200	41
0.05	0.16	530	109

Data for 5- and 10-percent values are not available, and it is recommended that the above values be applied to any equipment that is susceptible to the effects of blowing snow. The typical particle-size distribution and associated temperature is provided in 5.1.12.

5.1.12.3 Long-term Extremes. Not applicable for this climatic element.

5.1.13 Snow Load. Snow that falls on shelters, buildings, and equipment will impose a structural load on the supporting surface and must be considered in the design of the structure or equipment. The magnitude of the load depends not only on snowfall accumulations and densities, but also on the configuration of the receiving surface and whether or not snow is typically allowed to accumulate. Measurements of snow loads on structures and equipment are not normally available; therefore, the snow-load values must be estimated based on measured ground surface snow accumulations. Such estimates are difficult to make and are subject to large errors; however, snow loads on equipment will usually be much less than on the ground because of structure slope, internal heating, and greater exposure to wind. Snow-load criteria for permanently installed equipment, which is designed and built for a specific location, must be determined by special studies based on the maximum snow load ever observed or expected in that location. Values for snow load are given for three classes of transportable equipment.

These are:

(a) Portable Equipment. Usually small items, such as tents, that may be moved daily. This equipment generally will shed snow, but in instances where it does not, the resultant distortion will require mandatory daily clearing. The load for portable equipment is based on 24-hour snowfalls.

(b) Temporary Equipment. Usually includes large items on which snow can collect, i.e., rigid shelters, portable hangers, etc. that can be cleared of snow between storms. The load for this type of equipment is based on snowfalls resulting from storms that last longer than 24 hours.

(c) Semi-permanently Installed Equipment. Usually includes equipment that is not very mobile. Snow is not removed between snowfalls. The load for this type of equipment is based on accumulation from many storms.

5.1.13.1 Highest Recorded. The values given in this section are for snow loads on the ground, not on shelters or equipment. Although snow loads on equipment are generally less than ground snow loads, the latter may be used as a guide in determining the maximum snow loads that are possible. Values, provided as kg/m^2, can be converted to lbs/ft^2 by multiplying by 0.205.

(a) Portable Equipment. In mountainous areas 194 kg/m^2; in non-mountainous areas 137 kg/m^2. These are based on the extreme 24-hour snowfalls that occurred at Silver Lake, Colorado (193 cm) in April 1921, and Barnes Corner, New York (137 cm) in January 1976, respectively.

(b) Temporary Equipment. In mountainous areas, 484 kg/m^2; in non-mountainous areas 191 kg/m^2. These are based on the extreme single-storm snowfalls exceeding 24 hours. They occurred at Mt Shasta, California (480 cm) in February 1959, and Watertown, New York (175 cm) in January 1922, respectively.

(c) Semi-permanently Installed Equipment. In mountainous areas, 1155 kg/m^2; for non-mountainous areas, the record extreme is not available, but an extreme that is likely to occur one year in 30 is a snow load of 590 kg/m^2. The estimate for mountainous areas was based on the greatest recorded depth, 1146 cm, which occurred at Tamarack, California in March 1911. The non-mountain value was based on a study of Canadian snowfall statistics.

5.1.13.2 Frequency of Occurrence. Not applicable because equipment should be designed to withstand, without collapse or severe damage, snow loads that are expected over long periods.

5.1.13.3 Long-term Extremes. Snow loads recommended for use in design would be expected to occur one year in ten at the worst non-mountainous areas in the world. They are based on data obtained for stations located in the United States and Canada. The values presented are based on ground snow loads from non-mountainous areas converted to loads on horizontal and exposed surfaces of the equipment over which the wind flow is unimpeded and unobstructed. Inclined surfaces need to support only as much snow as can accumulate on the slope involved.

(a) Portable Equipment. 49 kg/m^2. Based on a 24-hour snowfall to a depth of 51 cm (20 in) with a specific gravity of 0.1.

(b) Temporary Equipment. 98 kg/m^2. Based on a single-storm snow depth of 102 cm (40 in) with a specific gravity of 0.1.

(c) Semi-permanently Installed Equipment. 246 kg/m^2. Based on an estimated ground snowload of 393 kg/m^2 (80 lb/ft^2) one year in 10 (10 percent probability each year) and a conversion factor of 0.625 for determining equipment loads from ground loads.

5.1.14 Ice Accretion. Ice accretion can be a major destructive force to structures, such as towers, located in middle and high latitudes just about anywhere in the world. Concurrent or subsequent strong winds may be the critical force in damaging equipment loaded with ice. There are three basic kinds of ice formed by accretion in the atmosphere: glaze, hard rime, and soft rime.

Glaze occurs when rain (sometimes drizzle) freezes on objects; it is clear and nearly as dense as pure ice. Hard rime is less transparent than glaze because of air trapped in the ice. The density with respect to water (specific gravity) varies from 0.6 to 0.9. It is usually the result of freezing drizzle, but may occur from exposure to supercooled cloud droplets during high winds with the temperature near freezing. Soft rime ice occurs when supercooled clouds or fog droplets freeze upon impact with surfaces colder than 0°C. It is opaque with a specific gravity of 0.2 to 0.5. It occurs most commonly on hills or mountaintops exposed to clouds at freezing temperatures.

Unfortunately, quantitative records of glaze and rime are not available because icing has not been routinely observed at operational weather stations. In order to determine reasonable values of ice and wind loading, it was necessary to study case histories of major ice storms, when structures have failed due to the strain of combined ice and wind loading.

5.1.14.1 Highest Recorded. Not available.

5.1.14.2 Frequency of Occurrence. Except for locations such as mountaintops exposed to supercooled clouds, the frequency of occurrence is normally quite low. Equipment exposed to the environment should be designed to survive the extreme accumulation of ice and concurrent wind expected to occur once over a period of years.

5.1.14.3 Long-term Extremes. These values are estimated to occur once in ten years at icing-prone locations such as eastern Labrador, Canada. More severe conditions will be found on cloud-immersed mountain peaks during periods of continuous passage of supercooled water clouds (specific information will be required for equipment designed especially for such installations). Strong winds are frequently associated with icing, occurring during its formation or after it has formed but before melting. Forces of such winds must be added to forces due to ice accretion as part of the stress in design for ice accretion.

Values of ice provided below are thicknesses extending horizontally into the wind. They apply to structures extending up to heights of 125 m. Associated wind loading can be considered as gusts of 100 knots at about 10 m increasing to 123 knots at 125 m. Independent design considerations shall be for the value of each of the three types of icing below:

(1) 75 mm glaze, specific gravity 0.9.
(2) 150 mm hard rime, specific gravity 0.6.
(3) 150 mm soft rime near the surface increasing linearly to 500 mm at 125 m, specific gravity 0.2.

5.1.15 Hail Size. Hail is capable of causing considerable damage to military equipment depending on the stone's size, hardness, number density, and impact velocity. It generally occurs during thunderstorms. Despite the prevalence of thunderstorms in the humid tropics, hail is not as frequent in the low latitudes as it is in the mid-latitudes, except possibly in some tropical areas at high elevation. The principal zone of occurrence is between 30-50°N latitude. Incomplete or inaccurate reporting of hail occurrences makes it difficult to state positively which section of this zone has the greatest frequency of hailstorms and the largest hailstone sizes. Some authorities cite north India as the area of most severe hail-storms. However, because of its long-term, high-quality records and its high frequency of very large hailstones, the Western Great Plains of the U.S. is selected as the most severe location for determination of design guidance. For this area, hailstone sizes were estimated from analyses of previous studies on hailstone sizes.

Since hail is a relatively infrequent climatic phenomenon and each occurrence is limited to a small area, the probability of a given site being hit by damaging hail is small. Considering the area of most severe conditions, observations indicate that Cheyenne, Wyoming, with over 9 occurrences per year, has the greatest average number of hailstorms annually. The most severe month at Cheyenne averages 2.9 occurrences, but a more representative worst-month average for the most severe area is assumed to be 2 storms. Individual hailstorms may deposit hail over an area ranging from about 10 km^2 up to a large strip as much as 50 km wide by 400 km long. Coverage of the ground is not uniform, nor necessarily continuous. Hail from a single storm cell may have a duration of 10 to 15 minutes at any one site. A large storm may result from several cells each producing a hailstreak, which together comprise a hailswath. The largest hailstones in a storm tend to be near the center of a cell or along the axis of a hailstreak.

In addition to hailstone size, two other characteristics of hail that have bearing on design considerations are density and terminal velocity. The density of hail-stones varies according to the relative proportions of rime and ice in the stone. The average density is near .8 gm/cm^3 (50 lbs/ft^3). A value of .9 gm/cm^3 (56 lbs/ ft^3) is acceptable as an extreme for design calculations. The terminal velocity (w) of falling hailstones is directly proportional to the square root of the hailstone diameter (d) according to the formula $w = K (d)^{1/2}$, where K is an empirically determined coefficient. For w in cm/sec, d in cm, K values at the surface ranging from 1150 to 1990 have been found. Maximum terminal velocities for large hailstones have been variously measured or estimated at 47 to 58 m/s. Fifty-eight m/s is acceptable as an extreme terminal velocity.

5.1.15.1 Largest Recorded. A hailstone, irregular in shape, with a diameter of approximately 142 mm, fell at Coffeyville, Kansas, 3 September 1970.

5.1.15.2 Frequency of Occurrence. Hail occurs very infrequently, and design considerations should be based on the largest sizes expected to occur over many years. For general information, the estimated .001- and .01- percent hailstone diameters at the most severe location during the most severe month are approximately 50 mm and 20 mm, respectively.

5.1.15.3 Long-term Extremes. Hailstone sizes that would be expected to occur at least once in the most severe area during 10, 30, and 60 years of exposure are 70, 80, and 90 mm, respectively.

5.1.16 High Atmospheric Pressure. A pressure of 1083.8 mb (32.01 in. Hg) was observed at Agata, Siberia on 31 December 1968. Station pressures over 1050 mb have occurred in the contiguous United States.

Design for the extreme value of 1083.8 mb should not present difficulties. Therefore, frequencies of occurrence and long-term extremes are not presented.

5.1.17 Low Atmospheric Pressure. The lowest atmospheric pressure to which ground military equipment may be subjected is primarily a function of height. The highest elevation contemplated for ground military operation is 4572 m. Unfortunately, surface pressure data for such elevations are virtually nonexistent; therefore, pressure measurements made at these elevations in the free air by balloon-borne sensors were used to estimate these values.

5.1.17.1 Lowest Recorded. Previous studies indicated that the minimum observed pressure at 4000 m was 548 mb and at 6000 m, 406 mb. Both of these pressures occurred in January in the Canadian Northwest, although not necessarily at the same time or location. Had these minima occurred at the same place and time, the all-time recorded low pressure at 4572 m would have been near 503 mb (14.85 in. Hg). This value should approximate the lowest pressure at that height.

The world's lowest recorded sea level pressure, 870 mb (25.69 in. Hg), was recorded by hurricane reconnaissance in the eye of typhoon Tip, at 16°44′N, 137°46′E, on 12 October 1979.

5.1.17.2 Frequency of Occurrence. Based on free-air observations, the estimated 1-, 5-, 10-, and 20-percent low-pressure values are 508, 514, 520, and 527 mb, respectively, for an altitude of 4572 m, the highest elevation contemplated for ground observations.

5.1.17.3 Long-term Extremes. The lowest estimated value of 503 mb is recommended.

5.1.18 High Atmospheric Density. Extremes of high density will occur where temperatures are lowest and pressures highest. To determine reasonable density extremes, one can assume that highest densities have occurred with high pressure extremes or with low temperature extremes. Using a temperature of -46°C (-51°F) with a 1080 mb high-pressure value, one obtains a density of 1.656 kg/m^3. Conservatively assuming that a pressure of 1050 mb accompanied the -68°C (-90°F) low temperature record extreme, one obtains a density of 1.783 kg/m^3. Therefore, high density extremes should be calculated using previously determined low temperature extremes.

5.1.18.1 Highest Recorded. As described above, a density of 1.783 kg/m^3 can be assumed for highest recorded.

5.1.18.2 Frequency of Occurrence. Assuming a pressure of 1050 mb with the 1-percent low-temperature extreme of -61°C (-78°F), one obtains a density of 1.720 kg/m^3.

5.1.18.3 Long-term Extremes. The highest recorded value is recommended.

5.1.19 Low Atmospheric Density. The lowest density to which ground military equipment may be subjected is a function primarily of altitude. As discussed in Section 5.1.17, the highest altitude contemplated for military operations is 4572 m. low density extremes for this and lower elevations are presented in this section.

Low air density greatly affects aircraft aerodynamic and engine performance. The density of the air near the ground is especially important in aircraft design since the lower the density, the longer the takeoff roll required by fixed-wing aircraft and the less weight a rotary-wing aircraft can lift. Concurrent temperature also has an important secondary effect and is necessary for a thorough analysis of engine performance.

5.1.19.1 Lowest Recorded. Not available.

5.1.19.2 Frequency of Occurrence. Based on the assumption that low density extremes for a given elevation will occur during extremes of high temperature, 48 stations representing different hot regions of the world and elevations from 3 to 4497 m were selected for study from various climatological tables. The 1-, 5-, 10-, and 20-percentile densities for each station/month and associated mean temperatures were plotted as a function of station elevation and examined for internal consistency.

Based on this analysis, the 1-percent density values and accompanying typical temperatures are:

ELEVATION		DENSITY		TEMPERATURES	
(m)	(ft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
0	0	1.078	0.0673	47	117
305	1000	1.047	0.0657	47	117
914	3000	0.986	0.0616	44	111
1524	5000	0.929	0.0580	40	104
2134	7000	0.878	0.0548	36	97
2743	9000	0.833	0.0520	31	88
3353	11000	0.790	0.0493	26	79
3962	13000	0.748	0.0467	20	68
4572	15000	0.707	0.0441	17	63

The 5-, 10-, and 20-percent values are in Table VIII (page 79).

5.1.19.3 Long-term Extremes. Not available.

5.1.20 Ozone Concentration. Accurate ozone measurement is more difficult than for most atmospheric elements, as might be expected for a gas that is usually present in concentrations of less than 1 part per million (ppm) and is also highly reactive. Frequent calibration of instruments is very important to assure accurate observations. Ozone measurements are expressed in two types of units: (1) mixing ratios and (2) concentration per unit volume. The mixing ratio is an expression of the amount of ozone in a given amount of air, if both are in the same units. The concentration per unit volume gives the mass of ozone in a given volume of air. These units can be related, but the conversion factors vary with changes in pressure and temperature. For example, a mixing ratio of 1 ppm is equivalent to a concentration of 2.14 X 10^3 µg/m^3 at 1 atmosphere (1.013 X 10^5 pascals or 1013 mb) pressure, whereas 1 ppm equals only about 1.07 X 10^3 µg /m^3 at .5 atmosphere (.51 X 10^5 pa or 507 mb) pressure.

Because of the great geographic differences in the factors that influence its generation and disintegration in the atmosphere, the distribution of ozone exhibits considerable spatial and temporal variations. Ozone can be generated by natural processes in the troposphere and stratosphere and by chemical reactions between sunlight and pollutants in the troposphere.

Most damage done to materiel would be expected to occur at or near the ground, because equipment must be in contact with high concentrations of ozone for hours or days before effects become serious. In unpolluted air, concentrations tend to average less than 30 $\mu g/m^3$ at sea level. However, where pollution is a factor, as it is in many urban areas, concentrations may exceed 200 $\mu g/m^3$

5.1.20.1 Highest Recorded. In extremely severe pollution situations, such as in the Los Angeles basin, surface ozone concentrations as high as 1765 $\mu g/m^3$ have been measured. A more likely extreme value in such areas is 980 $\mu g/m^3$. These high levels do not normally persist for more than a few days.

5.1.20.2 Frequency of Occurrence. Ozone concentrations for 1-, 5-, and 10-percent frequencies of occurrence are 220, 190, and 145 $\mu g/m^3$, respectively.

5.1.20.3 Long-term Extremes. Not available.

5.1.21 Sand and Dust. Sand and dust are terms used to designate small particles of matter, usually of mineral origin. A distinction is often made between sand and dust on the basis of size (dust particles are smaller), but there are no generally accepted specific size limits for the two kinds of particles. However, for most military applications it is important to distinguish between the smaller particles (dust) and the larger particles (sand) because of their primary effects on equipment. Airborne dust is primarily damaging because of its penetration and subsequent possible damage; whereas airborne sand is primarily damaging because of its erosion and abrasion effects on equipment. Important characteristics are size, hardness, atmospheric concentrations, and to some extent, shape. Particles vary in diameter from 0.1 to 1,000 micrometers, but most airborne particles are less than 74 micrometers. Hardness also varies widely (from 1 to 9 on the Mohs scale) depending largely on mineral composition. Quartz, by far the most common mineral in larger particles, has a hardness of 7. Greatest particle concentrations are found near helicopters hovering over dry loose surfaces. Secondary concentrations are found near ground vehicles operating on unpaved surfaces, including many roads. Lesser concentrations are associated with natural dust storms, although the areal extent of such storms may be substantial. Very few areas are exempt from sand and dust problems, at least during some part of the year.

5.1.21.1 Highest Recorded. Too few reliable and systematic measurements have been made to establish an extreme value. However, concentrations as high as 6.00 g/m^3 (particles smaller than 74 micrometers) have been measured inside the engine compartment of a tank moving over a very dusty surface.

5.1.21.2 Frequency of Occurrence. Since this is not an observed climatic element, and is most often mechanically created, frequencies of occurrence are not applicable. Three concentration levels are provided; selection of the appropriate one depends on intended use of the materiel under consideration. Items likely to be used in close proximity to aircraft operating over unpaved surfaces should be designed for particle concentrations of about 2.19 g/m^3 in multidirectional strong winds (downwash from helicopter rotors). Such particles range in size up to 500 micrometers in diameter. Items never in close proximity to operating aircraft, but which may be found near operating surface vehicles, should be designed for particle concentrations of 1.06 g/m^3 with wind speeds up to 18 mps at a height of 3 m. Particle sizes will range from less than 74 micrometers in diameter to 1000 micrometers, with the bulk of the particles ranging in size between 74 and 350 micrometers. These two categories are likely to include most military items. However, items that are assured of being subjected only to natural conditions should be designed for particle concentrations of .177 g/m^3 with wind speeds of 18 m/s at a height of 3 m. Under these conditions, the bulk of the particle sizes are likely to be less than 150 micrometers except that some larger particles (up to 1000 micrometers) may be in motion within several feet above the ground. In all categories, temperatures are typically above 21 °C (70°F) and relative humidities are less than 30%. For testing purposes, particle sizes up to 150 micrometers should be used if the primary concern is with the penetration of fine particles. If the abrasion effect of blowing sand is the primary concern, particle sizes up to 1000 micrometers should be used, but the bulk of the particles should be between 150 and 500 micrometers.

5.1.21.3 Long-term Extremes. Not available.

5.1.22 Freeze-Thaw cycles. A freeze-thaw cycle occurs at a specific site on any day that the temperature crosses the freezing mark. It is possible for more than one freeze-thaw cycle to occur at any site during a 24-hour period; however, because of the normal control of the daily temperature cycle by the solar cycle, this is not a common occurrence. Therefore, freeze-thaw cycles are described by the number of days in which they occur.

Freeze-thaw is an important consideration in the design of many kinds of military equipment. The effects on materiel are caused by alternate expansion and contraction of different materials and, especially, the change of state that water experiences during the freezing and thawing processes. These effects can exert great stress on susceptible components of materiel. For the above reason, freeze-thaw is of greatest potential concern as a factor affecting materiel in areas where abundant moisture is present immediately before or during the occurrence of the freeze-thaw cycle. The maximum number of freeze-thaw days in non-mountainous areas occurs in the mid-latitudes. The midlatitudes also have great variance in average number of freeze-thaw days. In general, sites that have the most months with mean monthly temperatures at or near 0°C will have the greatest annual number of freeze-thaw days in nonmountainous areas. However, the greatest number of freeze-thaw cycles for the entire Earth occurs at high elevations in the tropics, where a freeze-thaw cycle may be an almost daily occurrence. For the purposes of this standard, high elevation sites in the tropics are considered anomalous locations and should not be used for the derivation of design criteria unless equipment is specifically intended for use in such areas.

5.1.22.1 Highest Recorded. In tropical mountains at high elevations, freeze-thaw cycles 337 days annually and 31 days per month have been recorded. Elsewhere, a maximum of 31 days in one month also has been recorded.

5.1.22.2 Frequency of Occurrence. Due to the nature of this climatic condition, frequency of occurrence expressed as a percent of the time does not apply. An occurrence of 20 cycles during the worst month is recommended. This would occur in low elevation, mid-latitude areas such as central Germany. Concurrent weather would be dew points, -2°C to 1°C, a trace or more of precipitation on the day of the cycle, and the occurrence of fog.

5.1.22.3 Long-term Extremes. Not applicable.

5.2 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 (see 4.2 for applicability and limitations). The four types representing land environments are partitioned on the basis of temperature during the worst month in the most severe part of the regional type. The four land regional types and their defining temperatures are:

(a) Basic Regional Type - One-percent cold and hot 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.

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

(c) Cold Regional Type - Colder than basic regional type with a 1-percent temperature of -45.6°C (-50°F) in the coldest parts.

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

Areas of the world where these 4 regional types prevail are shown in Figure 1 (page 101). The climatic data for the land regional types are presented differently than that for the Coastal/Ocean Regional Type (section 5.2.5), the Worldwide Surface Environment (section 5.1), and the Worldwide Air Environment (section 5.3). These provide climatic information for a wide range of meteorological elements, whereas climatic data 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 (see 4.2(a) and 4.2(b)). 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.

5.2.1 Basic Regional Type. The basic regional type includes all the land areas of the world that have neither extremely high nor extremely low temperatures, as defined above. The basic type incorporates most of the mid-latitudes, which are often referred to climatically as temperate, moderate, or intermediate zones. It also includes the humid tropics, which are warm throughout the year, but do not record the extremely high temperatures that occur in the hot regional type. The basic type is roughly coincident with the more densely populated, industrialized, and agriculturally productive areas of the world; therefore, most of the land areas with the highest probability of combat operations are within its limits.

In addition to the basic hot and basic cold temperature cycles that delineate this regional type, three daily weather cycles are included because of their high humidity conditions. These are: (1) constant high humidity; (2) variable high humidity; and (3) cold-wet. The first two are conditions associated with the humid tropics, where they occur with high frequency throughout the year. They also occur in parts of the subtropics and mid latitudes during the summer. The cold-wet cycle occurs in certain mid latitude areas during winter, and is characterized by frequent temperatures near 0°C, with concurrent high relative humidity and frequent precipitation, including frozen varieties. It should be noted that the worldwide surface extremes for the climatic elements discussed in 5.1.6, 5.1.10, 5.1.11, 5.1.12, 5.1.15, 5.1.17, 5.1.19, 5.1.20, 5.1.21 and 5.1.22 occur within this regional type.

5.2.1.1 Basic/Hot Diurnal cycle. These conditions occur in sections of the United States, Mexico, northern Africa, southwestern Asia, India, Pakistan, and southern Spain in the Northern Hemisphere, and smaller sections of South America, southern Africa, and Australia in the Southern Hemisphere. Table IX (page 80) provides values of temperature, solar radiation, and humidity for the basic hot daily weather cycle.

5.2.1.2 Basic/Cold Diurnal cycle. Extensive basic cold areas occur only in the Northern Hemisphere, in the northern United States, the coast of Alaska, southern Canada, the coast of southern Greenland, northern Europe, the Soviet Union, and Central Asia. Small, isolated areas of basic cold conditions may be found at high elevations in lower latitudes. Table X (page 81) provides values of temperature, solar radiation, and humidity for the basic cold daily weather cycle.

5.2.1.3 Basic/Constant High Humidity Diurnal cycle. The constant high humidity cycle is the result of conditions in heavily forested areas in the tropics under thick cloud cover, which tends to produce near constancy of temperature, solar radiation, and humidity near the ground during rainy seasons. Exposed materiel is likely to be constantly wet or damp for many days at a time. Table VII (page 78) provides values of climatic elements in the daily cycle for this condition. This cycle corresponds to the worldwide surface conditions discussed in 5.1.6 and 5.1.6.3.

5.2.1.4 Basic/Variable High Humidity Diurnal cycle. The variable high humidity cycle occurs in the tropics in open areas with clear skies or intermittent cloudiness, with consequent daily control of temperature and humidity by the solar radiation cycle. Items will be subject to alternate wetting and drying. Table VI (page 77) provides values of climatic elements in the daily cycle for this condition. This cycle corresponds to the worldwide surface conditions discussed in 5.1.6 and 5.1.6.2.

5.2.1.5 Basic/Cold-Wet Diurnal cycle. Basic cold-wet conditions occur throughout the colder, humid sections of the basic regional type adjoining the areas of basic cold conditions. Cold-wet conditions, as defined here, may occur in any part of the basic type that regularly experiences freezing and thawing on a given day; however, the conditions are found most frequently in Western Europe, the central United States, and northeastern Asia (China and Japan). In the Southern Hemisphere, cold-wet conditions occur only at moderately high elevations except in South America where they are found in Argentina and Chile south of 40º latitude. Table XI (page 82) provides values of temperature, solar radiation, and relative humidity for the cold-wet daily weather cycle.

5.2.2 Hot Regional Type. This regional type includes the hot subtropical deserts of the world where the 1-percent temperature during the worst month exceeds 43.3°C (110°F) as shown in Figure 1 (page 101). The worldwide surface extremes for the climatic elements discussed in 5.1.1, 5.1.3, 5.1.5, and 5.1.8 occur within this regional type. The hottest parts of this regional type are the hottest areas of the world as discussed in 5.1.1 through 5.1.1.3. Other parts of this regional type, while not as hot, are prone to occurrences of the highest absolute humidities in the world, as discussed in 5.1.3 through 5.1.3.2. Therefore, two cycles are provided to describe these diverse climatic conditions.

5.2.2.1 Hot-Dry Diurnal cycle. This daily cycle of temperature and associated elements, provided in Table I (page 72), occurs in the hottest parts of the world as discussed in 5.1.1 through 5.1.1.3.

5.2.2.2 Hot-Humid Diurnal cycle. This daily cycle of temperature and associated elements, provided in Table IV (page 75), occurs in the area of the world that experiences the highest absolute humidities as discussed in 5.1.3 through 5.1.3.2.

5.2.3 Cold Regional Type. The cold regional type is characterized by temperatures that are lower than those of the basic cold daily weather cycle, but higher than those of the severe cold regional type. The cold regional type requires only one daily weather cycle to establish its range of conditions.

Figure 1 (page 101) indicates the areas of the world where the cold daily weather cycle occurs. These areas include most of Canada, and large sections of Alaska, Greenland, northern Scandinavia, northeastern USSR, and Mongolia. Cold conditions also exist in parts of the Tibetan Plateau of Central Asia and at high elevations in both the Northern and Southern Hemispheres. The worldwide surface extremes for the climatic elements discussed in 5.1.12, 5.1.13, and 5.1.14 occur within this regional type.

5.2.3.1 Cold Diurnal cycle. This daily cycle of temperature and associated elements is provided in Table XII (page 83).

5.2.4 Severe Cold Regional Type. Except for Antarctica, which is excluded from consideration in this standard, the severe cold regional type records the world's lowest temperatures. Thus, the extreme temperatures of this type are identical with the worldwide extremes for low temperature as discussed in 5.1.2 through 5.1.2.3. Also, the worldwide surface extremes for the climatic elements discussed in 5.1.4, 5.1.7, 5.1.12, 5.1.16, and 5.1.18 occur within this regional type.

5.2.4.1 Severe Cold Diurnal cycle. No cycle in tabular format is presented for the severe cold regional type, because temperature, solar radiation, and humidity remain nearly constant for the 24-hour period. Temperatures are provided in 5.1.2 through 5.1.2.3.

5.2.5 Coastal/Ocean Regional Type. This regional type includes open seas and coastal ports north of 60°S (see 4.2 (c)). Climatic data are excluded for the periods during which locations are closed to navigation due to sea ice. Information for each climatic element is generally divided into three subsections. The first of these is the most extreme value ever recorded. The second subsection presents values that occur for specified frequencies-of-occurrence during the most severe month (see 4.1 (a)). The third subsection presents long-term climatic extremes that would be equalled or exceeded at least once during 10 to 60 years of exposure (see 4.1 (b)).

In general, equipment should be designed to operate during all but a small percentage of the time (see 4.3.3 (b)). Once an acceptable frequency of occurrence of a meteorological element has been determined, the corresponding climatic value can be obtained from the second subparagraph for each element. It is recommended that a 1-percent frequency be initially considered for all elements except rainfall rate, for which a 0.5-percent frequency is recommended.

More extreme climatic values should be considered for equipment whose failure to operate is life-threatening, or for materiel that could be rendered useless or dangerous after one-time exposure (see 4.3.3 (c)). Another option for such material would be protection from exposure to these extremes.

5.2.5.1 High Temperature. See 5.1.1 for discussion on method of observation and considerations in the application of these temperatures for design.

5.2.5.1.1 Highest Recorded. Maximum maritime temperatures occur at Persian Gulf ports. The river port of Abadan, Iran is representative of such locations. A climatic summary for a 14-year period at this location shows an absolute maximum of 51°C (123°F) which occurred in August (exact date unknown).

5.2.5.1.2 Frequency of Occurrence. From seven years of hourly temperatures at Abadan, Iran during the hottest month, the 1-, 5-, 10-, and 20-percent values were determined to be 48°C (119°F), 46°C (114°F), 45°C (113°F), and 43°C (110°F), respectively.

These high temperatures are part of a diurnal cycle that includes associated solar radiation, relative humidity, and wind speed. A representative cycle in which the 1-percent value is attained as a maximum is provided in Table XIII (page 84) Diurnal cycles associated with 5-, 10-, and 20-percent values as a maximum can be approximated by subtracting 2°C, 3°C, and 5°C, respectively, from each of the hourly temperatures in Table XIII. Values of other elements in the cycle would not vary significantly from those associated with the 1-percent value.

5.2.5.1.3 Long-term Extremes. Using a statistical analysis of data from Abadan, the temperatures that would be expected to occur at least once during 10, 30, and 60 years of exposure are 50°C (123°F) for 10 years, and 51°C (124°F) for the 30 and 60 year periods. The 30 and 60 year value is higher than the recorded extreme because it represents a longer time period than the period-of-record. Diurnal cycles wherein these temperatures are attained as a maximum can be approximated by adjusting the hourly values in Table XIII upwards at each hour by the difference between them and the 1 percent value (48°C).

5.2.5.2 Low Temperature. See 5.1.2 for a discussion of low temperature extremes.

5.2.5.2.1 Lowest Recorded. Based on a study of a number of open ports (navigable during the winter) worldwide, Anchorage, Alaska was chosen to represent the world's coldest open port. The lowest temperature recorded at this location was -39°C (-39°F) in February 1947.

5.2.5.2.2 Frequency of Occurrence. Using data for Anchorage, Alaska, the 1-, 5-, 10-, and 20-percent low temperature values during the coldest month were estimated to be -34°C (-30°F), -28°C (-19°F), -25°C (-14°F) and -22°C (-7°F), respectively. A typical temperature regime for 6 days with a minimum temperature of -34°C is given in Table XIV (page 85).

5.2.5.2.3 Long-term Extremes. Low temperatures that would be expected to occur at least once during 10, 30, and 60 years at the coldest open port are -37°C (-34°F), -38°C (-37°F), and -39°C (-39°F), respectively. These were derived from statistical analysis of annual minimum temperatures at Anchorage. Temperature regimes for 6 days wherein these temperatures are a minimum can be approximated by adjusting the values in Table XIV downwards at each hour and day by the difference between them and the 1-percent value (-34°C).

5.2.5.3 High Absolute Humidity. Extremes for this element occur in the same area where worldwide extremes occur. The discussion and values in 5.1.3 through 5.1.3.3 apply here. Also see 5.1.5 through 5.1.5.3 for high humidities associated with very high temperatures at a coastal port.

5.2.5.4 Low Absolute Humidity. Values in this section are given in terms of frost point and mixing ratio (parts by weight of water vapor per million parts of dry air - ppm) calculated from the frost points assuming an atmospheric pressure of 1000 mb (29.53 in Hg). Low absolute humidities in this section were determined by assuming 90-percent relative humidity with the low temperature values in 5.2.5.2.1 through 5.2.5.2.3.

5.2.5.4.1 Lowest Recorded. A mixing ratio of 87.0 ppm based on a frost point of -39°C (-39°F).

5.2.5.4.2 Frequency of Occurrence. A mixing ratio of 133 ppm (a 1-percent value) based on a frost point of -35°C (-32°F). A typical humidity regime with this value as the minimum is given in Table XV (page 85).

5.2.5.4.3 Long-term Extremes. Mixing ratios associated with low temperatures expected to occur at least once during 10, 30, and 60 years are 105, 87.1, and 76.9 ppm based on frost points of -38°C (-36°F), -39°C (-39°F), and -40°C (-40°F), respectively. A typical humidity regime with these minima is given in Table XVI (page 86).

5.2.5.5 High Relative Humidity with High Temperature. See discussion in 5.1.6.

5.2.5.5.1 Highest Recorded. Assume a relative humidity of 100 percent with the highest recorded dew point of 34°C (93°F), which occurred at the coastal port of Sharjah, Arabia, since this dew point is probably representative of the air temperature near the ocean surface.

5.2.5.5.2 Frequency of Occurrence. It was determined that the relative humidity environment with accompanying warm temperatures over ocean areas is more severe than in ports. Available data indicated that the area between 0- and 10°S, and 130° to 140°E represents the most extreme ocean area. For this area the 1-percent value was determined to be 100 percent. A diurnal cycle, including temperature and solar radiation, wherein this 100-percent RH persists for 5 hours based on hourly data for this area is provided in Table XVII (Page 87). The 5-percent value approaches 100 percent in this and other ports of the maritime tropics.

5.2.5.5.3 Long-term Extremes. Not available.

5.2.5.6 High Relative Humidity with Low Temperature. Relative humidities of 100 percent are common with low temperatures. Therefore, 100 percent RH with the low temperatures in 5.2.5.2.1 through 5.2.5.2.3 is recommended.

5.2.5.7 Low Relative Humidity with High Temperature.

5.2.5.7.1 Lowest Recorded. Not available but is assumed to be about 3 percent in ports adjacent to deserts.

5.2.5.7.2 Frequency of Occurrence. Abadan, Iran was found to have the lowest RH with high temperatures of any port with readily available data for study. Interestingly, this location is also known for its high humidity extremes with very high temperature (see 5.2.5.1 and 5.2.5.3). The reason for these dual climatic conditions is the proximity of the desert and the warm waters of the Persian Gulf. Very dry conditions exist when there is a strong circulation from the inland desert. The 1-percent RH of 12 percent occurs with a temperature of 45°C (113°F). A diurnal cycle for this 1-percent value, based on analysis of hourly data from Abadan when these hot-dry conditions exist, is provided in Table XVIII (page 88). The 5-, 10-, and 20-percent low relative humidity with high temperature extremes are 15, 17, and 21 percent, respectively, and are associated with a diurnal maximum temperature of 45°C.

5.2.5.7.3 Long-term Extremes. Not available.

5.2.5.8 Low Relative Humidity with low Temperature. Not available.

5.2.5.9 Wind Speed. A survey of wind data collected over the open ocean shows that winds are stronger and high winds more frequent over the open ocean than in ports. When designing equipment for this regional type, it is recommended that the values discussed and presented in sections 5.1.10 through 5.1.10.3 be used as an interim measure until wind statistics are prepared for open ocean areas. The recommended wind speeds in 5.1.10.2, are representative of a coastal location. If used for design in the marine environment, they should be employed with the understanding that wind speeds are greater and occur more frequently over the open ocean.

5.2.5.10 Rainfall Rate. Rainfall rates discussed and presented in 5.1.11 through 5.1.11.3 can be considered as representative of the worst expected in the marine environment and are recommended for use here.

5.2.5.11 Blowing Snow. Not available.

5.2.5.12 Snow load. Snow load is not ordinarily considered a problem in the marine environment. If design for snow load is necessary, values in 5.1.13 for temporary equipment are recommended.

5.2.5.12.1 Highest Recorded. 191kg/m^2 (39 lbs/ft^2) from a single snowstorm.

5.2.5.12.2 Frequency of Occurrence. Not applicable since design to withstand a one-time occurrence is desirable.

5.2.5.12.3 Long-term Extremes. 98 kg/m^2 (20 lbs/ft^2) on horizontal and exposed surfaces.

5.2.5.13 Ice Accretion. The following information on this climatic element was based on design requirements in use in Iceland, the United Kingdom, and the USSR.

5.2.5.13.1 Highest Recorded. Ice 17 cm thick was measured on a Russian vessel. This corresponds to a load of 143 kg/m^2 for a typical ice density of 847 kg/m^3.

5.2.5.13.2 Frequency of Occurrence. Not applicable since design to withstand a one-time occurrence is desirable.

5.2.5.13.3 Long-term Extremes. For exposed horizontal surfaces, a loading of 30 kg/m^2 (6 lbs/ft^2) corresponding to an ice thickness of 3.5 cm (1.4 in) for a typical density of 847 kg/m is recommended. For exposed vertical surfaces, a loading of 15 kg/m^2 (3 lbs/ft^2) corresponding to a thickness of 1.8 cm (0.7 in) is recommended.

5.2.5.14 Hail Size. Not available.

5.2.5.15 High Atmospheric Pressure. Not available.

5.2.5.16 Low Atmospheric Pressure. Designing for the lowest recorded sea level pressure of 870 mb (see 5.1.17.1) should not present difficulty and is recommended for design.

5.2.5.17 High Atmospheric Density. See discussion in 5.1.18.

5.2.5.17.1 Highest Recorded. A density of 1.56 kg/m^3 (.097 lb/ft^3) with the temperature of -39°C in 5.2.5.2.1.

5.2.5.17.2 Frequency of Occurrence. A density of 1.53 kg/m^3 (.096 lb/ft^3) based on the 1-percent temperature of -34°C in 5.2.5.2.2.

5.2.5.17.3 Long-term Extremes. The highest recorded value is recommended.

5.2.5.18 Low Atmospheric Density. Extremes of low density in the maritime environment will occur where temperatures are highest and pressures lowest. Using the high temperature extreme of 51°C with an assumed pressure of 1000 mb results in a density of 1.075 kg/m^3. Using the extreme of low pressure (870 mb) with an assumed temperature of 29°C results in a density of 1.004 kg/m^3. Thus the lowest recorded density in the maritime environment is associated with the low pressure extreme. However, since such low pressures are rare occurrences, the 1-percent low density value should be based on the 1-percent high temperature.

5.2.5.18.1 Lowest Recorded. As described above, a density of 1.004 kg/m^3 can be assumed for lowest recorded.

5.2.5.18.2 Frequency of Occurrence. The 1-percent high temperature extreme with which to calculate the 1-percent low density extreme is 48°C. Assuming a pressure of 1000 mb with this temperature results in a density of 1.085 kg/m^3.

5.2.5.18.3 Long-term Extremes. Not available.

5.2.5.19 Ozone Concentration. The values discussed and presented in 5.1.20 through 5.1.20.3 are recommended.

5.2.5.20 Sand and Dust. A study of these extremes for the maritime environment has not been made. Maritime extremes of these parameters would probably occur in port locations for which the values discussed and provided in 5.1.21 through 5.1.21.3 are applicable and recommended.

5.2.5.21 High Surface Water Temperature.

5.2.5.21.1 Highest Recorded. A temperature of 38°C (101°F) was recorded in the Persian Gulf.

5.2.5.21.2 Frequency of Occurrence. A survey of marine atlases indicates that the warmest applicable body of water is the Persian Gulf. The 1-, 5-, 10-, and 20-percent values for the warmest month (August) were determined to be 36°C (96°F), 35°C (95°F), 34°C (94°F), and 34°C (93°F), respectively.

5.2.5.21.3 Long-term Extremes. Based on analysis of annual high water temperature extremes for the Persian Gulf, the values expected to occur at least once in 10, 30, and 60 years are 37°C (99°F), 38°C, (100°F), and 38°C (101°F), respectively.

5.2.5.22 Low Surface Water Temperature.

5.2.5.22.1 Lowest Recorded. A temperature of -6°C (22°F) was recorded off the coast of Newfoundland, Canada.

5.2.5.22.2 Frequency of Occurrence. Marine atlases indicate that very cold sea temperatures exist off the coast of Newfoundland during the winter. Probable 1-, 5-, 10- and 20-percent low sea surface temperatures during the worst month are -2°C (28°F), -2°C (29°F), -1°C (31°F), and -1°C (31°F), respectively.

5.2.5.22.3 Long-term Extremes. Using data for the same area in 5.2.5.22.2, the minimum sea surface temperature expected at least once in 10, 30, and 60 years are -6°C (22°F), -6°C (21°F), and -6°C (21°F), respectively.

5.2.5.23 Salinity. The variability of salinity over the ocean has not been observed sufficiently to determine the distribution of extremes. Salinities over the North Pacific and North Atlantic Oceans of greater than 36.0 parts per thousand (PPT) and 37.0 PPT, respectively have been measured. Average maximum salinities of about 41 PPT in the northern parts of the Red and Arabian Seas are also indicated, and extremes of 45 PPT have been measured there.

5.2.5.24 Wave Height and Spectra. Both the mean height of the highest waves and extreme wave heights are important in the design of ships. In addition, the response induced in ships by the frequencies and energies of the waves or wave trains is important. These factors are interrelated such that standardized values of extremes cannot be specified.

5.3 Worldwide Air Environment to 80 km (262,000 ft). This section provides climatic information for use in designing airborne and air projected combat 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 aero-dynamically-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 4572 m are provided in 5.1).

Climatic information for the worldwide air environment is presented in terms of envelopes of climatic values in 5.3.1, and profiles of temperature, density, and rainfall rate/water concentration in 5.3.2 (see 4.3.1(b)). The data presentations are discussed at the beginning of each section.

5.3.1 Atmospheric Envelopes. Climatic data in this section 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 representative of the influence of the total atmosphere on a vertically rising or descending 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. long-term climatic extremes are not provided since military equipment will not be permanently deployed or in a standby status in the free atmosphere. Values with a 1-, 5-, 10-, and 20-percent frequency of occurrence are presented. It is recommended that a 1-percent value be initially considered for all climatic elements with the exception of precipitation rate and water content for which 0.5-percent value is recommended. For those items that may be rendered dangerous or inoperable during exposure to percentile values, the use of the recorded extremes may be more appropriate for design purposes (see 4.3.3(c)).

Climatic data up through 30 km (98,425 ft) are generally given for both actual (geometric) and pressure altitude. Values above this altitude are provided for only geometric altitude. Actually the geometric altitudes to 30 km are geopotential heights, but for design purposes these may be considered geometric heights above sea level; for instance at 30 km, the difference between geopotential and geometric heights is 143 m, and less than that at lower altitudes. Information at geometric altitudes is applicable in missile design whereas information at pressure altitudes is applicable in aircraft design since aircraft generally fly on given pressure surfaces. Pressure altitude is the geopotential height corresponding to a given pressure in the Standard Atmosphere. The heights given by most altimeters are based on the relationship between pressure and height in the Standard Atmosphere. Since atmospheric conditions are seldom standard, aircraft flying at a given pressure altitude may be at significantly different true altitudes above sea level; an aircraft flying at a constant pressure altitude may be ascending, descending, or flying level.

Extremes for zero altitude represent conditions at sea level for which the values in 5.1 generally apply. linear interpolation between adjacent levels is acceptable to obtain extremes for heights not specified. For pressure and density, logarithmic interpolation will be more accurate. Details on the data and analytical methods used to determine the information in this section are provided in Appendix A.

5.3.1.1 High Temperature.

5.3.1.1.1 Highest Recorded. Temperatures given at actual (geometric) and pressure altitudes follow. Densities associated with temperature extremes at actual altitudes are included.

ALTITUDE		GEOMETRIC ALTITUDE				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
0	0	58	136	1052 x 10^{-3}	657 x 10^{-4}	-	-
1	3.28	41	106	1018	636	40	104
2	6.56	32	90	916	572	31	88
4	13.1	19	66	762	476	19	66
6	19.7	8	46	611	381	6	43
8	26.2	-4	25	499	312	-4	25
10	32.8	-13	9	393	245	-18	0
12	39.4	-22	-8	316	197	-27	-17
14	45.9	-30	-22	208	130	-34	-29
16	52.5	-35	-31	156	97	-35	-31
18	59.1	-35	-31	118	74	-34	-29
20	65.6	-31	-24	86	54	-31	-24
22	72.2	-29	-20	64	40	-31	-24
24	78.7	-33	-27	48	30	-31	-24
26	85.3	-27	-17	36	22	-27	-17
28	91.9	-22	-8	27	17	-22	-8
30	98.4	-17	1	20	12	-17	0

5.3.1.1.2 Frequency of Occurrence. Temperatures (1-percent values) given at actual (geometric) and pressure altitudes follow. Densities associated with temperatures at geometric altitudes are included; departures in these values of up to 1 15 percent are possible above 30 km.

ALTITUDE		GEOMETRIC ALTITUDE				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
0	0	49	120	1081 x 10^{-3}	675 x 10^{-4}	-	-
1	3.28	40	104	1007	629	39	102
2	6.56	30	86	919	574	29	84
4	13.1	17	63	757	473	16	61
6	19.7	6	43	613	383	4	39
8	26.2	-5	23	497	310	-7	19
10	32.8	-13	9	397	248	-18	0
12	39.4	-22	-8	317	198	-27	-17
14	45.9	-30	-22	210	131	-34	-29
16	52.5	-37	-35	159	99	-37	-35
18	59.1	-37	-35	119	74	-38	-36
20	65.6	-32	-26	87	54	-37	-35
22	72.2	-30	-22	67	42	-37	-35
24	78.7	-33	-27	49	31	-36	-33
26	85.3	-28	-18	36	22	-34	-29
28	91.9	-23	-9	27	17	-30	-22
30	98.4	-18	0	20	12	-30	-22
35	115	3	37	6.15	3.84	-	-
40	131	25	77	3.12	1.95	-	-
45	148	30	86	1.40	0.874	-	-
50	164	37	99	0.997	0.622	-	-

(Continued on next page)

ALTITUDE		GEOMETRIC ALT.				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
55	180	19	66	0.992x 10^{-3}	0.619x 10^{-4}	-	-
60	197	29	84	0.176	0.110	-	-
65	213	37	99	0.101	0.063	-	-
70	230	24	75	0.055	0.034	-	-
75	246	16	61	0.015	0.009	-	-
80	262	5	41	0.007	0.004	-	-

The 5-, 10-, and 20-percent values are given in Table XIX (page 89).

5.3.1.2 Low Temperature.

5.3.1.2.1 Lowest Recorded. Temperatures given at actual (geometric) and pressure altitudes follow. Densities associated with temperatures extremes at geometric altitudes are included.

ALTITUDE		GEOMETRIC ALTITUDE				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
0	0	-68	-90	1780 x 10^{-3}	1111 x 10^{-4}	-	-
1	3.28	-54	-65	1419	886	-56	-69
2	6.56	-47	-53	1147	716	-47	-53
4	13.1	-53	-63	899	561	-51	-60
6	19.7	-61	-78	681	425	-60	-76
8	26.2	-68	-90	510	318	-64	-83
10	32.8	-75	-103	409	255	-73	-99
12	39.4	-80	-112	314	196	-77	-107
14	45.9	-77	-107	218	136	-78	-108
16	52.5	-87	-125	208	130	-87	-125
18	59.1	-88	-126	143	89	-85	-121
20	65.6	-87	-125	78	49	-83	-117
22	72.2	-85	-121	54	34	-85	-121
24	78.7	-86	-123	38	24	-85	-121
26	85.3	-84	-119	29	18	-85	-121
28	91.9	-84	-119	20	12	-85	-121
30	98.4	-85	-121	11	6.9	-85	-121

5.3.1.2.2 Frequency of Occurrence. Temperatures (1-percent values) given at actual (geometric) and pressure altitudes follow. Densities associated with temperatures at geometric altitudes are included; departures in these values of up to 1 15 percent are possible above 30 km.

ALTITUDE		GEOMETRIC ALTITUDE				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
0	0	-61	-78	1610 x 10^{-3}	1005 x 10^{-4}	-	-
1	3.28	-53	-63	1408	879	-55	-67
2	6.56	-41	-42	1132	706	-42	-44
4	13.1	-48	-54	868	542	-46	-51

(Continued on next page)

ALTITUDE		GEOMETRIC ALTITUDE				PRESSURE ALT.	
		TEMP		DENSITY		TEMP	
(km)	(kft)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
6	19.7	-57	-71	675 x 10^{-3}	421 x 10^{-4}	-55	-67
8	26.2	-66	-87	523	326	-64	-83
10	32.8	-74	-101	415	259	-71	-96
12	39.4	-73	-99	297	185	-72	-98
14	45.9	-75	-103	214	134	-77	-107
16	52.5	-86	-123	206	129	-86	-123
18	59.1	-86	-123	143	89	-85	-121
20	65.6	-86	-123	78	49	-83	-117
22	72.2	-84	-119	54	34	-85	-121
24	78.7	-85	-121	38	24	-85	-121
26	85.3	-84	-119	29	18	-85	-121
28	91.9	-83	-117	20	12	-85	-121
30	98.4	-83	-117	16	10	-84	-119
35	115	-81	-114	7.22	4.51	-	-
40	131	-71	-96	2.85	1.78	-	-
45	148	-70	-94	1.66	1.04	-	-
50	164	-70	-94	0.723	0.451	-	-
55	180	-74	-101	0.681	0.425	-	-
60	197	-74	-101	0.282	0.176	-	-
65	213	-87	-125	0.126	0.079	-	-
70	230	-107	-161	0.046	0.029	-	-
75	246	-120	-184	0.020	0.012	-	-
80	262	-145	-229	0.006	0.004	-	-

The 5-, 10-, and 20-percent values are given in Table XX (page 90).

5.3.1.3 High Absolute Humidity. Climatic data on absolute humidity are in terms of dew (or frost) point temperatures; such data were used to determine extremes of absolute humidity. These extremes are also provided as mixing ratios (MIX. RAT.), parts of water vapor per million parts of dry air (ppm) by weight. This conversion was accomplished by using pressures found in the U.S. Standard Atmosphere, 1976 (GPO, 1976) for the specified altitudes; vapor pressures over water for dew/frost points of -40°C and above, and over ice for colder dew/frost points were assumed.

5.3.1.3.1 Highest Recorded. Humidities at actual (geometric) and pressure altitudes follow. Values terminate at 8 km (26,200 ft) because routine observations are unavailable above this level.

ALTITUDE		GEOMETRIC ALTITUDE			PRESSURE ALT.		
		MIX. RAT.	DEWPOINT		MIX. RAT.	DEWPOINT	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
0	0	35 x 10^3	34	93	-	-	-
1	3.28	31	30	86	31 x 10^3	30	86
2	6.56	28	26	79	28	26	79
4	13.1	22	18	64	22	18	64
6	19.7	10	3	37	8.9	1	34
8	26.2	6.4	-7	19	4.7	-11	12

5.3.1.3.2 Frequency of Occurrence. One-percent values given at actual (geometric) and pressure altitudes follow:

ALTITUDE		GEOMETRIC ALTITUDE.			PRESSURE ALT.		
		MIX. RAT.	DEWPOINT		MIX. RAT.	DEWPOINT	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
0	0	30×10^3	31	88	-	-	-
1	3.28	29	29	84	29×10^3	29	84
2	6.56	24	24	75	24	24	75
4	13.1	19	16	61	18	15	59
6	19.7	10	3	37	8.9	1	34
8	26.2	5.9	-8	18	4.3	-12	10
10	32.8	1.3	-29	-20	1.2	-30	-22
12	39.4	0.23	-45	-49	0.23	-45	-49
14	45.9	0.05	-60	-76	0.048	-60	-76
16	52.5	0.04	-64	-83	0.038	-64	-83
18	59.1	0.09	-60	-76	0.090	-60	-76
20	65.6	0.21	-56	-69	0.18	-57	-71
22	72.2	0.19	-59	-74	0.19	-59	-74
24	78.7	0.20	-61	-78	0.20	-61	-78
26	85.3	0.21	-63	-81	0.21	-63	-81
28	91.9	0.21	-65	-85	0.21	-65	-85
30	98.4	0.21	-67	-89	0.19	-68	-90
35	115	0.18	-73	-99	-	-	-
40	131	0.16	-78	-110	-	-	-
45	148	0.12	-84	-119	-	-	-
50	164	0.09	-89	-130	-	-	-
55	180	0.055	-95	-139	-	-	-
60	197	0.040	-100	-150	-	-	-
65	213	0.024	-106	-159	-	-	-
70	230	0.015	-111	-170	-	-	-
75	246	0.009	-117	-179	-	-	-
80	262	0.005	-122	-189	-	-	-

The 5-, 10-, and 20-percent values are given in Table XXI (page 91).

5.3.1.4 Low Absolute Humidity. Information on the presentation of humidity values is in 5.3.1.3.

5.3.1.4.1 Lowest Recorded. Humidities at actual (geometric) and pressure altitudes follow. Values terminate at 8 km (26,200 ft) because routine observations are unavailable at higher levels.

ALTITUDE		GEOMETRIC ALTITUDE.			PRESSURE ALT.		
		MIX. RAT.	FROST POINT		MIX. RAT.	FROST POINT	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
0	0	-	-	-	-	-	-
1	3.28	24	-51	-60	24	-51	-60
2	6.56	21	-53	-63	21	-53	-63
4	13.1	14	-58	-72	16	-57	-71
6	19.7	6.2	-66	-87	6.2	-66	-87
8	26.2	3.9	-71	-96	6.1	-68	-90

5.3.1.4.2 Frequency of Occurrence. One-percent values at actual (geometric) and pressure altitudes follow. Values terminate at 8 km (26,200 ft) because routine observations are unavailable at higher levels.

ALTITUDE		GEOMETRIC ALTITUDE			PRESSURE ALT.		
		MIX. RAT.	FROST POINT		MIX. RAT.	FROST POINT	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
0	0	5.2	-62	-79	-	-	-
1	3.28	27	-50	-58	27	-50	-58
2	6.56	27	-51	-60	31	-50	-58
4	13.1	19	-56	-69	24	-54	-65
6	19.7	7.1	-65	-85	12	-61	-78
8	26.2	3.9	-71	-96	6.1	-68	-90

The 5-, 10-, and 20-percent values are given in Table XXII (page 91).

5.3.1.5 High Relative Humidity. Not available.

5.3.1.6 Low Relative Humidity. Not available.

5.3.1.7 Wind speed.

5.3.1.7.1 Highest Recorded.

Wind speeds at actual (geometric) and pressure altitudes follow:

ALTITUDE		GEOMETRIC ALTITUDE		PRESSURE ALTITUDE	
(km)	(kft)	(m/s)	(Ft/s)	(m/s)	(Ft/s)
0	0	95	312	-	-
1	3.28	60	197	55	157
2	6.56	57	187	52	151
4	13.1	76	249	71	174
6	19.7	92	302	87	262
8	26.2	129	423	122	361
10	32.8	153	502	150	492
12	39.4	140	459	140	459
14	45.9	110	361	108	354
16	52.5	93	305	93	305
18	59.1	74	243	72	236
20	65.6	118	387	107	351
22	72.2	102	335	102	295
24	78.7	118	387	113	318
26	85.3	116	381	116	367
28	91.9	118	387	123	440
30	98.4	130	427	127	371

5.3.1.7.2 Frequency of Occurrence. Wind speeds (1-percent values) at actual (geometric) and pressure altitudes follow:

ALTITUDE		GEOMETRIC ALTITUDE		PRESSURE ALTITUDE	
(km)	(kft)	(m/s)	(Ft/s)	(m/s)	(Ft/s)
0	0	22	73	-	-
1	3.28	43	141	37	121
2	6.56	45	148	45	148
4	13.1	53	174	50	164
6	19.7	73	240	66	217
8	26.2	87	285	83	272
10	32.8	100	328	100	328
12	39.4	110	361	110	361
14	45.9	93	305	92	302
16	52.5	74	243	72	236
18	59.1	73	240	70	230
20	65.6	76	249	73	240
22	72.2	84	276	78	256
24	78.7	88	289	87	285
26	85.3	94	308	93	305
28	91.9	102	335	96	315
30	98.4	121	397	102	335
35	115	150	492	-	-
40	131	200	656	-	-
45	148	210	689	-	-
50	164	213	699	-	-
55	180	213	699	-	-
60	197	180	591	-	-
65	213	169	554	-	-
70	230	165	541	-	-
75	246	145	476	-	-
80	262	145	476	-	-

The 5-, 10-, and 20-percent values are given in Table XXIII (page 92).

5.3.1.8 Wind Shear. The wind shears in this section are applicable to a layer thickness of 1 km (3281 ft) centered at a specified altitude. Wind shears for thinner layers cannot be obtained by linear interpolation as shear increases exponentially with decreasing thickness. Since shear is the change in a velocity through a specific thickness the units are per time period.

5.3.1.8.1 Highest Recorded. One-km (3281-ft) layer wind shears at actual (geometric) and pressure altitudes follow:

ALTITUDE		GEOMETRIC ALTITUDE	PRESSURE ALTITUDE
(kft)	(km)	(sec^{-1})	(sec^{-1})
0	0	-	-
3.28	1	0.042	0.042
6.56	2	0.032	0.034
13.1	4	0.045	0.044
19.7	6	0.049	0.049

(Continued on next page)

ALTITUDE		GEOMETRIC ALTITUDE	PRESSURE ALTITUDE
(km)	(kft)	(sec^{-1})	(sec^{-1})
8	26.2	0.044	0.044
10	32.8	0.057	0.057
12	39.4	0.065	0.065
14	45.9	0.053	0.052
16	52.5	0.057	0.059
18	59.1	0.070	0.071
20	65.6	0.061	0.062
22	72.2	0.049	0.049
24	78.7	0.046	0.047
26	85.3	0.044	0.041
28	91.9	0.042	0.040
30	98.4	0.038	0.037

5.3.1.8.2 Frequency of Occurrence. One-km (3281-ft) layer wind shears (1percent values) at actual (geometric) and pressure altitudes up through 30 km and for 10 km thickness above 30 km follow:

ALTITUDE		GEOMETRIC ALTITUDE	PRESSURE ALTITUDE
(km)	(kft)	(sec^{-1})	(sec^{-1})
0	0	-	-
1	3.28	0.025	0.026
2	6.56	0.023	0.022
4	13.1	0.024	0.023
6	19.7	0.029	0.030
8	26.2	0.032	0.032
10	32.8	0.032	0.031
12	39.4	0.033	0.032
14	45.9	0.050	0.050
16	52.5	0.056	0.058
18	59.1	0.045	0.046
20	65.6	0.041	0.042
22	72.2	0.037	0.037
24	78.7	0.033	0.033
26	85.3	0.034	0.033
28	91.9	0.041	0.039
30	98.4	0.030	0.030
LAYER ALTITUDES			
(km)	(kft)		
30 to 40	98.4 to 131	0.051	-
40 to 50	131 to 164	0.046	-
50 to 60	164 to 197	0.042	-
60 to 70	197 to 230	0.121	-

The 5-, 10-, and 20-percent values are given in Table XXIV (page 93).

5.3.1.9 Precipitation Rate. The distribution of precipitation rate aloft is assumed to be at the same time and place as the surface precipitation rate. In this way, the entire profile can be assigned the frequency of occurrence associated with the surface rate for which far more data are available. Since these are consistent vertical profiles (i.e. values at each level occur approximately simultaneously) they are presented in 5.3.2.5.

5.3.1.10 Water Concentration (Liquid/Solid) in Precipitation. The distribution aloft is based on the surface rainfall rate. See discussion in 5.3.1.9. Values are provided in 5.3.2.5.

5.3.1.11 Hail Size. Estimating the point probabilities of hail sizes aloft required considerable inference based on limited objective data. The estimated probabilities of encountering hail at all altitudes were found to be quite small and should not be of concern for vertically rising equipment unless life is endangered. However, the probability of encountering hail while horizontally traversing the atmosphere (for distances greater than 200 mi) in the worst location for hail occurrences (see 5.1.15) is considerably greater. These frequencies were estimated by using a statistical model that relates spatial and lineal probabilities of a climatic event to its single-point probability.

5.3.1.11.1 Largest Recorded. The largest measured hailstone to reach the surface was 142 mm (5.6 in.) in diameter (see 5.1.15.1). This size is applicable for all altitudes up to 12 km.

5.3.1.11.2 Frequency of Occurrence. Presented in this section are the 1-percent values for the hailstone diameters that would be encountered by airborne vehicles normally traversing the atmosphere for at least 300 km. Values associated with a 0.1-percent frequency are also provided for those circumstances when failure due to encountering hail would endanger human life and design for the record size is not feasible. (Note: values are for airborne vehicles traversing the atmosphere and are not comparable to the values presented for a point location in 5.1.15).

GEOMETRIC ALTITUDE		DIAMETER			
		1 PERCENT		0.1 PERCENT	
(km)	(kft)	(cm)	(in)	(cm)	(in)
0	0	1.1	0.42	3.0	1.2
1	3.3	1.1	0.42	3.0	1.2
2	6.6	1.4	0.54	4.1	1.6
4	13.1	2.1	0.81	6.1	2.4
6	19.7	2.1	0.81	6.1	2.4
8	26.2	1.5	0.59	4.7	1.9
10	32.8	1.4	0.53	4.1	1.6
12	39.4	1.0	0.40	2.9	1.1
14	45.9	0	0	0	0

5.3.1.12 High Atmospheric Pressure.

5.3.1.12.1 Highest Recorded. Pressures at actual (geometric) altitudes follow:

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
0	0	1084	32.0
1	3.28	930	27.5
2	6.56	821	24.2
4	13.1	643	19.0
6	19.7	501	14.8
8	26.2	385	11.4
10	32.8	294	8.68
12	39.4	226	6.67
14	45.9	168	4.96
16	52.5	123	3.63
18	59.1	88	2.60
20	65.6	65	1.92
22	72.2	45	1.33
24	78.7	35	1.03
26	85.3	26	0.768
28	91.9	20	0.591
30	98.4	15	0.443

5.3.1.12.2 Frequency of Occurrence. Pressures (1-percent values) at actual (geometric) altitudes follow:

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
0	0	-	-
1	3.28	920	27.2
2	6.56	817	24.1
4	13.1	642	19.0
6	19.7	499	14.7
8	26.2	384	11.3
10	32.8	293	8.65
12	39.4	226	6.67
14	45.9	167	4.93
16	52.5	123	3.63
18	59.1	88	2.60
20	65.6	65	1.92
22	72.2	45	1.33
24	78.7	34	1.00
26	85.3	25	0.738
28	91.9	19	0.561
30	98.4	15	0.443
35	115	7.6	0.224
40	131	4.1	0.121
45	148	2.2	0.065

(Continued on next page)

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
50	164	1.2	0.035
55	180	0.71	0.021
60	197	0.39	0.012
65	213	0.19	0.0056
70	230	0.086	0.0025
75	246	0.037	0.0011
80	262	0.015	0.00044

The 5-, 10-, and 20-percent values are given in Table XXV (page 94).

5.3.1.13 Low Atmospheric Pressure.

5.3.1.13.1 Lowest Recorded. Pressures at actual (geometric) altitudes follow:

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
0	0	870	25.7
1	3.28	842	24.9
2	6.56	736	21.7
4	13.1	548	16.2
6	19.7	406	12.0
8	26.2	296	8.74
10	32.8	215	6.35
12	39.4	154	4.55
14	45.9	111	3.28
16	52.5	79	2.33
18	59.1	56	1.65
20	65.6	40	1.18
22	72.2	28	0.827
24	78.7	20	0.591
26	85.3	14	0.413
28	91.9	10	0.295
30	98.4	7	0.207

5.3.1.13.2 Frequency of Occurrence. Pressures (1-percent value) at actual (geometric) altitudes follow:

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
0	0	-	-
1	3.28	847	25.0
2	6.56	742	21.9
4	13.1	550	16.2

(Continued on next page)

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE	
(km)	(kft)	(mb)	(in Hg)
6	19.7	408	12.0
8	26.2	299	8.83
10	32.8	218	6.44
12	39.4	157	4.64
14	45.9	111	3.28
16	52.5	79	2.33
18	59.1	56	1.65
20	65.6	41	1.21
22	72.2	29	0.856
24	78.7	21	0.620
26	85.3	15	0.443
28	91.9	11	0.325
30	98.4	9	0.266
35	115	3.1	0.092
40	131	1.5	0.044
45	148	0.67	0.020
50	164	0.31	0.0092
55	180	0.15	0.0044
60	197	0.074	0.0022
65	213	0.035	0.0010
70	230	0.017	0.00050
75	246	0.0080	0.00024
80	262	0.0035	0.00010

The 5-, 10-, and 20-percent values are given in Table XXVI (page 95).

5.3.1.14 High Atmospheric Density.

5.3.1.14.1 Highest Recorded. Densities at actual (geometric) and pressure altitudes follow. Mean temperatures accompany extremes at actual altitudes.

ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
0	0	$1.78x10^0$	$1.11x10^{-1}$	-68	-90	-	-
1	3.28	1.35	$8.43x10^{-2}$	-43	-45	$1.38x10^0$	$8.62x10^{-2}$
2	6.56	1.17	7.30	-45	-49	1.22	7.62
4	13.1	$8.99x10^{-1}$	5.61	-53	-63	$9.68x10^{-1}$	6.04
6	19.7	7.01	4.38	-49	-56	7.71	4.81
8	26.2	5.52	3.45	-43	-45	5.88	3.67
10	32.8	4.35	2.72	-49	-56	4.54	2.83
12	39.4	3.45	2.15	-61	-78	3.43	2.14
14	45.9	2.67	1.67	-69	-92	2.50	1.56
16	52.5	2.06	1.28	-76	-105	1.94	1.21
18	59.1	1.50	$9.36x10^{-3}$	-80	-112	1.41	$8.80x10^{-3}$
20	65.6	1.08	6.74	-70	-94	1.01	6.31
22	72.2	$7.3x10^{-2}$	4.56	-66	-87	$7.3x10^{-2}$	4.56

(Continued on next page)

ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
24	78.7	5.7x10^{-2}	3.56x10^{-3}	-59	-74	5.3x10^{-2}	3.31x10^{-3}
26	85.3	4.3	2.68	-40	-40	4.1	2.56
28	91.9	2.8	1.75	-38	-36	2.9	1.81
30	98.4	2.1	1.31	-35	-31	2.2	1.37

5.3.1.14.2 Frequency of Occurrence. Densities (1-percent value) at actual (geometric) and pressure altitudes follow. Mean temperatures accompany extremes at actual altitude; departures in these values of up to 20°C (36°F) are possible above 30 km.

ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
0	0	1.72 x 10^{0}	1.07 x 10^{-1}	-61	-78	-	-
1	3.28	1.32	8.24 x 10^{-2}	-37	-35	1.36 x 10^{0}	8.49 x 10^{-2}
2	6.56	1.16	7.24	-39	-38	1.21	7.55
4	13.1	8.92 x 10^{-1}	5.57	-47	-53	9.52 x 10^{-1}	5.94
6	19.7	6.95	4.34	-44	-47	7.51	4.69
8	26.2	5.50	3.43	-47	-53	5.87	3.66
10	32.8	4.34	2.71	-49	-56	4.51	2.82
12	39.4	3.41	2.13	-66	-87	3.39	2.12
14	45.9	2.67	1.67	-69	-92	2.50	1.56
16	52.5	2.05	1.28	-74	-101	1.93	1.20
18	59.1	1.49	9.30 x 10^{-3}	-83	-117	1.41	8.80 x 10^{-3}
20	65.6	1.05	6.55	-76	-105	1.00	6.24
22	72.2	7.3x10^{-2}	4.56	-71	-96	7.3 x 10^{-2}	4.56
24	78.7	5.7	3.56	-59	-74	5.3	3.31
26	85.3	4.3	2.68	-40	-40	4.1	2.56
28	91.9	2.8	1.75	-38	-36	2.9	1.81
30	98.4	2.1	1.31	-35	-31	2.2	1.37
35	115	1.09	6.80 x 10^{-4}	-17	1	-	-
40	131	5.27 x 10^{-3}	3.29	-5	23	-	-
45	148	2.79	1.74	7	44	-	-
50	164	1.48	9.24 x 10^{-5}	12	53	-	-
55	180	8.64 x 10^{-4}	5.39	5	41	-	-
60	197	4.86	3.03	-16	3	-	-
65	213	2.75	1.72	-48	-55	-	-
70	230	1.50	9.36 x 10^{-6}	-78	-109	-	-
75	246	7.20 x 10^{-5}	4.49	-94	-138	-	-
80	262	3.32	2.05	-102	-152	-	-

The 5-, 10-, and 20-percent values are given in Table XXVII (page 96).

5.3.1.15 Low Atmospheric Density

5.3.1.15.1 Lowest Recorded. Densities at actual (geometeric) and pressure altitudes follow. Mean temperatures accompany extremes at actual altitude.

ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
0	0	1.01 x 10^0	6.31 x 10^{-2}	29	85	-	-
1	3.28	1.04	6.49	25	77	l.04 x 10^0	6.49 x 10^{-2}
2	6.56	9.11 x 10^{-1}	5.69	30	86	9.28 x 10^{-1}	5.79
4	13.1	7.61	4.75	12	54	7.60	4.75
6	19.7	6.19	3.86	-17	1	6.06	3.78
8	26.2	4.59	2.87	-51	-60	4.76	2.97
10	32.8	3.40	2.12	-55	-67	3.83	2.39
12	39.4	2.54	1.59	-48	-54	2.87	1.79
14	45.9	1.89	1.18	-48	-54	2.10	1.31
16	52.5	1.35	8.43 x 10^{-3}	-43	-45	1.52	9.49 x 10^{-3}
18	59.1	9.6 x 10^{-2}	5.99	-41	-42	1.10	6.87
20	65.6	6.6	4.12	-27	-17	8.0 x 10^{-2}	5.00
22	72.2	4.9	3.06	-32	-26	5.7	3.56
24	78.7	3.5	2.19	-39	-38	4.2	2.62
26	85.3	2.2	1.37	-45	-49	2.0	1.25
28	91.9	1.4	8.74 x 10^{-4}	-44	-47	1.2	7.49 x 10^{-4}
30	98.4	1.0	6.24	-42	-44	9.0 x 10^{-3}	5.62

5.3.1.15.2 Frequency of Occurrence. Densities (1-percent values) at actual (geometric) and pressure altitudes follow. Mean temperatures accompany extremes at actual altitudes; departures in these values of up to 20°C (36°F) are possible above 30 km.

ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
0	0	1.09 x 10^0	6.80 x 10^{-2}	48	118	-	-
1	3.28	1.04	6.49	24	75	1.04 x 10^0	6.49 x 10^{-2}
2	6.56	9.15 x 10^{-1}	5.71	30	86	9.28 x 10^{-1}	5.79
4	13.1	7.62	4.76	11	52	7.65	4.78
6	19.7	6.20	3.87	-2	28	6.10	3.81
8	26.2	4.60	2.87	-45	-49	4.82	3.01
10	32.8	3.41	2.13	-44	-47	3.84	2.40
12	39.4	2.55	1.59	-49	-56	2.89	1.80
14	45.9	1.90	1.19	-48	-54	2.11	1.32
16	52.5	1.36	8.49 x 10^{-3}	-43	-45	1.54	9.61 x 10^{-3}
18	59.1	9.7 x 10^{-2}	6.06	-43	-45	1.12	6.99
20	65.6	6.7	4.18	-27	-17	8.2 x 10^{-2}	5.12
22	72.2	4.9	3.06	-37	-35	5.9	3.68
24	78.7	3.6	2.25	-39	-38	4.3	2.68
26	85.3	2.3	1.44	-45	-49	2.1	1.31
28	91.9	1.4	8.74 x 10^{-4}	-44	-47	1.3	8.12 x 10^{-4}
30	98.4	1.1	6.87	-42	-44	9.0 x 10^{-3}	5.62
35	115	4.74 x 10^{-3}	2.96x10^{-4}	-58	-73	-	-

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ALTITUDE		GEOMETRIC ALTITIUDE				PRESSURE ALTITUDE	
		DENSITY		TEMP		DENSITY	
(km)	(kft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)	(kg/m^3)	(lb/ft^3)
40	131	2.00 x 10^{-3}	1.25 x 10^{-4}	-43	-46	-	-
45	148	9.63 x 10^{-4}	6.01 x 10^{-5}	-20	-4	-	-
50	164	4.62	2.88	-17	1	-	-
55	180	2.30	1.44	-20	-4	-	-
60	197	1.01	6.31 x 10^{-6}	-24	-12	-	-
65	213	5.16 x 10^{-5}	3.23	-47	-53	-	-
70	230	2.54	1.59	-63	-82	-	-
75	246	1.13	7.05 x 10^{-7}	-68	-91	-	-
80	262	4.00 x 10^{-6}	2.50	-62	-80	-	-

The 5-, 10-, and 20-percent values are given in Table XXVIII (page 97).

5.3.1.16 Ozone Concentration. In unpolluted atmospheres ozone generally attains highest concentrations between 12 and 18 km altitude at about 600 to 700 latitude. At most altitudes maximum concentrations occur during spring, and minimum concentrations occur in the winter. At low elevations there is often a well-defined daily cycle, with the highest values occurring during mid-day to late afternoon. Ozone is constantly being created and destroyed in the atmosphere, and moves from one place to another by force of gravity and various circulation mechanisms (See 5.1.20).

5.3.1.16.1 Highest Recorded. The following are the highest recorded ozone concentrations at actual (geometric) altitudes:

GEOMETRIC ALTITUDE		OZONE CONCENTRATION	
(km)	(kft)	(g/m^3)	(1b/ft^3)
0	0	980	612 x 10^{-10}
1	3.28	280	175
2	6.56	235	147
4	13.1	180	112
6	19.7	180	112
8	26.2	410	256
10	32.8	685	428
12	39.4	900	562
14	45.9	1000	624
16	52.5	970	606
18	59.1	860	537
20	65.6	730	456
22	72.2	640	400
24	78.7	590	368
26	85.3	520	325
28	91.9	410	256
30	98.4	300	188

5.3.1.16.2 Frequency of Occurrence. The 1-, 5-, and 10-percent values for ozone concentration at actual (geometric) altitudes are provided. The 1-percent values were estimated by statistically modeling observed means and 10-percent values from a previous study. Five-percent values were determined by interpolation between

1-and 10-percent values. At some altitudes the estimated 1- and 5-percent values exceed the highest recorded values due to the small sample of actual observations. Data were not available to calculate extremes above 30 km (98,425 ft), but extreme concentrations should be less than the 30 km value since mean ozone concentration continues to decrease with height, reaching a value of less than 25 g/m^3 (15.6 x 10^{-10} 1b/ft^3) at 50 km (164,000 ft.) The 1-, 5-, and 10-percent values follow.

GEOMETRIC ALTITUDE		OZONE CONCENTRATION (µg/m^3)*		
(km)	(kft)	1%	5%	10%
0	0	220	190	145
1	3.28	205	179	140
2	6.56	190	166	130
4	13.1	170	150	120
6	19.7	170	150	120
8	26.2	460	396	300
10	32.8	735	647	515
12	39.4	865	771	630
14	45.9	975	871	715
16	52.5	1100	982	805
18	59.1	1075	973	820
20	65.6	845	787	700
22	72.2	730	684	615
24	78.7	650	602	530
26	85.3	505	479	440
28	91.9	430	412	385
30	98.4	330	318	300

*To convert to 1b/ft^3 multiply by 0.6241 x 10^{-10}

5.3.2 Atmospheric Profiles. Climatic data in this section 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 most severe month. The temperature profiles include associated densities, and the density profiles include associated temperatures. It is recommended that the 1-percent value be initially considered for these temperature and density profiles. Each of the forty profiles should be considered individually to determine which are the most appropriate for a given application. Details on the data and analytical methods used to derive these temperature and density profiles are provided in Appendix A.

The rainfall rate/water concentration profiles aloft are related to the surface rates specified in 5.1.11.1 and 5.1.11.2. 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. It is recommended that the 0.5-percent value be initially considered for these profiles.

Values for all the profiles are presented for geometric (actual) altitudes above sea level. Linear interpolation between adjacent levels is acceptable to obtain temperature values for altitudes not specified. For density, logarithmic interpolation will be more accurate.

5.3.2.1 High Temperature.

5.3.2.1.1 High Temperature at 5 km. Model profiles of temperature and associated density based on 1- and 10-percent high temperature values at 5 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kg/m^3)
0	290.150	1.215+0*	291.650	1.209+0*
2	294.163	9.506-1	291.133	9.571-1
4	284.183	7.773-1	283.190	7.761-1
6	272.745	6.343-1	268.276	6.399-1
8	256.796	5.209-1	253.337	5.220-1
10	240.858	4.224-1	238.407	4.206-1
12	224.930	3.377-1	223.496	3.343-1
14	210.558	2.637-1	208.575	2.615-1
16	201.411	1.982-1	193.674	2.009-1
18	204.873	1.392-1	196.813	1.393-1
20	212.817	9.689-2	204.751	9.559-2
22	216.953	6.933-2	212.683	6.651-2
24	220.920	4.996-2	217.607	4.748-2
26	224.885	3.622-2	221.173	3.432-2
28	228.847	2.641-2	224.735	2.494-2
30	232.806	1.937-2	228.296	1.821-2
32	236.763	1.428-2	231.855	1.337-2
34	240.718	1.058-2	235.411	9.868-3
36	244.670	7.885-3	238.965	7.315-3
38	248.620	5.902-3	242.517	5.447-3
40	252.567	4.439-3	246.066	4.074-3
42	256.512	3.354-3	249.613	3.061-3
44	260.454	2.546-3	253.159	2.309-3
46	264.394	1.940-3	256.701	1.749-3
48	266.150	1.496-3	260.150	1.331-3
50	266.150	1.162-3	260.150	1.028-3
52	262.796	9.138-4	260.150	7.945-4
54	258.473	7.181-4	260.150	6.139-4
56	253.609	5.633-4	254.522	4.839-4
58	246.936	4.425-4	246.679	3.822-4
60	240.268	3.454-4	238.840	2.996-4
62	233.604	2.678-4	231.006	2.330-4
64	226.943	2.061-4	223.177	1.796-4
66	220.287	1.574-4	215.353	1.372-4
68	213.636	1.193-4	210.419	1.025-4
70	206.988	8.965-5	207.489	7.557-5
72	202.695	6.603-5	204.560	5.545-5
74	200.156	4.801-5	201.634	4.052-5
76	197.619	3.478-5	198.709	2.947-5
78	195.084	2.509-5	195.786	2.134-5
80	192.550	1.803-5	192.864	1.538-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.1.2 High Temperature at 10 km. Model profiles of temperature and associated density based on 1- and 10-percent high temperature values at 10 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kg/m^3)
0	299.150	1.173-0*	300.650	1.171+0*
2	289.177	9.632-1	289.682	9.651-1
4	279.210	7.850-1	278.721	7.894-1
6	269.249	6.351-1	267.767	6.405-1
8	259.295	5.098-1	256.820	5.153-1
10	245.985	4.110-1	243.005	4.152-1
12	229.084	3.315-1	226.108	3.340-1
14	212.193	2.630-1	209.221	2.642-1
16	195.314	2.048-1	195.008	2.024-1
18	186.150	1.500-1	189.610	1.457-1
20	202.781	9.710-2	206.663	9.496-2
22	211.443	6.729-2	211.757	6.709-2
24	216.197	4.795-2	216.114	4.791-2
26	220.948	3.443-2	220.468	3.445-2
28	225.696	2.490-2	224.819	2.494-2
30	230.441	1.814-2	229.168	1.817-2
32	235.183	1.330-2	233.514	1.332-2
34	239.922	9.816-3	237.357	9.825-3
36	244.659	7.287-3	242.198	7.286-3
38	249.392	5.442-3	246.535	5.433-3
40	254.122	4.087-3	250.870	4.073-3
42	258.849	3.087-3	255.203	3.069-3
44	263.574	2.343-3	259.532	2.324-3
46	268.150	1.789-3	263.859	1.768-3
48	268.150	1.392-3	268.150	1.352-3
50	268.150	1.084-3	268.150	1.052-3
52	268.150	8.443-4	268.150	8.197-4
54	264.940	6.650-4	268.150	6.384-4
56	258.077	5.284-4	262.555	5.066-4
58	251.217	4.173-4	256.677	4.004-4
60	244.362	3.275-4	250.803	3.148-4
62	237.511	2.552-4	244.932	2.461-4
64	230.664	1.975-4	239.065	1.913-4
66	223.822	1.517-4	233.201	1.478-4
68	216.984	1.156-4	227.893	1.132-4
70	210.150	8.736-5	223.013	8.610-5
72	203.320	6.541-5	218.136	6.507-5
74	198.150	4.811-5	213.262	4.887-5
76	198.150	3.438-5	208.391	3.647-5
78	198.150	2.457-5	203.523	2.703-5
80	198.150	1.756-5	198.658	1.990-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.1.3 High Temperature at 20 km. Model profiles of temperature and associated density based on 1- and 10-percent high temperature values at 20 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density-	Temperature	Density-
(km)	(K)	(kg/m^3)	(K)	(kg/rn^3)
0	228.150	1.552+0*	273.150	1.293+0*
2	238.650	1.110+0	263.128	1.040+0
4	231.113	8.575-1	253.105	8.296-1
6	221.103	6.623-1	241.094	6.603-1
8	216.150	4.947-1	229.090	5.196-1
10	217.659	3.584-1	228.701	3.847-1
12	219.657	2.599-1	234.150	2.802-1
14	221.654	1.891-1	234.150	2.094-1
16	223.650	1.379-1	234.150	1.565-1
18	232.225	9.855-2	234.150	1.170-1
20	240.796	7.126-2	234.150	8.748-2
22	243.192	5.336-2	234.150	6.542-1
24	239.210	4.092-2	234.150	4.893-2
26	235.232	3.124-2	234.150	3.660-2
28	231.255	2.375-2	237.071	2.709-2
30	230.150	1.777-2	240.051	2.013-2
32	230.150	1.323-2	243.030	1.501-2
34	230.150	9.860-3	247.720	1.117-2
36	230.150	7.346-3	252.480	8.363-3
38	230.150	5.473-3	257.932	6.277-3
40	230.150	4.079-3	264.270	4.728-3
42	230.150	3.040-3	270.605	3.585-3
44	230.150	2.267-3	278.935	2.737-3
46	230.150	1.690-3	283.262	2.102-3
48	232.791	1.248-3	287.150	1.838-3
50	235.753	9.242-4	287.150	1.295-3
52	238.713	6.870-4	287.150	1.024-3
54	241.671	5.126-4	284.317	8.174-4
56	240.994	3.890-4	279.587	6.547-4
58	239.615	2.957-4	274.859	5.224-4
60	238.237	2.244-4	270.135	4.153-4
62	236.860	1.701-4	285.414	3.288-4
64	235.484	1.287-4	260.696	2.593-4
66	235.150	9.693-5	253.933	2.053-4
68	235.150	7.287-5	240.974	1.649-4
70	235.150	5.480-5	228.023	1.309-4
72	233.501	4.147-5	215.079	1.026-4
74	231.149	3.140-5	202.144	7.919-5
76	228.799	2.371-5	189.217	6.009-5
78	226.450	1.786-5	178.298	4.472-5
80	224.102	1.341-5	163.387	3.255-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.1.4 High Temperature at 30 km. Model profiles of temperature and associated density based on 1- and 10-percent high temperature values at 30 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/rn³)	(K)	(kg/rn³)
0	279.150	1.262+0*	285.150	1.235+0*
2	275.124	1.000+0	274.135	1.006+0
4	262.106	8.137-1	263.113	8.130-1
6	249.097	6.552-1	245.112	6.669-1
8	236.095	5.216-1	227.140	5.388-1
10	223.162	4.098-1	223.652	4.037-1
12	226.358	2.982-1	227.645	2.932-1
14	227.751	2.195-1	228.650	2.166-1
16	228.549	1.622-1	228.650	1.608-1
18	229.346	1.201-1	228.650	1.194-1
20	230.143	8.899-2	228.650	8.868-2
22	235.087	6.502-2	230.611	6.539-2
24	240.063	4.782-2	232.599	4.834-2
26	245.035	3.540-2	234.587	3.584-2
28	250.005	2.637-2	239.651	2.635-2
30	254.971	1.976-2	244.813	1.949-2
32	259.386	1.492-2	249.971	1.451-2
34	263.156	1.135-2	255.126	1.087-2
36	266.923	8.668-3	260.278	8.200-3
38	270.688	6.644-3	265.427	6.216-3
40	274.451	5.113-3	270.572	4.738-3
42	278.211	3.949-3	275.714	3.630-3
44	281.969	3.061-3	280.853	2.796-3
46	285.724	2.381-3	285.989	2.164-3
48	286.150	1.878-3	286.650	1.706-3
50	286.150	1.483-3	286.650	1.349-3
52	286.150	1.172-3	286.650	1.066-3
54	282.406	9.379-4	283.813	8.511-4
56	276.100	7.538-4	278.890	6.819-4
58	269.799	6.029-4	273.970	5.443-4
60	263.501	4.797-4	269.054	4.327-4
62	257.207	3.796-4	264.140	3.426-4
64	250.917	2.988-4	256.228	2.731-4
66	243.303	2.350-4	245.235	2.184-4
68	231.524	1.861-4	234.248	1.728-4
70	219.752	1.457-4	223.269	1.353-4
72	207.988	1.125-4	212.296	1.046-4
74	196.231	8.565-5	201.331	7.985-5
76	184.481	6.410-5	190.372	6.002-5
78	172.739	4.707-5	179.420	4.436-5
80	161.004	3.383-5	168.474	3.218-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.1.5 High Temperature at 40 km. Model profiles of temperature and associated density based on 1- and 10-percent high temperature values at 40 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m³)	(K)	(kg/m³)
0	287.150	1.227+0*	283.150	1.244+0*
2	273.131	1.010+0	271.134	1.015+0
4	259.121	8.239-1	259.125	8.209-1
6	245.120	6.641-1	247.124	6.571-1
8	231.128	5.287-1	235.131	5.202-1
10	225.651	4.005-1	226.551	4.011-1
12	228.646	2.927-1	228.148	2.950-1
14	228.650	2.172-1	228.150	2.188-1
16	228.650	1.613-1	228.150	1.623-1
18	228.650	1.197-1	228.150	1.204-1
20	229.814	8.852-2	228.150	8.941-2
22	232.203	6.527-2	230.503	6.579-2
24	234.589	4.829-2	232.889	4.856-2
26	236.975	3.584-2	235.275	3.596-2
28	241.209	2.650-2	238.421	2.664-2
30	246.172	1.966-2	244.376	1.962-2
32	251.132	1.467-2	250.328	1.456-2
34	256.089	1.101-2	256.276	1.089-2
36	262.535	8.275-3	262.221	8.197-3
38	269.664	6.247-3	268.162	6.210-3
40	276.788	4.752-3	274.099	4.735-3
42	283.908	3.641-3	278.841	3.646-3
44	284.650	2.864-3	281.806	2.835-3
46	284.650	2.259-3	284.769	2.211-3
48	284.650	1.783-3	286.650	1.735-3
50	282.861	1.415-3	286.650	1.371-3
52	279.904	1.125-3	285.454	1.088-3
54	276.948	8.935-4	281.908	8.697-4
56	273.994	7.075-4	278.363	6.927-4
58	271.042	5.588-4	274.821	5.502-4
60	268.092	4.403-4	271.281	4.358-4
62	265.144	3.461-4	267.743	3.442-4
64	258.034	2.754-4	264.207	2.710-4
66	246.648	2.209-4	252.562	2.187-4
68	235.270	1.753-4	240.791	1.748-4
70	223.898	1.376-4	229.027	1.382-4
72	212.534	1.066-4	217.271	1.079-4
74	201.176	8.155-5	205.522	8.313-5
76	189.826	6.138-5	193.780	6.307-5
78	178.483	4.541-5	182.046	4.704-5
80	167.146	3.295-5	170.319	3.441-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.2 Low Temperature.

5.3.2.2.1 Low Temperature at 5 km. Model profiles of temperature and associated density based on 1- and 10-percent low temperature values at 5 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kg/m^3)
0	220.150	1.607+0*	229.650	1.541+0*
2	234.142	1.124+0	236.633	1.117+0
4	224.860	8.698-1	228.621	8.620-1
6	216.141	6.628-1	219.105	6.628-1
8	214.141	4.869-1	209.150	5.045-1
10	211.633	3.575-1	209.150	3.640-1
12	207.637	2.631-1	209.137	2.626-1
14	203.643	1.925-1	205.143	1.926-1
16	199.652	1.400-1	202.150	1.397-1
18	199.650	9.958-2	202.150	9.979-2
20	199.650	7.080-2	202.150	7.126-2
22	199.650	5.035-2	206.061	5.000-2
24	207.129	3.474-2	214.023	3.482-2
26	214.688	2.428-2	221.980	2.458-2
28	222.243	1.719-2	229.932	1.757-2
30	229.792	1.231-2	237.879	1.270-2
32	237.337	8.916-3	245.821	9.289-3
34	244.877	6.523-3	252.753	6.886-3
36	250.612	4.850-3	255.727	5.214-3
38	255.567	3.639-3	258.700	3.961-3
40	260.518	2.747-3	261.671	3.019-3
42	265.467	2.084-3	263.889	2.315-3
44	269.650	1.594-3	262.306	1.801-3
46	269.650	1.241-3	260.725	1.400-3
48	268.438	9.706-4	259.144	1.086-3
50	265.279	7.628-4	257.565	8.420-4
52	262.122	5.978-4	255.986	6.516-4
54	258.967	4.672-4	254.409	5.035-4
56	255.814	3.641-4	252.832	3.885-4
58	252.663	2.829-4	251.256	2.993-4
60	249.317	2.193-4	248.101	2.317-4
62	241.646	1.721-4	241.217	1.810-4
64	233.979	1.340-4	234.336	1.405-4
66	230.150	1.019-4	229.150	1.074-4
68	230.150	7.615-5	229.150	8.021-5
70	230.150	5.691-5	229.150	5.987-5
72	228.507	4.281-5	227.781	4.493-5
74	226.155	3.222-5	225.821	3.374-5
76	223.805	2.418-5	223.862	2.527-5
78	221.456	1.810-5	221.905	1.888-5
80	219.109	1.350-5	219.949	1.408-5

* Power of ten by which preceding numbers should be multiplied

5.3.2.2.2 Low Temperature at 10 km. Model profiles of temperature and associated density based on 1- and 10-percent low temperature values at 10 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kgm^3)
0	237.150	1.497+0*	246.150	1.438+0*
2	259.625	1.043+0	258.124	1.048+0
4	247.607	8.349-1	246.105	8.385-1
6	233.074	6.678-1	232.681	6.667-1
8	216.070	5.312-1	217.876	5.256-1
10	199.159	4.147-1	203.150	4.074-1
12	201.150	2.922-1	203.137	2.912-1
14	201.150	2.079-1	199.542	2.112-1
16	201.150	1.482-1	195.950	1.523-1
18	201.150	1.056-1	192.360	1.092-1
20	203.319	7.455-2	188.773	7.790-2
22	207.701	5.241-2	185.187	5.518-2
24	212.080	3.712-2	188.105	3.773-2
26	216.456	2.648-2	191.089	2.595-2
28	220.830	1.903-2	194.071	1.796-2
30	225.201	1.376-2	197.051	1.250-2
32	229.569	1.001-2	202.882	8.638-3
34	233.934	7.338-3	212.010	5.961-3
36	238.297	5.407-3	221.132	4.180-3
38	240.470	4.040-3	230.249	2.973-3
40	241.658	3.036-3	239.361	2.144-3
42	242.846	2.285-3	248.466	1.565-3
44	244.033	1.723-3	257.566	1.156-3
46	245.219	1.301-3	266.660	8.630-4
48	246.404	9.839-4	275.749	6.507-4
50	247.589	7.452-4	279.150	5.045-4
52	248.773	5.652-4	279.150	3.962-4
54	249.956	4.294-4	279.150	3.113-4
56	251.139	3.266-4	279.150	2.445-4
58	248.299	2.526-4	267.802	1.995-4
60	242.394	1.967-4	254.024	1.625-4
62	241.771	1.493-4	240.253	1.309-4
64	242.557	1.127-4	226.491	1.041-4
66	243.343	8.529-5	215.516	8.065-5
68	244.128	6.456-5	212.964	5.967-5
70	244.913	4.892-5	210.413	4.400-5
72	244.055	3.734-5	207.863	3.233-5
74	242.487	2.854-5	205.316	2.367-5
76	240.920	2.177-5	203.150	1.723-5
78	239.354	1.659-5	203.150	1.241-5
80	237.789	1.262-5	203.150	8.925-6

*Power of ten by which preceding numbers should be multiplied

5.3.2.2.3 Low Temperature at 20 km. Model profiles of temperature and associated density based on 1- and 10-percent low temperature values at 20 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kgm^3)
-0	236.650	1.496+0*	240.150	1.472+0*
2	250.023	1.072+0	254.130	1.054+0
4	237.604	8.525-1	245.095	8.312-1
6	225.192	6.693-1	230.482	6.629-1
8	212.788	5.183-1	215.877	5.210-1
10	206.650	3.844-1	207.136	3.922-1
12	206.631	2.763-1	204.139	2.855-1
14	201.639	2.027-1	201.144	2.069-1
16	196.650	1.476-1	198.150	1.493-1
18	191.664	1.066-1	195.159	1.072-1
20	186.682	7.637-2	192.169	7.661-2
22	189.619	5.237-2	192.150	5.377-2
24	192.605	3.612-2	192.150	3.774-2
26	198.920	2.471-2	196.068	2.606-2
28	205.282	1.711-2	200.045	1.812-2
30	211.640	1.198-2	204.019	1.270-2
32	217.994	8.484-3	207.990	8.963-3
34	224.344	6.067-3	211.959	6.368-3
36	230.690	4.380-3	219.700	4.488-3
38	237.032	3.191-3	227.628	3.200-3
40	243.370	2.345-3	235.551	2.308-3
42	249.705	1.737-3	243.468	1.684-3
44	256.035	1.297-3	251.381	1.241-3
46	262.362	9.754-4	259.289	9.237-4
48	264.650	7.490-4	264.150	7.012-4
50	264.650	5.805-4	264.150	5.432-4
52	264.650	4.499-4	264.150	4.208-4
54	264.650	3.488-4	264.150	3.261-4
56	263.152	2.719-4	262.977	2.538-4
58	258.622	2.138-4	259.432	1.988-4
60	254.094	1.673-4	255.889	1.552-4
62	245.367	1.325-4	247.055	1.231-4
64	235.537	1.043-4	236.832	9.735-5
66	227.468	8.082-5	228.858	7.543-5
68	224.719	6.080-5	227.679	5.651-5
70	221.971	4.559-5	226.502	4.228-5
72	219.226	3.407-5	223.951	3.177-5
74	216.482	2.537-5	220.815	2.384-5
76	213.740	1.883-5	217.681	1.782-5
78	211.000	1.392-5	214.549	1.327-5
80	208.261	1.025-5	211.420	9.842-6

* Power of ten by which preceding numbers should be multiplied

5.3.2.2.4 Low Temperature at 30 km. Model profiles of temperature and associated density based on 1- and 10-percent low temperature values at 30 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m^3)	(K)	(kgm^3)
0	241.150	1. 462+0*	253.150	1.393+0*
2	241.547	1.101+0	254.374	1.061+0
4	237.242	8.431-1	241.356	8.484-1
6	229.645	6.500-1	228.347	6.702-1
8	222.053	4.969-1	215.345	5.222-1
10	220.150	3.678-1	212. 150	3.844-1
12	220.150	2.698-1	212.150	2.786-1
14	219.657	1.984-1	210.648	2.033-1
16	218.661	1.461-1	207.655	1.489-1
18	217.665	1.074-1	204.664	1.085-1
20	216.670	7.893-2	201.675	7.882-2
22	208.851	5.949-2	198.688	5.695-2
24	200.899	4.440-2	195.702	4.096-2
26	195.448	3.236-2	194.150	2.911-2
28	192.867	2.312-2	194.150	2.052-2
30	190.288	1.645-2	194.150	1.446-2
32	190.150	1.153-2	197.074	1.006-2
34	190.150	8.077-3	203.423	6.949-3
36	193.829	5.569-3	209.768	4.855-3
38	197.787	3.863-3	216.109	3.429-3
40	205.328	2.656-3	222.446	2.447-3
42	218.177	1.817-3	228.779	1.763-3
44	231.018	1.270-3	235.108	1.282-3
46	243.851	9.061-4	241.433	9.403-4
48	256.676	6.575-4	247.754	6.954-4
50	258.650	5.028-4	254.071	5.182-4
52	255.536	3.918-4	258.150	3.923-4
54	251.794	3.050-4	258.150	3.022-4
56	248.862	2.358-4	256.356	2.344-4
58	247.878	1.806-4	250.843	1.837-4
60	246.895	1.382-4	245.332	1.432-4
62	245.913	1.057-4	239.825	1.111-4
64	244.932	8.075-5	237.756	8.451-5
66	243.951	6.163-5	238.935	6.346-5
68	242.970	4.699-5	240.113	4.772-5
70	241.990	3.580-5	241.290	3.595-5
72	238.583	2.750-5	238.657	2. 751-5
74	233.886	2.113-5	234.346	2.111-5
76	229.192	1.616-5	230.038	1.612-5
78	224.500	1.229-5	225.733	1.225-5
80	219.812	9.296-6	221.430	9.264-6

* Power of ten by which preceding numbers should be multiplied

5.3.2.2.5 Low Temperature at 40 km. Model profiles of temperature and associated density based on 1- and 10-percent low temperature values at 40 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Temperature	Density	Temperature	Density
(km)	(K)	(kg/m³)	(K)	(kg/m³)
0	253.150	1.396-0*	253.150	1.396+0*
2	255.874	1.057+0	255.874	1.057+0
4	242.856	8.470-1	242.856	8.470-1
6	229.847	6.701-1	229.847	6.701-1
8	216.845	5.230-1	216.845	5.230-1
10	215.157	3.834-1	214.404	3.846-1
12	217.155	2.770-1	215.403	2.786-1
14	216.648	2.029-1	212.647	2.054-1
16	213.655	1.499-1	208.656	1.514-1
18	210.664	1.102-1	204.668	1.110-1
20	207.675	8.079-2	200.683	8.094-2
22	204.688	5.893-2	199.663	5.791-2
24	201.702	4.280-2	198.667	4.137-2
26	200.150	3.073-2	197.673	2.950-2
28	200.150	2.189-2	198.233	2.087-2
30	200.150	1.559-2	198.829	1.478-2
32	200.150	1.111-2	199.424	1.048-2
34	200.150	7.921-3	200.019	7.448-3
36	200.150	5.647-3	200.614	5.295-3
38	200.150	4.026-3	205.305	3.706-3
40	201.835	2.849-3	210.256	2.613-3
42	205.793	2.005-3	215.204	1.857-3
44	212.087	1.407-3	220.148	1.331-3
46	219.599	9.941-4	226.409	9.562-4
48	227.105	7.105-4	234.705	6.883-4
50	234.607	5.135-4	242.997	5.012-4
52	242.104	3.750-4	246.528	3.753-4
54	249.596	2.766-4	249.288	2.828-4
56	252.792	2.092-4	250.189	2.153-4
58	247.082	1.635-4	247.235	1.662-4
60	241.374	1.271-4	244.283	1.280-4
62	242.467	9.578-5	241.333	9.826-5
64	245.415	7.186-5	242.160	7.413-5
66	248.362	5.410-5	244.125	5.580-5
68	251.307	4.088-5	246.088	4.210-5
70	254.249	3.099-5	248.050	3.184-5
72	252.157	2.400-5	245.657	2.453-5
74	247.846	1.868-5	241.346	1.896-5
76	243.538	1.448-5	237.038	1.460-5
78	239.233	1.117-5	232.733	1.118-5
80	234.930	8.587-6	228.430	8.530-6

* Power of ten by which preceding numbers should be multiplied

5.3.2.3 High Atmospheric Density.

5.3.2.3.1 High Atmospheric Density at 5 km. Model profiles of density and associated temperature based on 1- and 10-percent high density values at 5 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.431+0	251.150	1. 509-0*	238.150
2	1.113+0	245.142	1.104+0	247.129
4	8.774-1	234.117	8.739-1	235.116
6	6.774-1	224.643	6.833-1	223.110
8	5.055-1	221.652	5.270-1	211.159
10	3.701-1	222.650	3.772-1	213.957
12	2.714-1	223.649	2.712-1	216.753
14	1.993-1	224.646	1.977-1	217.352
16	1.469-1	225.150	1.454-1	215.756
18	1.086-1	225.150	1.067-1	214.161
20	8.030-2	225.150	7.815-2	212.567
22	5.937-2	225.150	5.711-2	210.975
24	4.390-2	225.150	4.164-2	209.383
26	3.247-2	225.150	3.030-2	207.792
28	2.402-2	225.150	2.199-2	206.202
30	1.777-2	225.150	1.535-2	213.832
32	1.295-2	228.812	1.084-2	221.771
34	9.354-3	236.941	7.752-3	229.704
36	6.829-3	245.065	5.608-3	237.634
38	3.038-3	253.184	4.101-3	245.558
40	3.753-3	261.298	3.029-3	253.477
42	2.854-3	266.150	2.270-3	260.150
44	2.215-3	266.150	1.751-3	260.150
46	1.718-3	266.150	1.354-3	259.310
48	1.334-3	266.150	1.052-3	257.138
50	1.050-3	261.917	8.154-4	254.967
52	8.259-4	256.988	6.307-4	252.797
54	6.463-4	252.062	4.868-4	250.629
56	3.034-4	247.139	3.740-4	249.150
58	3.902-4	242.219	2.855-4	249.150
60	3.010-4	237.302	2.180-4	249.150
62	2.289-4	234.645	1.665-4	249.150
64	1.732-4	232.681	1.271-4	249.150
66	1.308-4	230.718	9.715-5	249.150
68	9.855-5	228.756	7.423-5	249.150
70	7.407-5	226.795	5.672-5	249.150
72	5.596-5	222.996	4.391-5	245.663
74	4.221-5	218.297	3.405-5	240.570
76	3.165-6	213.600	2.626-5	235.480
78	2.359-5	208.906	2.014-5	230.393
80	1.746-5	204.215	1.536-5	225.309

* Power of ten by which preceding numbers should be multiplied

5.3.2.3.2 High Atmospheric Density at 10 km. Model profiles of density and associated temperature based on 1- and 10-percent high density values at 10 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.203+0*	295.150	1.228+0*	289.150
2	9.786-1	287.567	9.948-1	281.160
4	8.035-1	274.792	8.005-1	273.175
6	6.668-1	260.756	6.596-1	256.245
8	5.331-1	242.815	5.365-1	239.298
10	4.342-1	224.884	4.298-1	222.361
12	3.442-1	206.965	3.384-1	205.436
14	2.491-1	205.673	2.433-1	205.150
16	1.797-1	204.678	1.747-1	205.150
18	1.285-1	205.360	1.243-1	207.469
20	9.144-2	207.942	8.878-2	209.853
22	6.532-2	210.522	6.366-2	212.235
24	4.686-2	213.101	4.583-2	214.615
26	3.376-2	215.678	3.311-2	216.994
28	2.430-2	219.356	2.402-2	219.372
30	1.751-2	224.503	1.748-2	221.748
32	1.271-2	229.648	1.277-2	224.122
34	9.294-3	234.789	9.366-3	226.495
36	6.843-3	239.926	6.891-3	228.867
38	5.072-3	245.062	5.027-3	234.368
40	3.784-3	250.192	3.690-3	240.289
42	2.840-3	255.321	2.730-3	246.207
44	2.176-3	256.150	2.034-3	252.121
46	1.673-3	256.150	1.527-3	258.032
48	1.287-3	256.150	1.154-3	263.650
50	9.901-4	256.150	8.949-4	263-650
52	7.695-4	253.254	6.938-4	263.583
54	5.980-4	249.520	5.456-4	259.260
56	4.630-4	245.789	4.274-4	254.939
58	3.571-4	242.060	3.334-4	250.621
60	2.744-4	238.334	2.591-4	246.306
62	2.100-4	234.609	2.004-4	241.993
64	1.601-4	230.888	1.543-4	237.683
66	1.215-4	227.168	1.183-4	233.276
68	9.182-5	223.451	9.031-5	229.071
70	6.907-5	219.736	6.853-5	224.890
72	5.125-5	218.150	5.150-5	221.959
74	3.775-5	218.150	3.856-5	219.029
76	2.781-5	218.103	2.876-5	216.102
78	2.081-5	214.202	2.138-5	213.176
80	1.548-5	210.304	1.582-5	210.252

* Power of ten by which preceding numbers should be multiplied

5.3.2.3.3 High Atmospheric Density at 20 km. Model profiles of density and associated temperature based on 1- and 10-percent high density values at 20 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.169+0*	301.150	1.169+0*	301.150
2	9.609-1	291.179	9.639-1	290.182
4	7.843-1	281.214	7.886-1	279.221
6	6.356-1	271.256	6.401-1	268.267
8	5.110-1	261.304	5.152-1	257.319
10	4.160-1	245.483	4.180-1	241.483
12	3.342-1	229.580	3.345-1	225.580
14	2.643-1	213.687	2.634-1	209.687
16	2.053-1	197.803	2.038-1	193.803
18	1.475-1	193.482	1.455-1	189.211
20	9.994-2	203.000	9.795-2	198.134
22	6.891-2	212.512	6.710-2	207.652
24	4.929-2	216.845	4.711-2	214.014
26	3.554-2	220.803	3.377-2	218.369
28	2.578-2	224.759	2.437-2	222.720
30	1.880-2	228.712	1.770-2	227.069
32	1.380-2	232.663	1.294-2	231.415
34	1.017-2	236.612	9.519-3	235.758
36	7.548-3	240.558	7.033-3	240.363
38	5.603-3	245.514	5.186-3	247.264
40	4.159-3	252.411	3.857-3	254.161
42	3.112-3	259.303	2.892-3	261.053
44	2.347-3	266.191	2.185-3	267.941
46	1.795-3	271.150	1.664-3	274.650
48	1.401-3	271.150	1.303-3	274.650
50	1.094-3	271.150	1.020-3	274.650
52	8.710-4	265.321	8.106-4	270.610
54	6.899-4	259.435	6.442-4	265.116
56	5.437-4	253.554	5.096-4	259.627
58	4.261-4	247.675	4.012-4	254.140
60	3.321-4	241.801	3.142-4	248.657
62	2.572-4	235.930	2.448-4	243.178
64	1.980-4	230.063	1.897-4	237.702
66	1.514-4	224.199	1.461-4	232.229
68	1.150-4	218.339	1.118-4	226.760
70	8.673-5	212.483	8.514-5	221.294
72	6.489-5	206.631	6.468-5	214.624
74	4.815-5	200.782	4.893-5	206.826
76	3.542-5	194.937	3.662-5	199.032
78	2.582-5	189.095	2.710-5	191.243
80	1.805-5	190.448	1.911-5	191.549

* Power of ten by which preceding numbers should be multiplied

5.3.2.3.4 High Atmospheric Density at 30 km. Model profiles of density and associated temperature based on 1- and 10-percent high density values at 30 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.248+0*	282.150	1.204+0*	292.150
2	1.007+0	273.132	9.918-1	279.333
4	8.080-1	264.103	8.089-1	266.524
6	6.539-1	250.093	6.558-1	252.718
8	5.229-1	236.091	5.273-1	237.926
10	4.124-1	222.177	4.181-1	223.151
12	2.952-1	229.368	3.047-1	225.946
14	2.180-1	231.150	2.230-1	228.739
16	1.623-1	231.150	1.648-1	230.150
18	1.209-1	231.150	1.228-1	230.150
20	9.007-2	231.150	9.124-2	230.150
22	6.686-2	232.137	6.790-2	230.150
24	4.970-2	233.133	5.054-2	230.150
26	3.700-2	234.127	3.731-2	232.306
28	2.758-2	235.121	2.756-2	235.285
30	2.059-2	236.114	2.043-2	238.263
32	1.527-2	239.208	1.518-2	241.710
34	1.127-2	244.764	1.126-2	247.064
36	8.388-3	250.315	8.405-3	252.414
38	6.280-3	255.864	6.313-3	257.760
40	4.732-3	261.409	4.770-3	263.104
42	3.587-3	266.950	3.628-3	268.444
44	2.735-3	272.488	2.771-3	273.780
46	2.098-3	278.023	2.129-3	279.114
48	1.633-3	280.401	1.662-3	281.150
50	1.276-3	282.375	1.308-3	281.150
52	1.001-3	283.650	1.029-3	281.150
54	7.900-4	283.650	8.156-4	279.221
56	6.266-4	281.939	6.478-4	275.873
58	4.982-4	278.985	5.132-4	272.528
60	3.952-4	276.033	4.054-4	269.185
62	3.129-4	272.927	3.194-4	265.843
64	2.526-4	263.099	2.546-4	258.340
66	2.023-4	253.277	2.045-4	246.562
68	1.607-4	243.461	1.626-4	234.791
70	1.264-4	233.652	1.277-4	223.027
72	9.983-5	220.447	9.908-5	211.271
74	7.811-5	205.751	7.574-5	199.522
78	6.003-5	191.064	5.697-5	187.780
78	4.518-5	176.386	4.208-5	176.046
80	3.318-5	161.717	3.045-5	164.319

* Power of ten by which preceding numbers should be multiplied

5.3.2.3.5 High Atmospheric Density at 40 km. Model profiles of density and associated temperature based on 1- and 10-percent high density values at 40 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.196+0	294.150	1.213+0*	290.150
2	9.874-1	280.932	9.945-1	278.134
4	8.075-1	267.723	8.084-1	266.125
6	6.572-1	253.116	6.544-1	252.718
8	5.309-1	237.124	5.261-1	237.926
10	4.225-1	221.151	4.172-1	223.151
12	3.066-1	224.346	3.041-1	225.946
14	2.236-1	227.538	2.225-1	228.739
16	1.645-1	229.643	1.644-1	230.150
18	1.218-1	230.639	1.223-1	230.150
20	9.041-2	231.635	9.104-2	230.150
22	6.716-2	232.630	6.775-2	230.150
24	4.997-2	233.625	5.030-2	230.779
26	3.723-2	234.619	3.709-2	233.562
28	2.758-2	237.367	2.746-2	236.343
30	2.038-2	242.131	2.040-2	239.122
32	1.514-2	246.893	1.514-2	243.150
34	1.132-2	251.651	1.124-2	248.701
36	8.515-3	256.407	8.401-3	254.249
38	6.437-3	261.159	6.319-3	259.794
40	4.891-3	265.909	4.782-3	265.335
42	3.735-3	270.655	3.641-3	270.873
44	2.867-3	275.399	2.788-3	276.407
46	2.210-3	280.140	2.146-3	281.938
48	1.722-3	283.150	1.686-3	282.650
50	1.357-3	283.150	1.328-3	282.650
52	1.077-3	281.054	1.054-3	280.320
54	8.574-4	277.508	8.368-4	277.561
56	6.805-4	273.963	6.625-4	274.805
58	5.385-4	270.421	5.233-4	272.049
60	4.249-4	266.881	4.124-4	269.296
62	3.343-4	263.343	3.243-4	266.544
64	2.641-4	257.840	2.585-4	259.340
66	2.120-4	246.062	2.078-4	247.562
68	1.684-4	234.291	1.653-4	235.791
70	1.322-4	222.527	1.300-4	224.027
72	1.025-4	210.771	1.009-4	212.271
74	7.833-5	199.022	7.730-5	200.522
76	5.888-5	187.280	5.823-5	188.780
78	4.346-5	175.546	4.309-5	177.046
80	3.141-5	163.819	3.123-5	165.319

* Power of ten by which preceding numbers should be multiplied

5.3.2.4 Low Atmospheric Density.

5.3.2.4.1 Low Atmospheric Density at 5 km . Model profiles of density and associated temperature based on 1- and 10-percent low density values at 5 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.239+0*	281.650	1.219+0*	289.150
2	9.881-1	276.647	9.641-1	289.158
4	7.617-1	280.148	7.757-1	283.170
6	6.285-1	264.162	6.395-1	268.554
8	5.125-1	248.187	5.263-1	251.011
10	4.123-1	232.221	4.272-1	233.479
12	3.267-1	216.265	3.411-1	215.958
14	2.455-1	208.150	2.571-1	207.831
16	1.770-1	208.150	1.883-1	203.650
18	1.268-1	209.592	1.349-1	203.650
20	9.067-2	212.577	9.376-2	211.317
22	6.510-2	215.559	6.661-2	216.912
24	4.697-2	218.539	4.821-2	219.689
26	3.404-2	221.518	3.505-2	222.464
28	2.478-2	224.495	2.558-2	225.238
30	1.312-2	227.470	1.875-2	228.009
32	1.331-2	230.443	1.380-2	230.779
34	9.815-3	233.414	1.019-2	233.548
36	7.195-3	239.116	7.558-3	236.314
38	5.310-3	245.051	5.668-3	241.855
40	3.949-3	250.982	4.126-3	247.776
42	2.957-3	256.910	3.080-3	253.693
44	2.229-3	262.833	2.315-3	259.607
46	1.692-3	268.753	1.752-3	265.516
48	1.307-3	271.150	1.355-3	266.650
50	1.032-3	267.717	1.057-3	265.534
52	8.186-4	261.808	8.321-4	261.601
54	6.458-4	255.903	6.523-4	257.671
56	5.068-4	250.002	5.095-4	253.744
58	3.955-4	244.104	3.965-4	249.818
60	3.068-4	238.209	3.074-4	245.896
62	2.365-4	232.319	2.393-4	239.836
64	1.812-4	226.432	1.857-4	232.784
66	1.378-4	220.548	1.431-4	225.737
68	1.041-4	214.669	1.093-4	218.694
70	7.803-5	208.793	8.232-5	211.655
72	5.802-5	202.920	6.143-5	207.307
74	4.277-5	197.052	4.495-5	204.963
76	3.125-5	191.187	3.278-5	202.622
78	2.261-5	185.325	2.382-5	200.281
80	1.620-5	179.468	1.725-5	197.942

* Power of ten by which preceding numbers should be multiplied

5.3.2.4.2 Low Atmospheric Density at 10 km. Model profiles of density and associated temperature based on 1- and 10-percent low density values at 10 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.545-0*	228.150	1. 448-0*	243.150
2	1.143+0	229.142	1.102+0	241.338
4	8.676-1	223.165	8.601-1	231.732
6	6.200-1	231.152	6.639-1	222.154
8	4.597-1	232.151	4.838-1	224.553
10	3.413-1	233.150	3.538-1	226.950
12	2.548-1	233.150	2.609-1	228.150
14	1.908-1	232.364	1.935-1	228.150
16	1.440-1	229.174	1.441-1	227.165
18	1.083-1	225.986	1.076-1	225.173
20	8.112-2	222.799	8.018-2	223.182
22	6.052-2	219.615	5.957-2	221.192
24	4.497-2	216.433	4.415-2	219.203
26	3.327-2	213.253	3.264-2	217.215
28	2.421-2	213.150	2.397-2	216.150
30	1.761-2	213.150	1.752-2	216.150
32	1.281-2	213.150	1.280-2	216.150
34	9.328-3	213.150	9.360-3	216.150
36	6.790-3	213.150	6.696-3	221.710
38	4.943-3	213.150	4.826-3	227.650
40	3.548-3	216.777	3.508-3	233.587
42	2.558-3	220.732	2.571-3	239.520
44	1.856-3	224.685	1.899-3	245.449
46	1.354-3	228.636	1.413-3	251.374
48	9.939-4	232.583	1.059-3	257.296
50	7.332-4	236.529	8.132-4	258.150
52	5.438-4	240.472	6.264-4	258.150
54	4.053-4	244.412	4.843-4	257.206
56	3.039-4	248.030	3.766-4	254.252
58	2.337-4	245.668	2.921-4	251.301
60	1.792-4	243.308	2.258-4	248.351
62	1.360-4	243.250	1.741-4	245.403
64	1.024-4	245.410	1.338-4	242.457
66	7.735-5	247.570	1.025-4	239.768
68	5.856-5	249.728	7.800-5	238.002
70	4.445-5	251.884	5.924-5	236.238
72	3.404-5	252.342	4.491-5	234.474
74	2.629-5	250.384	3.398-5	232.712
76	2.027-5	248.427	2.566-5	230.951
78	1.559-5	248.471	1.934-5	229.191
80	1.197-5	244.517	1.455-5	227.432

* Power of ten by which preceding numbers should be multiplied

5.3.2.4.3 Low Atmospheric Density at 20 km. Model profiles of density and associated temperature based on 1- and 10-percent low density values at 20 km, follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.502+0*	2.35.150	1.537+0*	230.150
2	1.093+0	243.632	1.125+0	235.137
4	8.690-1	229.623	8.600-1	229.114
6	6.808-1	215.623	6.627-1	219.105
8	5.052-1	210.154	5.045-1	209.150
10	3.608-1	213.150	3.639-1	209.150
12	2.620-1	213.150	2.626-1	209.137
14	1.903-1	213.150	1.926-1	205.143
16	1.362-1	216.598	1.397-1	202.150
18	9.686-2	223.572	9.979-2	202.150
20	6.741-2	239.403	7.125-2	202.150
22	4.882-2	250.961	5.000-2	206.061
24	3.763-2	247.978	3.482-2	214.023
26	2.891-2	244.997	2.458-2	221.980
28	2.215-2	242.017	1.757-2	229.932
30	1.691-2	239.040	1.270-2	237.879
32	1.277-2	238.150	9.288-3	245.821
34	9.615-3	238.150	6.885-3	252.753
36	7.236-3	238.150	5.213-3	255.727
38	5.447-3	238.150	3.961-3	258.700
40	4.100-3	238.150	3.019-3	261.761
42	3.087-3	238.150	2.315-3	263.889
44	2.311-3	239.685	1.801-3	262.306
46	1.720-3	243.636	1.400-3	260.725
48	1.286-3	247.583	1.086-3	259.144
50	9.663-4	251.529	8.419-4	257.565
52	7.303-4	255.150	6.515-4	255.986
54	5.339-4	255.150	5.034-4	254.409
56	4.349-4	252.590	3.885-4	252.832
58	3.369-4	249.441	2.993-4	251.256
60	2.602-4	246.295	2.317-4	248.101
62	2.003-4	243.150	1.810-4	241.217
64	1.537-4	240.007	1.405-4	234.336
66	1.168-4	238.437	1.074-4	229.150
68	8.855-5	237.456	8.021-5	229.150
70	6.703-5	236.475	5.986-5	229.150
72	5.081-5	234.842	4.493-5	227.781
74	3.849-5	232.884	3.373-5	225.821
76	2.909-5	230.927	2.527-5	223.862
78	2.194-5	228.971	1.888-5	221.905
80	1.651-5	227.017	1.408-5	219.949

* Power of ten by which preceding numbers should be multiplied

5.3.2.4.4 Low Atmospheric Density at 30 km. Model profiles of density and associated temperature based on 1- and 10-percent low density values at 30 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.424+0*	248.150	1.430+0*	247.150
2	1.076+0	250.624	1.093+0	245.528
4	8.577-1	237.606	8.613-1	234.312
6	6.749-1	224.597	6.707-1	223.104
8	5.236-1	211.595	5.158-1	211.983
10	3. 881-1	205.150	3.772-1	209.139
12	2.810-1	202.892	2.755-1	206.142
14	2.032-1	199.898	2.003-1	203.148
16	1.463-1	196.905	1.450-1	200.155
18	1.048-1	193.914	1.044-1	197.164
20	7.433-2	192.133	7.490-2	194.175
22	5.172-2	194.125	5.344-2	191.188
24	3.613-2	196.115	3.701-2	193.901
26	2.534-2	198.104	2.576-2	196.686
28	1.773-2	201.374	1.789-2	201.164
30	1.226-2	209.121	1.244-2	207.521
32	8.602-3	216.863	8.750-3	213.874
34	6.109-3	224.601	6.218-3	220.223
36	4.390-3	232.334	4.463-3	226.568
38	3.190-3	240.062	3.233-3	232.909
40	2.342-3	247.785	2.363-3	239.246
42	1.736-3	255.504	1.742-3	245.579
44	1.317-3	259.189	1.300-3	250.648
46	1.009-3	260.771	9.764-4	255.590
48	7.760-4	262.150	7.374-4	260.528
50	5.999-4	262.150	5.682-4	261.150
52	4.639-4	262.150	4.389-4	261.150
54	3.661-4	256.305	3.440-4	257.172
56	2.882-4	249.408	2.709-4	250.472
58	2.255-4	242.516	2.120-4	243.777
60	1.752-4	235.628	1.648-4	237.085
62	1.329-4	233.069	1.252-4	234.569
64	1.001-4	231.693	9.452-5	233.193
66	7.534-5	230.318	7.124-5	231.818
68	5.659-5	228.944	5.362-5	230.444
70	4.244-5	227.570	4.029-5	229.070
72	3.192-5	225.109	3.037-5	228.473
74	2.398-5	222.170	2.287-5	223.338
76	1.794-5	219.233	1.715-5	220.205
78	1.338-5	216.297	1.281-5	217.074
80	9.939-6	213.363	9.539-6	213.944

* Power of ten by which preceding numbers should be multiplied

5.3.2.4.5 Low Atmospheric Density at 40 km. Model profiles of density and associated temperature based on 1- and 10-percent low density values at 40 km follow:

Geometric Altitude	1 Percent		10 Percent	
	Density	Temperature	Density	Temperature
(km)	(kg/m^3)	(K)	(kg/m^3)	(K)
0	1.398+0*	253.150	1.395+0*	253.650
2	1.052+0	257.122	1.054+0	256.626
4	8.468-1	243.103	8.421-1	244.610
6	6.726-1	229.093	6.649-1	232.601
8	5.266-1	215.091	5.185-1	220.599
10	4.055-1	201.150	3.987-1	208.635
12	2.888-1	201.150	2.922-1	204.640
14	2.079-1	198.747	2.128-1	200.647
16	1.495-1	195.555	1.540-1	196.656
18	1.070-1	192.365	1.108-1	192.668
20	7.616-2	189.176	7.919-2	188.683
22	5.315-2	189.150	5.522-2	188.650
24	3.710-2	189.150	3.851-2	188.650
26	2.581-2	189.831	2.653-2	191.226
28	1.782-2	192.813	1.818-2	196.593
30	1.237-2	195.793	1.259-2	201.957
32	8.646-3	198.771	8.805-3	207.317
34	5.945-3	206.639	6.216-3	212.674
36	4.118-3	216.553	4.388-3	220.053
38	2.901-3	226.460	3.108-3	229.960
40	2.075-3	236.362	2.234-3	239.862
42	1.504-3	246.257	1.627-3	249.757
44	1.105-3	256.147	1.200-3	259.647
46	8.218-4	266.030	8.963-4	269.530
48	6.177-4	275.907	6.761-4	279.407
50	4.748-4	282.150	5.293-4	280.650
52	3.757-4	280.753	4.187-4	278.974
54	2.992-4	276.810	3.338-4	274.242
56	2.376-4	272.869	2.652-4	269.513
58	1.880-4	268.930	2.098-4	264.786
60	1.503-4	261.222	1.653-4	260.063
62	1.206-4	250.404	1.307-4	253.382
64	9.584-5	239.594	1.045-4	241.589
66	7.536-5	228.790	8.265-5	229.803
68	5.857-5	217.993	6.456-5	218.024
70	4.496-5	207.202	4.975-5	206.252
72	3.328-5	201.150	3.642-5	202.650
74	2.386-5	201.150	2.617-5	202.650
76	1.711-5	201.150	1.881-5	202.650
78	1.227-5	201.150	1.352-5	202.650
80	8.804-6	201.150	9.728-6	202.650

*Power of ten by which preceding numbers should be multiplied

5.3.2.5 Rainfall Rate/Water Concentration. The distribution of precipitation rate and water concentration (or equivalent solid precipitation) from the surface to 20 km was modeled by structuring a profile that would realistically occur at the approximate time that specified heavy rainfall rates are occurring at the surface. In this way, the entire profile can be assigned the frequency of occurrence associated with the surface rate for which far more data are available.

Information on the surface rainfall rates used for these model profiles is provided in detail in 5.1.11 through 5.1.11.2. Previous studies of vertical radar reflectivity profiles indicate that when high precipitation rates reach the surface, the rate, and hence precipitation water content, stay fairly constant with altitude up to about 6 km then decrease above. The model profiles presented here are based on these earlier findings, and also on measurements of precipitation liquid water content in tropical cyclones and thunderstorms. Note that precipitation rates are surface equivalent intensities. Actual rates aloft are higher due to lower atmospheric density.

Cloud water contents provided with the model profiles were estimated assuming cloud droplet sizes to be less than 100 µm. The precipitation drop-size distributions were estimated from a gamma function fit to drop-size distributions observed during heavy rain in tropical cyclones. Reference to more information on these profiles is provided in Appendix A.

5.3.2.5.1 Highest Recorded. The world's greatest recorded 1-min rainfall is 31.2mm. Although thoroughly documented, this rate is suspect because it is approximately twice as great as the next several candidates. The record for 1 hr is 305 mm (7.25 mm/min), which occurred in 42 min (see 5.1.11.1). The model profile for the record 1-min surface rate (31.2 mm/min) follows:

GEOMETRIC ALTITUDE	PRECIP RATE	PRECIP WATER	CLOUD WATER	Drop Concentrations (per m^3)					
				Diameter Size Intervals (mm)					
(km)	(mm/min)	(g/m^3)	(g/m^3)	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4
0	31.2	60.3	0	4121	3547	1514	487	135	34
2	31.2	60.3	3.4	4121	3547	1514	487	135	34
4	31.2	60.3	3.9	4121	3547	1514	487	135	34
6	31.2	60.3	4.0	4121	3547	1514	487	135	34
8	23.1	45.8	2.7	3826	3052	1200	356	90	21
10	15.9	32.6	1.9	3475	2511	888	236	54	11
12	10.9	23.1	1.3	3135	2037	643	152	31	6
14	6.9	15.1	0.8	2739	1549	420	85	15	2
16	3.4	8.0	0.4	2202	992	211	33	5	<1
18	2.5	6.0	0.1	1978	796	150	21	3	<1
20	0	0	0	0	0	0	0	0	0

NOTES: (1) All rain rates are surface equivalent intensities.

(2) Distributions are all liquid below 4.5 km, mostly liquid 4.5-6.0 km, and nearly all ice above 7.0 km. Numbers are in terms of equivalent raindrops for solid precipitation.

(3) Cloud-Precipitation water division is at D = 100 µm. Cloud water includes ice with melted diameters D < 100 µm.

The profile for the record 42-min surface rate is given in Table XXIX (page 98).

5.3.2.5.2 Frequency of Occurrence. The model profile for the 0.5 percent surface rate (0.6 mm/min) follows (see 5.1.11.2):

GEOMETRIC ALTITUDE	PRECIP RATE	PRECIP WATER	CLOUD WATER	Drop Concentrations (per m^3)					
				Diameter Size Intervals (mm)					
(km)	(mm/min)	(g/m^3)	(g/m^3)	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4
0	0.60	1.6	0	1154	260	26	2	<1	<1
2	0.60	1.6	2.1	1154	260	26	2	<1	<1
4	0.60	1.6	2.4	1154	260	26	2	<1	<1
6	0.60	1.6	2.5	1154	260	26	2	<1	<1
8	0.44	1.2	1.7	1017	199	17	1	<1	0
10	0.31	0.9	1.2	864	141	10	<1	<1	0
12	0.21	0.6	0.8	728	98	6	<1	<1	0
14	0.13	0.4	0.5	583	60	3	<1	0	0
16	0.07	0.2	0.2	409	28	<1	<1	0	0
18	0.05	0.2	0.1	345	19	<1	<1	0	0
20	0	0	0	0	0	0	0	0	0

NOTES:
(1) All rain rates are surface equivalent intensities.
(2) Distributions are all liquid below 4.5 km, mostly liquid 4.5-6.0 km, and nearly all ice above 7.0 km. Numbers are in terms of equivalent raindrops for solid precipitation.
(3) Cloud-Precipitation water division is at D = 100 µm. Cloud water includes ice with melted diameters D < 100 µm.

The profiles for the 0.1- and 0.01-percent surface rates are given in Tables XXX and XXXI (pages 99 and 100).

6. NOTES (This section contains information of general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This data provided are intended to serve as natural environment for the starting points of sequence engineering analysis to derive environmental design criteria for material.

6.2 Subject Term (Key Word) Listing.

Atmospheric Profiles	Climatic Extremes	Environment, Natural	Humidity	Precipitation
Temperature	Weather	Weather Extremes	Wind	

6.3 International Standardization Agreement: Certain provisions of this handbook are the subject of international standardization agreement STANAG 2895, "Extreme Climatic Conditions and Derived Conditions for Use in Defining Design/Test Criteria for NATO Forces' Materiel." When proposed amendments, revisions or cancellations of this handbook will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental standardization offices if required.

6.4 Supersession. This document contains engineering data and frequencies that had previously been specified in Mil Std 210C.

6.5 Please note that since the temperature and density envelopes and profiles were derived from separate data bases, there are differences between some of the 1 and 10 percent extremes. For consistency, envelope values in this standard were revised at altitudes where more extreme conditions were found for the profiles. The rainfall rate/water concentration profiles and associated drop-size distributions from the surface to 20 km were taken from reference (19) in 40.1.11.

Table I. Daily Cycle of Temperature and Other Elements Associated with the Worldwide Hottest 1-Percent Temperature Value (see 5.1.1.2 and 5.2.2.1)

TIME	TEMPERATURE		R.H.	WIND (at 3m)		SOL. RAD.	
(LST)	(°C)	(°F)	(%)	(m/s)	(ft/s)	(W/m^2)	(Bph)
0l	35	95	6	3	9	0	0
02	34	94	7	3	9	0	0
03	34	93	7	3	9	0	0
04	33	92	8	3	9	0	0
05	33	91	8	3	9	0	0
06	32	90	8	3	9	55	18
07	33	91	8	3	9	270	85
08	35	95	6	3	9	505	160
09	38	101	6	3	9	730	231
10	41	106	5	4	14	915	291
11	43	110	4	4	14	1040	330
12	44	112	4	4	14	1120	355
13	47	116	3	4	14	1120	355
14	48	118	3	4	14	1040	330
15	48	119	3	4	14	915	291
16	49	120	3	4	14	730	231
17	48	119	3	4	14	505	160
18	48	118	3	4	14	270	85
19	46	114	3	4	14	55	18
20	42	108	4	4	14	0	0
21	41	105	5	4	14	0	0
22	39	102	6	4	14	0	0
23	38	100	6	4	14	0	0
24	37	98	6	3	9	0	0

Table II. Daily Cycle of Temperature and Other Elements Associated with the Worldwide Long-term Extremes of High Temperature (see 5.1.1.3)

TIME	TEMPERATURE °C (°F)			R H	WIND (at 3m)		SOL RAD	
(LST)	Period (yrs)			(%)	(m/s)	(ft/s)	(W/m^2)	(Bph)
	10	30	60					
01	36(97)	36(97)	36(97)	6	3	9	0	0
02	36(96)	36(96)	36(96)	7	3	9	0	0
03	36(96)	36(96)	36(96)	7	3	9	0	0
04	34(94)	34(94)	34(94)	8	3	9	0	0
05	33(92)	33(92)	33(92)	8	3	9	0	0
06	33(91)	33(91)	33(91)	8	3	9	55	18
07	33(92)	33(92)	33(92)	8	3	9	270	85
08	36(97)	36(97)	36(97)	6	3	9	505	160
09	41(105)	41(106)	41(106)	6	3	9	730	231
10	43(110)	44(112)	44(112)	5	4	14	915	291
11	46(115)	47(117)	47(117)	4	4	14	1040	330
12	48(119)	49(120)	49(121)	4	4	14	1120	355
13	51(123)	52(125)	52(126)	3	4	14	1120	355
14	52(126)	53(128)	54(129)	3	4	14	1040	330
15	53(127)	54(129)	54(130)	3	4	14	915	291
16	53(128)	54(130)	55(131)	3	4	14	730	231
17	53(127)	54(129)	54(130)	3	4	14	505	160
18	52(125)	53(127)	53(128)	3	4	14	270	85
19	49(121)	50(122)	51(123)	3	4	14	55	18
20	45(113)	46(114)	46(115)	4	4	14	0	0
21	43(110)	44(114)	44(111)	5	4	14	0	0
22	41(106)	42(107)	42(108)	6	4	14	0	0
23	39(103)	40(104)	40(104)	6	4	14	0	0
24	38(101)	39(102)	39(102)	6	3	9	0	0

Table III. Monthly Cycle of Temperatures Associated with the Worldwide Long Term Low Temperature Extremes (see 5.1.2.3).

TIME		HOURS BEFORE & AFTER						DAYS BEFORE & AFTER				
PERIOD (yrs)	TEMP	0	.5	1.5	3	6	12	1	2	4	8	16
10	°C	-66	-66	-66	-65	-65	-64	-63	-59	-55	-49	-42
	°F	-86	-86	-86	-85	-85	-84	-81	-75	-67	-56	-43
30	°C	-67	-67	-67	-67	-67	-66	-64	-62	-57	-51	-45
	°F	-89	-89	-89	-88	-88	-87	-84	-79	-71	-60	-49
60	°C	-69	-69	-68	-68	-67	-67	-65	-63	-58	-53	-47
	°F	-92	-92	-91	-90	-89	-88	-85	-81	-73	-63	-53

Table IV. Daily Cycle of Humidity, Temperature, and Other Elements Associated with the Worldwide High Absolute Humidity 1-Percent Value (see 5.1.3.2). This cycle also represents the Hot-Humid condition for the Hot Regional Type (see 5.2.2.2).

TIME	ABSOLUTE HUMIDITY			TEMPERATURE		R.H.	SOL. RAD.	
	MIX. RATIO	DEWPOINT						
(LST)	(ppm)	(°C)	(°F)	(°C)	(°F)	(%)	(W/m^2)	(Bph)
01	26×10^3	29	84	3-	88	88	0	0
02	26×10^3	29	84	31	88	88	0	0
03	26×10^3	29	84	31	88	88	0	0
04	26×10^3	29	84	31	88	88	0	0
05	26×10^3	29	84	31	88	88	0	0
06	27×10^3	29	85	32	91	88	45	15
07	28×10^3	30	86	34	93	83	315	100
08	29×10^3	31	87	36	96	78	560	177
09	30×10^3	31	88	37	98	73	790	251
10	30×10^3	31	88	38	100	70	950	302
11	30×10^3	31	88	39	102	66	1035	328
12	30×10^3	31	88	40	104	63	1080	343
13	30×10^3	31	88	41	105	60	1000	317
14	30×10^3	31	88	41	105	60	885	280
15	30×10^3	31	88	41	105	60	710	225
16	30×10^3	31	88	41	105	60	465	147
17	29×10^3	31	88	39	102	64	210	66
18	29×10^3	31	87	37	99	69	15	4
19	28×10^3	31	87	36	97	74	0	0
20	28×10^3	30	86	34	94	79	0	0
21	28×10^3	30	86	33	91	85	0	0
22	27×10^3	29	85	32	90	86	0	0
23	26×10^3	29	85	32	89	87	0	0
24	26×10^3	29	84	31	88	88	0	0

Note: Mixing ratios are based upon a typical surface atmospheric pressure of 1000 mb and dewpoints in adjacent column.

Table V. Monthly Regime of Daily Cycles of Humidity and Other Elements Associated with the Worldwide Long-term High Absolute Humidity Extreme (see 5.1.3.3).

TIME	ABSOLUTE HUMIDITY			TEMPERATURE		R.H.	SOL. RAD.	
	MIX. RATIO	DEWPOINT						
(LST)	(ppm)	(°C)	(°F)	(°C)	(°F)	(%)	(W/m^2)	(Bph)
01	22×10^3	27	80	28	82	91	0	0
02	22×10^3	26	79	28	82	92	0	0
03	22×10^3	26	79	28	82	92	0	0
04	22×10^3	26	79	28	82	93	0	0
05	22×10^3	26	79	27	81	93	0	0
06	22×10^3	26	79	27	81	94	45	15
07	22×10^3	26	79	28	82	93	230	73
08	23×10^3	27	80	28	82	93	435	138
09	23×10^3	27	80	29	84	92	630	200
10	24×10^3	28	82	29	84	92	795	252
11	24×10^3	28	82	30	86	91	900	286
12	25×10^3	28	83	30	86	91	970	307
13	25×10^3	28	83	30	86	91	970	307
14	24×10^3	28	83	30	86	91	900	286
15	24×10^3	28	83	29	84	91	795	252
16	24×10^3	28	82	29	84	91	630	200
17	24×10^3	27	81	29	84	91	435	138
18	23×10^3	27	81	29	84	91	230	73
19	23×10^3	27	81	29	84	91	45	15
20	23×10^3	27	81	29	84	91	0	0
21	23×10^3	27	81	29	84	91	0	0
22	23×10^3	27	80	29	84	91	0	0
23	23×10^3	27	80	28	82	91	0	0
24	23×10^3	27	80	28	82	91	0	0

Note: Mixing ratios are based upon a typical surface atmospheric pressure of 1000 mb and dewpoints in adjacent column.

Table VI. Daily Cycle of Relative Humidity and Temperature (Including Solar Radiation) Associated with the Worldwide 1-Percent High Relative Humidity with High Temperature (see 5.1.6.2). This cycle also represents the variable high humidity condition for the basic regional type (see 5.2.1.4).

TIME	R.H.	TEMPERATURE		SOL. RAD.	
(LST)	(%)	(°C)	(°F)	(W/m^2)	(Bph)
01	100	27	80	0	0
02	100	26	79	0	0
03	100	26	79	0	0
04	100	26	79	0	0
05	100	26	78	0	0
06	100	26	78	45	15
07	94	27	81	230	73
08	88	29	84	435	138
09	82	31	87	630	200
10	80	32	89	795	252
11	77	33	92	900	286
12	75	34	94	970	307
13	75	34	94	970	307
14	74	35	95	900	286
15	74	35	95	795	252
16	77	34	93	630	200
17	79	33	92	435	138
18	82	32	90	230	73
19	86	31	88	45	15
20	91	29	85	0	0
21	95	28	83	0	0
22	97	28	82	0	0
23	98	27	81	0	0
24	100	27	80	0	0

Table VII. Daily Cycle of Relative Humidity and Temperature Associated with the Worldwide Long-term High Relative Humidity with High Temperature Extreme (see 5.1.6.3). This cycle also represents the constant high humidity condition for the basic regional type (see 5.2.1.3). Solar radiation is negligible for this cycle.

TIME	R.H.	TEMPERATURE	
(LST)	(%)	(°C)	(°F)
01	100	24	75
02	100	24	75
03	100	24	75
04	100	24	75
05	100	24	75
06	100	24	75
07	98	24	75
08	97	24	75
09	95	24	75
10	95	24	75
11	95	24	75
12	95	24	75
13	95	24	75
14	95	24	75
15	95	24	75
16	95	24	75
17	95	24	75
18	95	24	75
19	97	24	75
20	98	24	75
21	100	24	75
22	100	24	75
23	100	24	75
24	100	24	75

Table VIII. Supplementary Low Density Values (with Typical Temperatures) for Terrain Elevations to 4572 m (see 5.1.19.2).

ELEVATION		DENSITY		TEMPERATURE	
(m)	(ft)	(kg/m^3)	(lb/ft^3)	(°C)	(°F)
		5%			
0	0	1.084	0.0677	46	115
305	1000	1.057	0.0660	45	113
914	3000	0.992	0.0619	42	108
1524	5000	0.934	0.0583	38	101
2134	7000	0.883	0.0551	33	93
2743	9000	0.838	0.0523	29	84
3353	11000	0.795	0.0496	24	75
3962	13000	0.753	0.0470	18	65
4572	15000	0.711	0.0444	13	55
		10%			
0	0	1.091	0.0681	45	113
305	1000	1.064	0.0664	44	111
914	3000	0.998	0.0623	41	106
1524	5000	0.939	0.0586	37	99
2134	7000	0.887	0.0554	33	91
2743	9000	0.843	0.0526	28	83
3353	11000	0.798	0.0498	23	73
3962	13000	0.754	0.0471	17	63
4572	15000	0.713	0.0445	12	53
		20%			
0	0	1.096	0.0684	43	110
305	1000	1.070	0.0668	43	109
914	3000	1.003	0.0626	39	103
1524	5000	0.945	0.0590	36	96
2134	7000	0.892	0.0557	32	89
2743	9000	0.847	0.0529	27	80
3353	11000	0.803	0.0501	22	71
3962	13000	0.759	0.0474	16	61
4572	15000	0.718	0.0448	11	52

Table IX. Hot Daily Cycle of Temperature, Relative Humidity, and Solar Radiation for the Basic Regional Type (see 5.2.1.1).

Recommended Values

Time	Ambient Air		Solar Radiation		R.H.	Dewpoint	
(LST)	°C	°F	W/m^2	Bph	%	°C	°F
0100	33	91	0	0	36	15	61
0200	32	90	0	0	38	16	60
0300	32	90	0	0	41	17	63
0400	31	88	0	0	44	17	62
0500	30	86	0	0	44	17	62
0600	30	86	55	18	44	17	62
0700	31	88	270	85	41	16	61
0800	34	93	505	160	34	16	61
0900	37	99	730	231	29	17	62
1000	39	102	915	291	24	14	58
1100	41	106	1040	330	21	14	58
1200	42	107	1120	355	18	13	55
1300	43	109	1120	355	16	11	52
1400	43	110	1040	330	15	11	52
1500	43	110	915	291	14	10	50
1600	43	110	730	231	14	10	50
1700	43	109	505	160	14	9	49
1800	42	107	270	85	14	9	49
1900	40	104	55	18	17	10	50
2000	38	100	0	0	20	11	51
2100	36	97	0	0	22	11	51
2200	35	95	0	0	25	12	54
2300	34	93	0	0	28	12	54
2400	33	91	0	0	33	14	58

Table X. Cold Daily Cycle of Temperature, Relative Humidity, and Solar Radiation for the Basic Regional Type (see 5.2.1.2).

Recommended Values

Time	Ambient Air		Solar Radiation		R.H.
(LST)	°C	°F	W/m^2	Bph	%
0100	-31	-24	Negligible during these conditions		Tending towards saturation
0200	-32	-25			
0300	-32	-25			
0400	-32	-25			
0500	-32	-25			
0600	-32	-25			
0700	-30	-22			
0800	-28	-18			
0900	-26	-15			
1000	-24	-12			
1100	-22	-8			
1200	-21	-5			
1300	-21	-5			
1400	-21	-6			
1500	-21	-6			
1600	-22	-8			
1700	-24	-11			
1800	-25	-13			
1900	-26	-15			
2000	-27	-17			
2100	-28	-19			
2200	-29	-21			
2300	-30	-22			
2400	-31	-24			

Table XI. Cold-Wet Daily Cycle of Temperature, Solar Radiation, and Relative Humidity for the Basic Regional Type (see 5.2.1.5).

Recommended Values

Time	Ambient Air		Solar Radiation		R.H.	Dewpoint	
(LST)	°C	°F	W/m^2	Bph	%	°C	°F
0100	-3	26	Negligible		100	-3	26
0200	-3	26	During		100	-3	26
0300	-4	25	These		100	-4	25
0400	-4	25	Conditions		100	-4	25
0500	-4	25			100	-4	25
0600	-4	25			100	-4	25
0700	-3	26			100	-3	26
0800	-2	28			100	-2	28
0900	-1	30			100	-1	30
1000	0	32			100	0	32
1100	1	33			100	1	33
1200	1	34			95	1	33
1300	2	35			95	1	34
1400	2	35			95	1	34
1500	2	35			95	1	34
1600	1	34			95	1	33
1700	1	33			100	1	33
1800	0	32			100	0	32
1900	-1	30			100	-1	30
2000	-2	29			100	-2	29
2100	-2	28			100	-2	28
2200	-3	27			100	-3	27
2300	-3	27			100	-3	27
2400	-3	26			100	-3	26

Table XII. Daily Cycle of Temperature, Relative Humidity, and Solar Radiation for the Cold Regional Type. Wind speed is less than 5 mps (see 5.2.3.1).

Recommended Values

Time	Ambient Air		Solar Radiation		R.H.
(LST)	°C	°F	W/m^2	Bph	%
0100	-46	-50	Negligible during these conditions		Tending towards saturation
0200	-46	-50			
0300	-46	-50			
0400	-46	-50			
0500	-46	-50			
0600	-46	-50			
0700	-45	-49			
0800	-44	-47			
0900	-43	-45			
1000	-41	-42			
1100	-39	-39			
1200	-37	-35			
1300	-37	-35			
1400	-37	-35			
1500	-37	-35			
1600	-38	-36			
1700	-39	-38			
1800	-39	-39			
1900	-41	-41			
2000	-42	-43			
2100	-43	-45			
2200	-44	-47			
2300	-44	-48			
2400	-45	-49			

Table XIII. Daily Cycle of Temperature and other Elements Associated with the 1-Percent High Temperature Value for the Coastal/Ocean Regional Type (see 5.2.5.1.2).

TIME	TEMPERATURE		R.H.	SOL. RAD.	
(LST)	(°C)	(°F)	(%)	(W/m^2)	(Bph)
01	33	91	51	0	0
02	32	89	53	0	0
03	31	87	55	0	0
04	30	86	60	0	0
05	29	85	64	0	0
06	29	84	67	186	59
07	30	86	61	419	133
08	33	92	51	649	206
09	38	100	38	848	269
10	41	105	32	987	313
11	43	110	28	1069	339
12	45	114	25	1103	350
13	47	116	22	1069	339
14	48	118	21	965	306
15	48	119	21	813	258
16	48	118	23	615	195
17	46	115	27	385	122
18	45	112	33	139	44
19	42	107	37	13	4
20	39	103	41	0	0
21	37	99	43	0	0
22	36	97	45	0	0
23	35	95	47	0	0
24	34	93	49	0	0

NOTE: Associated wind speed is approximately 3 m/s (9 ft/s) at each hour.

TABLE XIV. Cycle of Temperatures Associated with the 1-Percent Low Temperature Value for the Coastal/Ocean Regional Type (see 5.2.5.2.2).

TEMP	TIME									
	HOURS BEFORE AND AFTER							DAYS BEF. & AFT.		
	0	1	2	4	6	12	18	1	2	3
°F	-30	-29	-28	-26	-24	-19	-15	-12	-9	-7
°C	-34	-34	-33	-32	-31	-28	-26	-25	-23	-22

TABLE XV. Cycle of Humidity and Temperature Associated with the 1-Percent Low Absolute Humidity Value for the Coastal/Ocean Regional Type (see 5.2.5.4.2).

ABSOLUTE HUMIDITY	TIME									
	HOURS BEFORE AND AFTER							DAYS BEF. & AFT.		
	0	1	2	4	6	12	18	1	2	3
ppm	133	147	150	169	190	255	318	377	445	496
Frost Pt., °F	-32	-30	-30	-28	-26	-21	-17	-14	-11	-9
Frost Pt., °C	-35	-35	-34	-33	-32	-29	-27	-26	-24	-23
TEMP. °F	-30	-29	-28	-26	-24	-19	-17	-12	-9	-7
TEMP. °C	-34	-34	-33	-32	-31	-28	-26	-25	-23	-22

NOTE: Frost points and ppm computed from air temperatures in integral degrees Fahrenheit. Frost points in degrees Centigrade have been rounded to the nearest integral Centigrade degree.

Table XVI. Cycle of Humidity and Temperature Associated with the Low Absolute Humidity Long-Term Extremes for the Coastal/Ocean Regional Type (see 5.2.5.4.3)

		TIME									
PERIOD		HOURS BEFORE AND AFTER							DAYS BEF. & AFT.		
Yrs		0	1	2	4	6	12	18	1	2	3
10 years	ABSOLUTE HUMID., ppm	105	105	111	126	147	202	255	284	356	377
	FROST PT., °F	-36	-36	-35	-33	-30	-25	-21	-19	-15	-14
	FROST PT., °C	-38	-38	-37	-36	-35	-32	-29	-28	-26	-26
	TEMP., °F	-34	-34	-33	-31	-29	-23	-19	-17	-13	-12
	TEMP., °C	-37	-36	-36	-35	-34	-31	-28	-27	-25	-24
30 years	ABSOLUTE HUMID., ppm	87.1	92.8	98.6	111	126	169	214	240	301	318
	FROST PT., °F	-39	-38	-37	-35	-33	-28	-24	-22	-18	-17
	FROST PT., °C	-39	-39	-38	-37	-36	-33	-31	-30	-28	-27
	TEMP., °F	-37	-36	-35	-33	-31	-26	-22	-20	-16	-15
	TEMP., °C	-38	-38	-37	-36	-35	-32	-30	-29	-27	-26
60 years	ABSOLUTE HUMID., ppm	76.9	81.9	87.1	98.6	111	150	190	227	268	301
	FROST PT., °F	-41	-40	-39	-37	-35	-30	-26	-23	-20	-18
	FROST PT., °C	-40	-40	-39	-38	-37	-34	-32	-30	-29	-28
	TEMP., °F	-39	-38	-37	-35	-33	-28	-24	-21	-18	-16
	TEMP., °C	-39	-39	-38	-37	-36	-33	-31	-30	-28	-27

NOTE: Frost points and ppm computed from air temperatures in integral degrees Fahrenheit. Frost points in degrees Centigrade have been rounded to the nearest integral Centigrade degree.

Table XVII. Daily Cycle of Relative Humidity and Temperature (Including Solar Radiation) Associated with the 1-Percent High Relative Humidity with High Temperature Value for the Coastal/Ocean Regional Type (see 5.2.5.5.2).

TIME	R.H.	TEMPERATURE		SOL. RAD.	
(LST)	(%)	(°C)	(°F)	(W/m^2)	(Bph)
01	100	25	77	0	0
02	100	25	77	0	0
03	100	25	77	0	0
04	100	25	78	0	0
05	99	26	78	0	0
06	99	26	79	35	11
07	98	27	80	221	70
08	98	27	81	454	144
09	97	28	82	684	217
10	96	28	82	861	273
11	95	28	83	965	306
12	94	29	84	1012	321
13	93	29	84	965	306
14	93	29	84	883	280
15	93	29	84	731	232
16	93	29	84	511	162
17	94	29	84	268	85
18	95	29	83	35	11
19	96	28	83	0	0
20	97	28	82	0	0
21	98	27	81	0	0
22	99	26	79	0	0
23	99	26	78	0	0
24	100	25	77	0	0

Table XVIII. Daily Cycle of Relative Humidity and Temperature (Including Solar Radiation) Associated with the 1-Percent Low Relative Humidity with High Temperature Value for the Coastal/Ocean Regional Type (see 5.2.5.7.2).

TIME	R.H.	TEMPERATURE		SOL. RAD.	
(LST)	(%)	(°C)	(°F)	(W/m^2)	(Bph)
01	42	30	86	0	0
02	42	29	85	0	0
03	44	29	84	0	0
04	46	28	82	0	0
05	49	27	81	0	0
06	51	26	80	173	55
07	50	27	81	394	125
08	43	30	86	640	203
09	34	34	94	835	265
10	26	38	100	987	313
11	20	41	105	1081	343
12	16	43	109	1116	354
13	14	44	111	1069	339
14	12	45	113	965	306
15	12	45	113	813	258
16	13	45	113	580	184
17	14	44	111	359	114
18	18	42	108	129	41
19	25	40	103	0	0
20	31	36	97	0	0
21	36	34	93	0	0
22	39	32	90	0	0
23	41	31	88	0	0
24	41	31	87	0	0

Table XIX. Supplementary High Temperature Values for the Worldwide Air Environment to 80 km (see 5.3.1.1.2).

ALTITUDE		GEOMETRIC ALTITUDE						PRESSURE ALTITUDE					
		5%		10%		20%		5%		10%		20%	
(km)	(kft)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)
0	0	46	115	45	113	-	-	-	-	-	-	-	-
1	3.28	39	102	38	100	34	93	38	100	37	99	34	93
2	6.56	29	84	28	82	27	81	27	81	26	79	25	77
4	13.1	14	57	13	55	12	54	13	55	11	52	10	50
6	19.7	4	39	3	37	0	32	1	34	-1	30	-2	28
8	26.2	-6	21	-9	16	-11	12	-11	12	-13	9	-14	7
10	32.8	-17	1	-19	-2	-20	-4	-28	-19	-25	-13	-26	-15
12	39.4	-24	-11	-30	-22	-31	-24	-32	-26	-33	-27	-37	-35
14	45.9	-35	-31	-36	-33	-40	-40	-37	-35	-38	-36	-40	-40
16	52.5	-39	-38	-39	-38	-40	-40	-39	-38	-39	-38	-40	-40
18	59.1	-38	-36	-39	-38	-40	-40	-39	-38	-39	-38	-40	-40
20	65.6	-38	-36	-39	-38	-40	-40	-39	-38	-39	-38	-40	-40
22	72.2	-38	-36	-38	-36	-39	-38	-38	-36	-39	-38	-40	-40
24	78.7	-38	-36	-39	-38	-39	-38	-38	-36	-38	-36	-39	-38
26	85.3	-37	-35	-37	-35	-38	-36	-36	-33	-37	-35	-37	-35
28	91.9	-28	-18	-33	-27	-36	-33	-34	-29	-34	-29	-35	-31
30	98.4	-23	-9	-28	-18	-33	-27	-30	-22	-31	-24	-32	-26
35	115	-	-	-13	9	-	-	-	-	-	-	-	-
40	131	-	-	5	41	-	-	-	-	-	-	-	-
45	148	-	-	15	59	-	-	-	-	-	-	-	-
50	164	-	-	20	68	-	-	-	-	-	-	-	-
55	180	-	-	8	46	-	-	-	-	-	-	-	-
60	197	-	-	-3	27	-	-	-	-	-	-	-	-
65	213	-	-	3	37	-	-	-	-	-	-	-	-
70	230	-	-	4	39	-	-	-	-	-	-	-	-
75	246	-	-	-14	7	-	-	-	-	-	-	-	-
80	262	-	-	-19	-2	-	-	-	-	-	-	-	-

Table XX. Supplementary Low Temperature Values for the Worldwide Air Environment to 80 km (see 5.3.1.2.2).

ALTITUDE		GEOMETRIC ALTITUDE						PRESSURE ALTITUDE					
		5%		10%		20%		5%		10%		20%	
(km)	(kft)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)
0	0	-57	-70	-54	-65	-51	-60	-	-	-	-	-	-
1	3.28	-51	-60	-50	-58	-49	-56	-54	-65	-53	-63	-52	-62
2	6.56	-36	-33	-34	-29	-31	-24	-38	-36	-36	-33	-33	-27
4	13.1	-46	-51	-44	-47	-40	-40	-43	-45	-39	-38	-37	-35
6	19.7	-56	-69	-54	-65	-51	-60	-52	-62	-51	-60	-48	-54
8	26.2	-65	-85	-64	-83	-61	-78	-61	-78	-61	-78	-59	-74
10	32.8	-72	-98	-70	-94	-65	-85	-69	-92	-66	-87	-64	-83
12	39.4	-72	-98	-70	-94	-67	-89	-70	-94	-67	-89	-65	-85
14	45.9	-74	-101	-73	-99	-70	-94	-76	-105	-75	-103	-73	-99
16	52.5	-84	-119	-83	-117	-82	-116	-85	-121	-84	-119	-83	-117
18	59.1	-84	-119	-82	-116	-81	-114	-82	-116	-80	-112	-79	-110
20	65.6	-83	-117	-81	-114	-71	-114	-82	-116	-81	-114	-77	-107
22	72.2	-83	-117	-82	-116	-82	-116	-84	-119	-83	-117	-79	-110
24	78.7	-83	-117	-82	-116	-81	-114	-84	-119	-83	-117	-82	-116
26	85.3	-83	-117	-81	-114	-80	-112	-84	-119	-83	-117	-82	-116
28	91.9	-81	-114	-79	-110	-78	-108	-83	-117	-82	-116	-81	-114
30	98.4	-81	-114	-79	-110	-76	-105	-83	-117	-81	-114	-79	-110
35	115	-	-	-73	-99	-	-	-	-	-	-	-	-
40	131	-	-	-62	-80	-	-	-	-	-	-	-	-
45	148	-	-	-54	-65	-	-	-	-	-	-	-	-
50	164	-	-	-49	-56	-	-	-	-	-	-	-	-
55	180	-	-	-52	-62	-	-	-	-	-	-	-	-
60	197	-	-	-52	-62	-	-	-	-	-	-	-	-
65	213	-	-	-75	-103	-	-	-	-	-	-	-	-
70	230	-	-	-90	-130	-	-	-	-	-	-	-	-
75	246	-	-	-110	-166	-	-	-	-	-	-	-	-
80	262	-	-	-133	-207	-	-	-	-	-	-	-	-

Table XXI. Supplementary High Absolute Humidity Values for the Worldwide Air Environment to 8 km (see 5.3.1.3.2).

ALTITUDE		5%			10%			20%		
		MIX. RAT.	DEWPOINT		MIX. RAT.	DEWPOINT		MIX. RAT.	DEWPOINT	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
		GEOMETRIC ALTITUDE								
0	0	28×10^3	30	86	26×10^3	29	84	25×10^3	28	83
1	3.28	26	27	81	24	26	79	22	25	77
2	6.56	21	22	72	20	21	70	19	20	68
4	13.1	16	13	55	14	11	52	12	9	48
6	19.7	8.3	0	32	7.7	-1	30	7.1	-2	28
8	26.2	4.7	-11	12	4.3	-12	10	4.0	-13	9
		PRESSURE ALTITUDE								
1	3.28	26	27	81	24	26	79	22	25	77
2	6.56	21	22	72	20	21	70	18	19	66
4	13.1	15	12	54	13	10	50	11	8	46
6	19.7	7.1	-2	28	6.6	-3	27	6.1	-4	25
8	26.2	3.7	-14	7	3.4	-15	5	3.1	-16	3

Table XXII. Supplementary Low Absolute Humidity Values for the Worldwide Air Environment to 8 km (see 5.3.1.4.2).

ALTITUDE		5%			10%			20%		
		MIX. RAT.	FROST PT.		MIX. RAT.	FROST PT.		MIX. RAT.	FROST PT.	
(km)	(kft)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)	(ppm)	(°C)	(°F)
		GEOMETRIC ALTITUDE								
0	0	-	-	-	-	-	-	-	-	-
1	3.28	71	-42	-44	89	-40	-40	124	-37	-35
2	6.56	56	-45	-49	80	-42	-44	112	-39	-38
4	13.1	31	-52	-62	35	-51	-60	45	-49	-56
6	19.7	12	-61	-78	14	-60	-76	16	-59	-74
8	26.2	4.6	-70	-94	5.3	-69	-92	6.1	-68	-90
		PRESSURE ALTITUDE								
1	3.28	71	-42	-44	89	-40	-40	124	-37	-35
2	6.56	63	-44	-47	90	-41	-42	126	-38	-36
4	13.1	35	-51	-60	45	-49	-56	57	-47	-53
6	19.7	19	-58	-72	21	-57	-71	24	-56	-69
8	26.2	7.1	-67	-89	8.2	-66	-87	9.4	-65	-85

Table XXIII. Supplementary High Wind Speed Values for the Worldwide Air Environment to 80 km (see 5.3.1.7.2).

ALTITUDE		GEOMETRIC ALTITUDE						PRESSURE ALTITUDE					
		5%		10%		20%		5%		10%		20%	
(km)	(kft)	(m/s)	(ft/s)	(m/s)	(ft/s)	(m/s)	(ft/s)	(m/s)	(ft/s)	(m/s)	(ft/s)	(m/s)	(ft/s)
0	0	18	61	17	56	-	-	-	-	-	-	-	-
1	3.28	30	98	26	85	22	72	29	95	26	85	21	69
2	6.56	34	112	28	92	23	75	35	115	27	89	23	75
4	13.1	45	148	37	121	33	108	42	138	36	118	33	108
6	19.7	58	190	52	171	48	157	55	180	51	167	47	154
8	26.2	75	246	70	230	62	203	74	243	70	230	63	207
10	32.8	89	292	84	276	78	256	90	295	84	276	78	256
12	39.4	95	312	89	292	84	276	94	308	88	289	82	269
14	45.9	81	266	77	253	71	233	79	259	75	246	69	226
16	52.5	69	226	66	217	57	187	68	223	65	213	56	184
18	59.1	56	184	53	174	48	157	53	174	46	151	41	135
20	65.6	56	184	52	171	44	144	55	180	51	167	43	141
22	72.2	65	213	62	203	52	171	63	207	60	197	50	164
24	78.7	76	249	69	226	61	200	75	246	68	223	60	197
26	85.3	80	262	74	243	65	213	79	259	71	233	62	203
28	91.9	91	299	84	276	72	236	84	276	74	243	65	213
30	98.4	98	322	89	292	77	253	89	292	80	262	73	240
35	115	126	413	113	371	-	-	-	-	-	-	-	-
40	131	163	535	144	472	-	-	-	-	-	-	-	-
45	148	182	597	167	548	-	-	-	-	-	-	-	-
50	164	186	610	175	574	-	-	-	-	-	-	-	-
55	180	185	607	170	558	-	-	-	-	-	-	-	-
60	197	158	518	146	479	-	-	-	-	-	-	-	-
65	213	151	495	140	459	-	-	-	-	-	-	-	-
70	230	145	476	133	436	-	-	-	-	-	-	-	-
75	246	126	413	115	377	-	-	-	-	-	-	-	-
80	262	125	410	114	374	-	-	-	-	-	-	-	-

Table XXIV. Supplementary One-km Wind Shear Values up to 30 km and 10-km values above- for the Worldwide Air Environment to 70 km (see 5.3.1.8.2).

ALTITUDE		GEOMETERIC ALTITUDE			PRESSURE ALTITUDE		
		5%	10%	20%	5%	10%	20%
(km)	(kft)	(sec^{-1})	(sec^{-1})	(sec^{-1})	(sec^{-1})	(sec^{-1})	(sec^{-1})
0	0	-	-	-	-	-	-
1	3.28	0.019	0.017	0.013	0.019	0.017	0.013
2	6.56	0.016	0.015	0.012	0.016	0.015	0.012
4	13.1	0.018	0.015	0.013	0.018	0.015	0.013
6	19.7	0.022	0.018	0.014	0.023	0.019	0.014
8	26.2	0.024	0.020	0.017	0.024	0.020	0.017
10	32.8	0.020	0.018	0.017	0.019	0.017	0.016
12	39.4	0.022	0.017	0.014	0.021	0.017	0.014
14	45.9	0.029	0.020	0.018	0.029	0.019	0.018
16	52.5	0.028	0.021	0.019	0.030	0.022	0.019
18	59.1	0.024	0.017	0.014	0.024	0.017	0.014
20	65.6	0.020	0.014	0.012	0.020	0.014	0.012
22	72.2	0.020	0.015	0.013	0.020	0.015	0.013
24	78.7	0.017	0.013	0.010	0.017	0.014	0.011
26	85.3	0.018	0.015	0.010	0.020	0.015	0.010
28	91.9	0.028	0.017	0.012	0.026	0.015	0.010
30	98.4	0.020	0.016	0.013	0.020	0.016	0.013
LAYER ALTITUDES		GEOMETRIC ALTITUDE			PRESSURE ALTITUDE DATA NOT AVAILABLE FOR LAYERS.		
		5%	10%				
(km)	(kft)	(sec^{-1})	(sec^{-1})				
30 to 40	98.4 to 131	0.018	0.015				
40 to 50	131 to 164	0.021	0.017				
50 to 60	164 to 197	0.024	0.019				
60 to 70	197 to 230	0.085	0.076				

Note. Since shear is the change in velocity through a specific thickness, the units are per time period.

Table XXV. Supplementary High Pressure Values for the Worldwide Air Environment to 80 km (see 5.3.1.12.2).

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE					
		5%		10%		20%	
(km)	(kft)	(mb)	(in Hg)	(mb)	(in Hg)	(mb)	(in Hg)
0	0	-	-	-	-	-	-
1	3.28	918	27.1	917	27.1	916	27.0
2	6.56	816	24.1	815	24.1	814	24.0
4	13.1	641	18.9	640	18.9	639	18.9
6	19.7	497	14.7	496	14.6	495	14.6
8	26.2	383	11.3	382	11.2	381	11.2
10	32.8	292	8.62	291	8.59	290	8.56
12	39.4	224	6.61	223	6.59	222	6.56
14	45.9	166	4.90	165	4.87	164	4.84
16	52.5	122	3.60	121	3.57	120	3.54
18	59.1	87	2.57	86	2.54	85	2.51
20	65.6	64	1.89	63	1.86	62	1.83
22	72.2	44	1.30	44	1.30	43	1.27
24	78.7	33	0.974	32	0.944	32	0.944
26	85.3	25	0.738	24	0.709	24	0.709
28	91.9	19	0.561	18	0.532	18	0.532
30	98.4	14	0.413	14	0.413	13	0.384
35	115	-	-	7.4	0.219	-	-
40	131	-	-	3.9	0.115	-	-
45	148	-	-	2.2	0.065	-	-
50	164	-	-	1.2	0.035	-	-
55	180	-	-	0.66	0.019	-	-
60	197	-	-	0.35	0.010	-	-
65	213	-	-	0.18	0.0053	-	-
70	230	-	-	0.081	0.0024	-	-
75	246	-	-	0.034	0.0010	-	-
80	262	-	-	0.014	0.00041	-	-

Table XXVI. Supplementary Low Pressure Values for the Worldwide Air Environment to 80 km (see 5.3.1.13.2).

GEOMETRIC ALTITUDE		ATMOSPHERIC PRESSURE					
		5%		10%		20%	
(km)	(kft)	(mb)	(in Hg)	(mb)	(in Hg)	(mb)	(in Hg)
0	0	-	-	-	-	-	-
1	3.28	856	25.3	861	25.4	868	25.6
2	6.56	748	22.1	752	22.2	757	22.4
4	13.1	558	16.5	565	16.7	569	16.8
6	19.7	413	12.2	418	12.3	422	12.5
8	26.2	303	8.95	306	9.04	309	9.12
10	32.8	221	6.53	223	6.59	225	6.64
12	39.4	158	4.67	160	4.72	162	4.78
14	45.9	113	3.34	115	3.40	117	3.46
16	52.5	80	2.36	82	2.42	84	2.48
18	59.1	57	1.68	58	1.71	59	1.74
20	65.6	42	1.24	43	1.27	45	1.33
22	72.2	30	0.886	31	0.915	32	0.945
24	78.7	24	0.709	27	0.797	28	0.827
26	85.3	18	0.532	20	0.591	21	0.620
28	91.9	13	0.384	15	0.443	16	0.472
30	98.4	10	0.295	11	0.325	12	0.354
35	115	-	-	3.4	0.100	-	-
40	131	-	-	1.7	0.050	-	-
45	148	-	-	0.79	0.023	-	-
50	164	-	-	0.39	0.012	-	-
55	180	-	-	0.18	0.0053	-	-
60	197	-	-	0.090	0.0027	-	-
65	213	-	-	0.042	0.0012	-	-
70	230	-	-	0.020	0.00059	-	-
75	246	-	-	0.011	0.00032	-	-
80	262	-	-	0.0047	0.00014	-	-

Table XXVII. Supplementary High Density Values for the Worldwide Air Environment to 80 km (see 5.3.1.14.2).

ALTITUDE		GEOMETERIC ALTITUDE						PRESSURE ALTITUDE							
		5%		10%		20%		5%		10%		20%		EXP*	
(km)	(kft)	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3	kg/ m^3	1b/ ft^3
0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	3.28	130	812	129	805	128	799	132	824	131	818	130	812	-2	-4
2	6.56	114	712	113	705	112	699	117	730	116	725	115	718	-2	-4
4	13.1	882	551	876	547	869	542	930	581	924	577	915	571	-3	-4
6	19.7	688	430	686	428	681	425	742	463	737	460	733	458	-3	-4
8	26.2	548	342	546	341	542	338	584	365	581	363	578	361	-3	-4
10	32.8	432	270	430	267	426	266	447	279	445	279	442	276	-3	-4
12	39.4	340	212	339	212	338	211	334	209	328	205	325	203	-3	-4
14	45.9	266	166	266	166	265	165	246	154	245	153	244	152	-3	-4
16	52.5	203	127	202	126	201	125	191	119	190	119	188	117	-3	-4
18	59.1	147	918	145	905	144	899	138	862	138	862	137	855	-3	-5
20	65.6	105	655	101	631	97	606	99	618	99	618	98	612	-3	-5
22	72.2	730	456	720	449	700	437	730	456	720	449	720	449	-4	-5
24	78.7	570	356	560	350	560	350	530	331	530	331	520	325	-4	-5
26	85.3	430	268	420	262	420	262	400	250	400	250	390	243	-4	-5
28	91.9	280	175	280	175	270	169	290	181	290	181	280	175	-4	-5
30	98.4	210	131	210	131	200	125	220	131	210	131	210	131	-4	-5
35	115	-	-	102	637	-	-	-	-	-	-	-	-	-4	-6
40	131	-	-	503	314	-	-	-	-	-	-	-	-	-5	-6
45	148	-	-	267	167	-	-	-	-	-	-	-	-	-5	-6
50	164	-	-	146	911	-	-	-	-	-	-	-	-	-5	-7
55	180	-	-	847	529	-	-	-	-	-	-	-	-	-6	-7
60	197	-	-	477	298	-	-	-	-	-	-	-	-	-6	-7
65	213	-	-	267	167	-	-	-	-	-	-	-	-	-6	-7
70	230	-	-	142	886	-	-	-	-	-	-	-	-	-6	-8
75	246	-	-	668	417	-	-	-	-	-	-	-	-	-7	-8
80	262	-	-	304	190	-	-	-	-	-	-	-	-	-7	-8

NOTE: EXP. is the power of 10 to which these numbers should be raised. For instance, at 1 km above sea level and 5 percent risk, the density is equal to 130 x 10^{-2} kg/m^3 (812 x 10^{-4} 1b/ft^3), that is 1.30 kg/m^3 (0.0812 1b/ft^3).

Table XXVIII. Supplementary Low Density Values for the Worldwide Air Environment to 80 km (see 5.3.1.15.2).

ALTITUDE		GEOMETERIC ALTITUDE						PRESSURE ALTITUDE							
		5%		10%		20%		5%		10%		20%		EXP.	
(km)	(kft)	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3	kg/m^3	1b/ft^3
0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	3.28	105	655	105	655	105	655	105	655	105	655	105	655	-2	-4
2	6.56	920	574	924	577	928	579	931	581	935	584	942	588	-3	-4
4	13.1	788	486	780	487	782	488	768	479	769	480	771	481	-3	-4
6	19.7	632	395	634	396	635	396	613	383	614	383	616	385	-3	-4
8	26.2	480	300	484	302	499	312	487	304	489	305	490	306	-3	-4
10	32.8	350	218	354	221	362	226	386	241	386	241	388	242	-3	-4
12	39.4	259	162	261	163	266	166	289	180	289	180	289	180	-3	-4
14	45.9	192	120	193	120	197	123	211	132	211	132	211	132	-3	-5
16	52.5	139	868	140	874	145	905	154	961	154	961	154	961	-3	-5
18	59.1	985	615	998	623	105	655	112	699	112	699	112	699	-3	-5
20	65.6	700	437	712	444	760	474	820	512	820	512	820	512	-4	-5
22	72.2	495	309	500	312	530	331	590	368	590	368	590	368	-4	-5
24	78.7	360	225	370	231	370	231	430	268	430	268	430	268	-4	-5
26	85.3	240	150	240	150	250	156	220	137	220	137	240	150	-4	-5
28	91.9	150	936	150	936	160	999	140	874	140	874	150	936	-4	-6
30	98.4	121	755	124	774	130	812	90	562	90	562	90	562	-4	-6
35	115	-	-	550	343	-	-	-	-	-	-	-	-	-5	-6
40	131	-	-	223	139	-	-	-	-	-	-	-	-	-5	-6
45	148	-	-	108	674	-	-	-	-	-	-	-	-	-5	-7
50	164	-	-	544	340	-	-	-	-	-	-	-	-	-6	-7
55	180	-	-	258	161	-	-	-	-	-	-	-	-	-6	-7
60	197	-	-	125	780	-	-	-	-	-	-	-	-	-6	-8
65	213	-	-	583	364	-	-	-	-	-	-	-	-	-7	-8
70	230	-	-	306	191	-	-	-	-	-	-	-	-	-7	-8
75	-46	-	-	143	893	-	-	-	-	-	-	-	-	-8	-9
80	262	-	-	600	375	-	-	-	-	-	-	-	-	-8	-9

NOTE: EXP. is the power of 10 to which these numbers should be raised. For instance, at 1 km above sea level and 5 percent risk, the density is equal to 105 x 10^{-2} kg/m^3 (655 x 10^{-4} 1b/ft^3), that is, 1.05 kg/m^3 (0.0655 1b/ft^3).

Table XXIX. Model Profile for the 42-Minute World Record Surface Rainfall Rate (see 5.3.2.5.1).

Geometric ALT.	PRECIP RATE	PRECIP WATER	CLOUD WATER	Drop Concentrations (per m^3)					
				Diameter Size Intervals (mm)					
(km)	(mm/min)	(g/ m^3)	(g/ m^3)	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4-	4.5-5.4-	5.5-6.4
0	7.2	15.8	0	2779	1595	440	91	16	3
2	7.2	15.8	3.4	2779	1595	440	91	16	3
4	7.2	15.8	3.9	2779	1595	440	91	16	3
6	7.2	15.8	4.0	2779	1595	440	91	16	3
8	5.3	12.0	2.7	2535	1323	329	61	10	1
10	3.7	8.5	1.9	2251	1038	226	37	5	<1
12	2.5	6.1	1.3	1984	801	151	21	3	<1
14	1.6	4.0	0.8	1683	571	89	10	1	<1
16	0.8	2.1	0.4	1291	329	38	3	<1	<1
18	0.6	1.6	0.1	1135	251	25	2	<1	<1
20	0	0	0	0	0	0	0	0	0

NOTES: (1) All rain rates are surface equivalent intensities.

(2) Distributions are all liquid below 4.5 km, mostly liquid 4.5-6.0 km and nearly all ice above 7.0 km. Numbers are in terms of equivalent raindrops for solid precipitation.

(3) Cloud-Precipitation water division is at D = 100 µm. Cloud water includes ice with melted diameters D < 100 µm.

Table XXX. Model Profile for the 0.1-Percent Surface Rainfall Rate (see 5.3.2.5.2).

Geometric ALT.	PRECIP RATE	PRECIP WATER	CLOUD WATER	Drop Concentrations (per m^3)					
				Diameter Size Intervals (mm)					
(km)	(mm/min)	(g/ m^3)	(g/ m^3)	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4
0	1.40	3.5	0	1608	520	77	8	<1	<1
2	1.40	3.5	3.0	1608	520	77	8	<1	<1
4	1.40	3.5	3.4	1608	520	77	8	<1	<1
6	1.40	3.5	3.5	1608	520	77	8	<1	<1
8	1.04	2.7	2.4	1435	410	53	5	<1	<1
10	0.71	1.9	1.7	1239	302	33	3	<1	<1
12	0.49	1.4	1.1	1060	218	20	1	<1	0
14	0.31	0.9	0.7	867	142	10	<1	<1	0
16	0.15	0.5	0.4	628	71	3	<1	0	0
18	0.11	0.4	0.1	537	51	2	<1	0	0
20	0	0	0	0	0	0	0	0	0

NOTES: (1) All rain rates are surface equivalent intensities.

(2) Distributions are all liquid below 4.5 km, mostly liquid 4.5-6.0 km and nearly all ice above 7.0 km. Numbers are in terms of equivalent raindrops for solid precipitation.

(3) Cloud-Precipitation water division is at D = 100 µm. Cloud water includes ice with melted diameters D < 100 µm.

Table XXXI. Model Profile for the 0.01-Percent Surface Rainfall Rate (see 5.3.2.5.2).

Geometric ALT.	PRECIP RATE	PRECIP WATER	CLOUD WATER	Drop Concentrations (per m^3)					
				Diameter Size Intervals (mm)					
(km)	(mm/min)	(g/m^3)	(g/m^3)	0.5-1.4	1.5-2.4	2.5-3.4	3.5-4.4	4.5-5.4	5.5-6.4
0	2.80	6.7	0	2057	863	170	25	3	<1
2	2.80	6.7	3.4	2057	863	170	25	3	<1
4	2.80	6.7	3.9	2057	863	170	25	3	<1
6	2.80	6.7	4.0	2057	863	170	25	3	<1
8	2.07	5.1	2.7	1853	696	122	16	2	<1
10	1.43	3.6	1.9	1620	528	79	9	<1	<1
12	0.98	2.6	1.3	1404	392	50	5	<1	<1
14	0.62	1.7	0.8	1166	266	27	2	<1	<1
16	0.31	0.9	0.4	867	142	10	<1	<1	0
18	0.22	0.7	0.1	750	104	6	<1	<1	0
20	0	0	0	0	0	0	0	0	0

NOTES: (1) All rain rates are surface equivalent intensities.

(2) Distributions are all liquid below 4.5 km, mostly liquid 4.5-6.0 km and nearly all ice above 7.0 km. Numbers are in terms of equivalent raindrops for solid precipitation.

(3) Cloud-Precipitation water division is at D = 100 µm. Cloud water includes ice with melted diameters D < 100 µm.

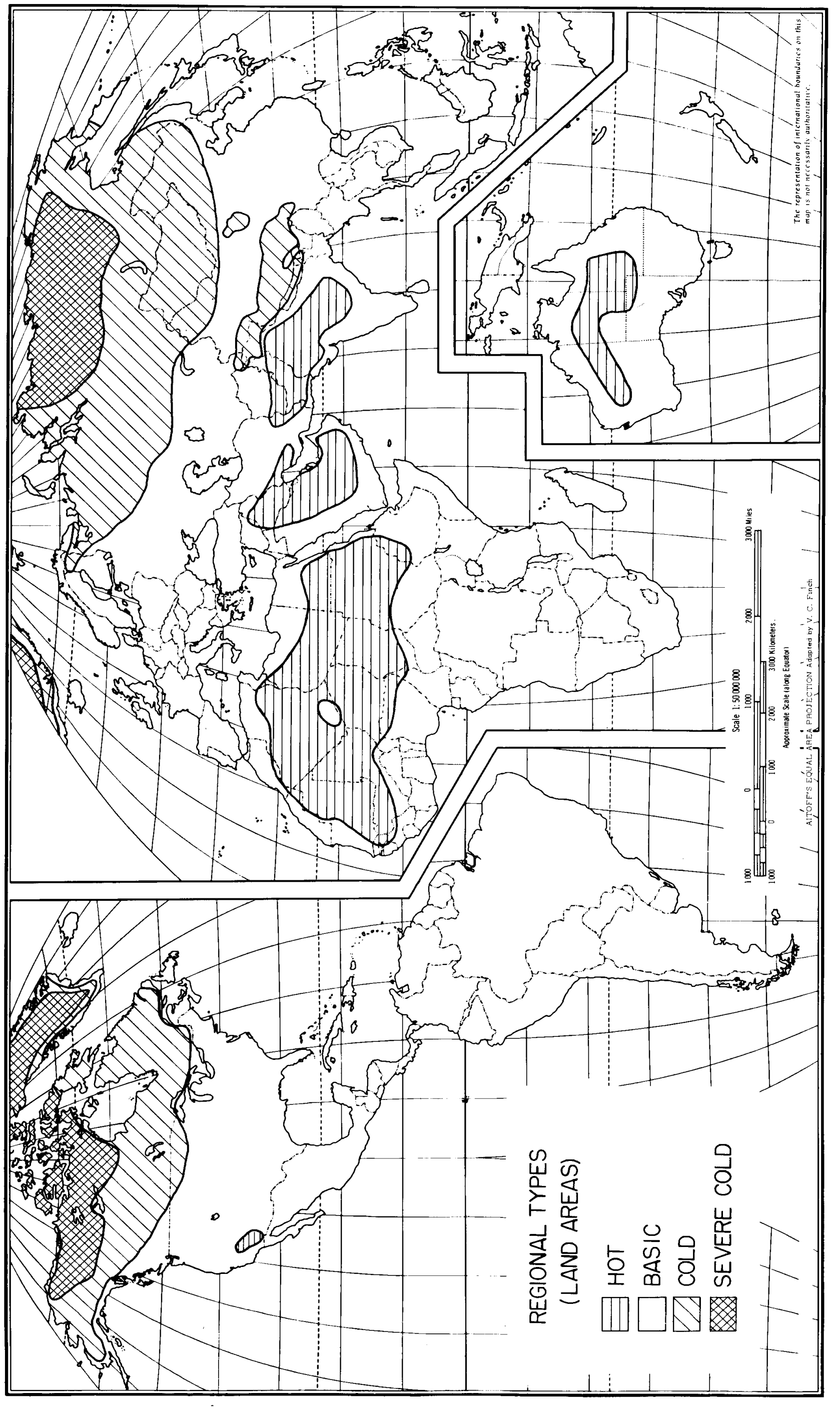

Figure 1. Location of Climatic Regional Types for the Land Areas of the World (Section 5.2)

SUPPLEMENTARY CLIMATIC INFORMATION

10. GENERAL

10.1 Scope. This appendix provides additional information for the climatic elements in section 5 primarily in the form of references to scientific reports, journal articles, and other supporting documentation. This appendix is not a mandatory part of the standard. The information presented here is intended for guidance only.

10.2 Application. The discussion and references in this appendix are intended to:

(a) Document the sources of the climatic information in section 5,
(b) Clarify questions that might arise regarding the derivation of values, and
(c) Provide sources of information on the climatic elements in section 5 to facilitate trade-off analyses.

20. REFERENCED DOCUMENTS

Not applicable.

30. DEFINITIONS

Not applicable.

40. GENERAL INFORMATION

The climatic information and references to technical reports in this appendix are provided in the same order of presentation as section 5. Section 40.1 supplements the data provided in 5.1, Worldwide Surface Environment; 40.2 supplements 5.2,Regional Surface Environments; 40.3 supplements 5.3, Worldwide Air Environment to 80 km.

It should be noted that most of the referenced reports in this appendix provided inputs to MIL-STD-210B and still remain valid for this revision. However, long-term climatic extremes presented in this revision were converted from the withstanding values in 210B. The referenced reports for long-term climatic extremes discuss values in terms of the previously used withstanding values. Long-term extremes for 10, 30, and 60 years are approximately equivalent to withstanding values which have a 10% risk during estimated durations of exposure of 2, 5, and 10 years, respectively.

40.1 Supplement to Worldwide Surface Environment. Unless otherwise indicated, information on recorded extremes can be found in the following publication:

(1) Riordan, P. and Bourget, P.G. (1985) World Weather Extremes, ETL-0416, U.S. Army Topographic Laboratories, Ft. Belvoir, VA.

40.1.1 High Temperature. Worldwide spatial distributions of high temperatures occurring 1, 5, and 10 percent of the time during the warmest month are available from the following two publications:

(2) Tattelman, P. and Kantor, A.J. (1976) Atlas of Probabilities of Surface Temperature Extremes: Part I - Northern Hemisphere, AFGL-TR-76-0084, Environmental Research Papers, No. 557, ADA027640.

(3) Tattelman, P. and Kantor, A.J. (1976) Atlas of Probabilities of Surface Temperature Extremes: Part II - Southern Hemisphere, AFGL-TR-77-OO01, Environmental Research Papers, No. 588, ADAO38237.

These reports were used to determine percentile values in 5.1.1 which remain the same as those in MIL-STD-210B. The derivation of the daily high temperature cycle and the long-term climatic extremes is described in:

(4) Gringorten, 1.1., and Sissenwine, N. (1970) Unusual Extremes and Diurnal Cycles of Desert Heat Loads, AFCRL-TR-70-0332, Environmental Research Papers, No. 323, AD711366.

40.1.2 Low Temperature. Worldwide spatial distributions of low temperatures occurring 1, 5, 10, and 20 percent of the time during the coldest month are available from publications (2) and (3) in 40.1.1. These reports support the percentile values of low temperature. Durations of cold temperature and long-term extremes are discussed in:

(5) Gringorten, 1.1. (1970) Duration and Unusual Extremes of Cold, AFCRL-TR-70-0381, Environmental Research Papers, No. 326, AD710611.

40.1.3 High Absolute Humidity. A discussion of high humidity for engineering design can be found in:

(6) Sissenwine, N. (1953) Maximum Humidity in Engineering Design, AFCRL-TR-53-61, Air Force Surveys in Geophysics, No. 49.

Other publications supporting and supplementing high absolute humidity values, including the highest recorded, are:

(7) Salmela, H., and Grantham, D.D. (1972) Diurnal Cycles of High Absolute Humidity at the Earth's Surface, AFCRL-TR-72-0587, Environmental Research Papers, No. 416, AD753078.

(8) Gringorten, 1.1., Salmela, HA., Solomon, I., and Sharp, J. (1966) Atmospheric Humidity Atlas - Northern Hemisphere, AFCRL-TR-66-0621, Air Force Surveys in Geophysics No. 186, AD642429.

(9) Grantham, D.D., and Sissenwine, N. (1970) High Humidity Extremes in the Upper Air, AFCRL-TR-70-0563, Environmental Research Papers, No. 333, AD715894.

(10) Watt, G.A. (1968) A comparison of effective temperatures at Bahrain and Sharjah, Met. Mag. 97 (No. 1155):320-313.

(11) Moon, P. (1940) Proposed standard radiation curves for engineering use. J. Franklin Inst. 230.

40.1.4 Low Absolute Humidity. The data and discussion in 5.1.4 are considered complete.

40.1.5 High Temperature and High Humidity. All of the information provided for this combination was taken from:

(12) Cormier, R.V. (1974) World-Wide Extremes of Humidity with Temperatures Between **850** and 120^0F, AFCRL-TR-74-0603, Air Force Surveys in Geophysics, No. 296, ADA007676.

40.1.6 High Relative Humidity with High Temperature. Data presented for this combination, including the highest recorded value, were taken from:

(13) Dodd, A.V. (1969) Areal and Temporal Occurrence of High Dew Points and Associated Temperatures, TF-70-4-ES, U.S. Army Natick Laboratories, Natick, Mass.

(14) Department of the Army (1979) Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions, Army Regulation AR 70-38, 1 August 1979, HQ Dept. of the Army, Washington, D.C.

40.1.7 High Relative Humidity with Low Temperature. The data and discussion in 5.1.7 are considered complete.

40.1.8 Low Relative Humidity with High Temperature. This combination occurs with the high temperature cycle discussed in reference (4) in 40.1.1.

40.1.9 Low Relative Humidity with Low Temperature. Not available.

40.1.10 Wind Speed. All of the wind speed data, including the highest recorded extremes, were taken from the following:

(15) Sissenwine, N., Tattelman, P.1., Grantham, D.D., and Gringorten, 1.1. (1973) Extreme Wind Speeds, Gustiness and Variations with Height for MIL-STD-210B, AFCRL-TR-73-0560, AF Surveys in Geophysics No. 273, AD774044.

The coefficients used in the method for estimating the variation of wind with height above the surface recommended in this report resulted in the problems discussed in 5.1.10.2. Nevertheless, the section on the behavior of extreme wind speeds and gusts with height provides useful information that may be pertinent in the design of surface structures sensitive to wind at large heights above the ground.

More information on surface wind gustiness is available from the following:

(16) Tattelman, P. (1975) Surface Gustiness and Wind Speed Range as a Function of Time Interval and Mean Wind Speed, Jour. of Appl. Meteor., Vol. 14, No. 7, October 1975, pp 1271-1276.

40.1.11 Rainfall Rate. Worldwide spatial distributions of 1-min rainfall rates occurring 0.01, 0.05, 0.10, 0.50 and 1.0 percent of the time during mid-season months and also for the worst month are available from the following two publications:

(17) Tattelman, P. and Grantham, D.D. (1983) Northern Hemisphere Atlas of 1-Minute Rainfall Rates, AFGL-TR-83-0267, Air Force Surveys in Geophysics No. 444, ADA145411.

(18) Tattelman, P. and Grantham, D.D. (1983) Southern Hemisphere Atlas of 1-Minute Rainfall Rates, AFGL-TR-83-0285, Air Force Surveys in Geophysics No. 443, ADA145421.

These were used to determine the most severe areas of the world for intense rainfall. Percentile values of rainfall rate for these areas, and associated drop size distributions for these and the record 1 and 42 min rates were taken from the following:

(19) Tattelman, P., and Willis, P.T. (1985) Model Vertical Profiles of Extreme Rainfall Rate, Liquid Water Content, and Drop-Size Distribution, AFGL-TR-85-0200, Environmental Research Papers, No. 928, ADA164424.

Rainfall amounts provided for the long-term extremes were taken from:

(20) Lenhard, R.W., and Sissenwine, N. (1973) Extremes of 1, 12, and 24-Hour Rain for MIL-STD-210B, AFCRL-TR-73-0329, Air Force Survey in Geophysics No. 266, AD766210.

40.1.12 Blowing Snow. Information for this climatic condition, including highest recorded values, was taken from:

(21) Mellor M. (1965) Blowing Snow, Cold Regions Science and Engineering, Part III, Section A3c, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

40.1.13 Snowload: Values provided in 5.1.13 were determined from the information provided in reference (1) and from the following:

(22) Boyd, D.W. (1961) Maximum Snow Depths and Snow Loads on Roofs in Canada, Research Paper No. 142, Div. Bldg. Res., National Research Council, Ottawa, Canada.

(23) Ludlum, D. (ed.) (1971) New U.S. seasonal snowfall record, Weatherwise 24, 4:163.

(24) U.S. Weather Bureau (1951) Determination of Snow-Loads for Building Construction, Div. Climatological and Hydrological Services, Washington, D.C.

(25) Environmental Science Services Administration (1966) Some Outstanding Snow-storms, LS 6211, Environmental Data Service, Washington, D.C.

(26) Lutes, D.A. (1972) Recommended Design Criteria for Roof Snow Loads as Outlined in the National Building Code of Canada (Letter Concerning). Personal Communication (1-18, 756, M43-13-27, M43-3-182), 14 March 1972, Building Structures Section, National Research Council of Canada, Ottawa.

Additional information on snowfall extremes are available from:

(27) Ludlum, D.M., Ed. (1970) Extremes of snowfall: United States and Canada, Weatherwise 23, 6:286-294.

(28) (28) Riordan, P. (1973) Extreme 24-Hour Snowfalls in the United States: Accumulation, Distribution, and Frequency, U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA., Special Report ETL-SR-73-4.

40.1.14 Ice Accretion. Much of the information used to estimate values in 5.1.14.3 were taken from unpublished sources. Most notable of these were engineer's reports describing the amount of ice and concurrent winds that caused structural failures (usually collapsed towers) in coastal areas of Canada from Nova Scotia and eastern Quebec to southern Baffin Island. Although they were not objectively derived, the concurrent ice and wind loads herein reflect the severity of icing conditions described in many such reports. Additional information on surface structural icing is available in the following:

(29) Minsk, L.D., Editor (1983) Atmospheric Icing of Structures, Proceedings of the First International Workshop, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, Special Report 83-17, 366 pp.

(30) Tattelman, P. and Gringorten, 1.1. (1973) Estimated Glaze Ice and Wind Loads for the Contiguous United States, AFCRL-TR-73-0646, Air Force Surveys in Geophysics No. 277, AD775068.

40.1.15 Hail Size. Information on the largest hailstone on record can be found in:

(31) Ludlum, D. (ed.) (1971) The "New Champ" Hailstone, Weatherwise 24, 4:151.

The method used to derive the hailstone statistics is described in:

(32) Gringorten, 1.1. (1972) Hailstone Extremes for Design, AFCRL-TR-72-0081, Air Force Surveys in Geophysics No. 238, AD743831.

40.1.16 High Atmospheric Pressure. It is presumed that designing for the highest recorded extreme does not present any design problems. Extremes of high atmospheric pressure are discussed in:

(33) Court, A. (1969) Improbable pressure extreme: 1070 mb, Bull. Am. Meteorol. Soc. 50, 4:248-250.

(34) Loewe, F. (1969) More on "Improbable pressure extreme: 1070 mb", Bull.Am. Meteorol. Soc. 50, 10:804-806.

40.1.17 Low Atmospheric Pressure. Discussion in 5.1.17 is considered complete.

40.1.18 High Atmospheric Density. Discussion in 5.1.18 is considered complete.

40.1.19 Low Atmospheric Density. Information provided for this climatic element was taken from:

(35) Cormier, R.V. (1972) Extremes of Low Atmospheric Density Near the Ground for Elevations up to 15,000 ft for MIL-STD-210B, AFCRL-TR-72-0711, Air Force Surveys in Geophysics No. 251, AD755791.

40.1.20 Ozone Concentration. Ozone concentration extremes at the ground were estimated by extrapolating to zero elevation the information aloft referenced in 40.3.1.1 for ozone concentration (Ref. nos. 45, 46, and 47).

40.1.21 Sand and Dust. Extremes of sand/dust likely to be encountered by military equipment are not those of nature, but rather those caused by heavy traffic over dry dirt roads. Such extremes are not true climatic extremes and as such do not belong in this standard. However, design for these elements is extremely important, and since extremes for design purposes will probably not appear elsewhere, it was decided to present the most logical values of these elements in MIL-HDBK-310. The information presented in 5.1.21 through 5.1.21.2 was taken from:

(36) Blackford, P.A., and McPhilimy, H.S. (1972) Sand and Dust Considerations in the Design of Military Equipment, ETL-TR-72-7, U.S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA.

Subsequent amendments to this report by McPhilimy were not published.

40.1.22 Freeze-Thaw Cycles. Information on freeze-thaw conditions in 5.1.22 through 5.1.22.2 were taken from the following two reports:

(37) Wexler, R.L. (1982) A General Climatological Guide to Daily Freezing Conditions: Frost Days, Ice Days, and Freeze-Thaw Days, ETL-0287, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA.

(38) Wexler, R.L. (1984) Diurnal Freeze-Thaw Frequencies in Selected Regions of the High Latitudes, ETL-0364, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA.

40.2 Supplement to Regional Surface Environments. The methodology used to determine the four regional types into which the land areas of the world are partitioned was taken from reference (14) in 40.1.6.

The climatic data provided for the coastal/ocean regional type, for those elements (or combinations) that have less severe extremes than the worldwide surface environment, or pertain strictly to the marine environment, were taken from:

(39) Crutcher, H.L., Meserve, J., and Baker, 5. (1970) Working Paper for the Revision of MIL-STD-210A to MIL-STD-210B, U.S. Navy, Naval Weather Service Environmental Detachment, National Weather Records Center, Federal Building, Asheville, North Carolina.

40.3 Supplement to the Worldwide Air Environment.

40.3.1 Atmospheric Envelopes. Values provided for these envelopes are the same as those in MIL-STD-210B except for the more extreme temperature and density values found during the derivation of the atmospheric profiles (see 40.3.2).

40.3.1.1 One km to 30 km. The climatological information up to 30 km was provided by the USAF Environmental Technical Applications Center (ETAC) for all elements except high absolute humidity above 8 km (5.3.1.3), precipitation rate (5.3.1.9), water concentration in precipitation (5.3.1.10), hail size (5.3.1.11), and ozone concentration (5.3.1.16). The results were provided in the following four documents prepared for the B revision of this standard:

(40) Richard, O.E., and Snelling, H.J. (1971) Working Paper for the Revision of MIL-STD-210A, "Climatic Extremes for Military Equipment" (1 Km to 30 Km), ETAC 5850, USAF Environmental Technical Applications Center, Washington, D.C.

(41) Richard, O.E. (1972) Changes in 1-30 Km Data for MIL-STD-210B, letter of 19 Sep 1972 from ETAC/EN (Richard) to AFCRL/LKI (Sissenwine).

(42) Snelling, H.J. (1973) Coincident Temperature-Density Values for MIL-STD-210B, letter from ETAC/EN of 5 Jan 1973 to AFCRL (LKI).

(43) Richard, O.E. (1973) Changes in Temperature at Pressure Altitude Tables and Dew Point Tables. Personal correspondence ETAC/EN (O.E. Richard) of 23 Jan 1973 to AFCRL/LKI (N. Sissenwine).

The first of these provided the initial information. The last three provided improvements and additional information. These documents are not readily available; however, a detailed summary is available on pages 163-217 in the following:

(44) Sissenwine, N., and Cormier, R.V. (1974) Synopsis of Background Materiel for MIL-STD-210B, Climatic Extremes for Military Equipment, AFCRL-TR-74-0052, Air Force Surveys in Geophysics No. 280, AD780508, Hanscom AFB, Bedford, MA.

A brief summary of the ETAC data analysis procedures follows:

The selection of the area or areas with the most extreme conditions, as they pertained to a particular element, and the selection of the month or year at which these extreme conditions might be expected to occur, was accomplished subjectively by ETAC. Data from radiosonde stations in or near these areas were processed. The fact that the extreme conditions do not necessarily occur directly over a particular radiosonde site was noted. Adjustments were made to the observed data to more correctly represent the worldwide extreme conditions when deemed appropriate.

For most stations, only about five years of data, usually taken twice a day, were readily available in an acceptable format (complete period of record, data at a sufficient number of intervals) for summarization of reliable statistics. Only data from standard meteorological pressure levels had been recorded for many overseas stations. With the increased distance between standard levels, especially above 700 mb, "straight line" extrapolating procedures introduced the ever-increasing possibility of error if these data were used. In addition, a number of stations had broken periods of record which did not appear to be dependable. In both of these cases, ETAC indicated that the reliability sought for this study could not be obtained from such data. On several occasions substitute stations had to be used. Records to altitudes above approximately 24 km were incomplete so a more thorough evaluation of these data than the data at lower levels was required. This was accomplished by comparison with data from nearby stations to attempt to establish the validity of the extreme based on a station with more complete data, as well as by spatial analysis.

Highest/lowest recorded and 1-, 5-, 10-, and 20-percent extremes are provided. These percent extremes are based on observed extreme values or are estimates based on observed values; they are not extrapolated extremes obtained assuming a normal (or any other) distribution for the values of a given element. Because upper atmospheric observations are not routinely taken 24 hours per day, but usually only 2 times per day, the percent extremes do not strictly represent the number of hours per month that the value of a given element is equalled or surpassed. However, since diurnal cycles in the free air below 30 km are small, the distributions as obtained from summaries of original sounding data for each kilometer level for the extreme month and location selected are considered as fairly representative of percent extremes.

A comparison was made between the various locations selected in order to arrive at a final most severe extreme for each level. When it was determined that the extreme condition existed either between two stations having sounding data or displaced from a sounding station, extrapolation through spatial analysis and/or subjective evaluation was accomplished in order to obtain a worldwide extreme value for a given element.

Inputs up to 30 km not provided by ETAC are described as follow:

For precipitation rate and water concentration in precipitation, reference to supporting technical material is provided in 40.3.2 since these are presented as profiles. Information on hail sizes aloft came from the studies referenced in 40.1.15 for the worldwide surface environment. For inputs on absolute humidity above 8 km, see ref. (50) in 40.3.1.2.

The inputs on ozone concentration were taken from the following:

(45) Borden, T.R., Jr. (1970) Extreme Values of Ozone Observed in the AFCRL Ozonesonde Network, AFCRL-TR-70-0072, Environmental Research Papers No. 312, AD704547.

(46) Kantor, A.J. (1972) Ozone Density Envelopes up to 30 km for MIL-STD-210B, AFCRL ('XI) INAP No. 96, (Unpublished internal report).

The first of these provided background data that was manipulated in the second report to determine values originally provided for MIL-STD-210B, but remain valid. For this revision, background information on ozone concentrations, variability, and temporal and spatial distributions was provided in the following unpublished report:

(47) Niedringhaus, T. (1985) Ozone Concentrations for MIL-STD-210C, United States Army Engineer Topographic Laboratories (ETL-GS-LB) File Study Series, Fort Belvoir, VA.

40.3.1.2 Altitudes 30 km to 80 km. Observations of climatic elements at these altitudes are very limited. Consequently, estimates of extremes are generally not as accurate as those at lower altitudes, and are limited to frequencies of occurrence of 1 and 10 percent of the worst month for most elements. Estimates of extremes for altitudes between 30 and 55 km, for all elements except humidity, were based on daily Meteorological Rocket Network (MRN) data available for more than 30 Northern Hemisphere locations. Values were extrapolated up to 80 km using results from special observation programs. The values provided in this revision are the same as those in 210B except where more extreme values were found during the derivation of the atmospheric profiles (see 40.3.2). A detailed summary of the data and analytical methods is available on pages 217-241 in reference (44) in 40.3.1.1. The original reports supporting the estimated values are:

For temperature, pressure, and density:

(48) Cole, A.E. (1970) Extreme Temperature, Pressure and Density Between 30 and 80 km, AFCRL-TR-70-0462, Environmental Research Papers, No. 330, AD712019.

(49) Cole, A.E. (1972) Distribution of Thermodynamic Properties of the Atmosphere Between 30 and 80 km, AFCRL-TR-72-0477, Environmental Research Papers, No. 409, AD751874.

For absolute humidity:

(50) Grantham, D.D., and Sissenwine, N. (1970) High Humidity Extremes in the Upper Air, AFCRL-TR-70-0563, Environmental Research Papers, No. 333, AD715894.

For wind and wind shear:

(51) Kantor, A.J. (1969) Strong Wind and Vertical Wind Shear above 30 km, AFCRL-TR-69-0346, Environmental Research Papers, No. 303, AD696598.

(52) Crutcher, H.L. (1959) Upper Wind Statistics Charts of the Northern Hemisphere, NAVAER 5O-K-535, Vol. I and II.

(53) Salmela, H.A., and Sissenwine, N. (1969) Distribution of ROBIN Sensed Wind Shears at 30 to 70 Kilometers, AFCRL-TR-69-0053, Environmental Research Papers, No. 298, AD686110.

40.3.2 Atmospheric Profiles. The temperature and density profiles were modeled using rawinsonde data up to about 25 km, and Meteorological Rocket Network (MRN) data from about 25 to 55 km. Correlation studies from special observation programs and the Air Force Reference Atmospheres were used to extend the profiles up to 80 km. Rawinsonde data were available for about 170 locations, while MRN data were available for only 21 locations. The 1 and 10 percent high and low temperatures and densities were determined using rawinsonde data at 5, 10, and 20 km, and MEN data at 30 and 40 km. Once the locations with the most severe 1- and 10-percent values were determined, the profiles were modeled by pairing the most appropriate MEN and rawinsonde observation sites. Since detailed discussion of the data and analytical methods used to derive the profiles would be too extensive to include here, it is recommended that the following technical report be obtained to answer questions that may impact the use of the profiles:

(54) Kantor, A.J. and Tattleman, P. (1984) Profiles of Temperature and Density Based on 1- and 10-Percent Extremes in the Stratosphere and Troposphere, AFGL-TR-84-0336, Air Force Surveys in Geophysics, No. 447, ADA160552.

The above referenced report includes the profiles presented as a function of geo-potential height in addition to those presented as a function of geometric height that are provided in this standard. Comparisons of the profiles with the envelopes in this standard are also provided. These show that the profiles generally are much less extreme than the envelopes at all altitudes except those close to the threshold extreme. An interesting feature of the profiles is that hot and cold profiles of the troposphere and lower stratosphere become relatively cold and hot profiles, respectively, above about 60 km.

CUSTODIANS:		PREPARING ACTIVITY
Army	CE	Air Force 19
Navy	AS	Project ENVR-0043

REVIEW ACTIVITIES

Army	AT, AV, GL, MI, SM, TE
Navy	EC, MC, OS, SH
Air Force	10, 11, 17

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL
(See Instructions - Reverse Side)

1. DOCUMENT NUMBER MIL -HDBK-310	**2. DOCUMENT TITLE**
3a NAME OF SUBMITTING ORGANIZATION	**4.TYPE OF ORGANIZATION (Mark one)** ☐ **VENDOR** ☐ **USER** ☐ **MANUFACTURER** ☐ **OTHER (*specify*):** ________
b. ADDRESS-.(Street. City State ZIP Code)	

5. PROBLEM AREAS (*Street, City, State, ZIP Code*)

a. Paragraph Number and Wording

b. Recommended Wording:

c. Reason/Rationale for Recommendation

6. REMARKS

7a. NAME OF SUBMITTER (*Last, First, MI*) -Optional	**b. WORK TELEPHONE NUMBER (*Include Area Code*) - Optional**
c. MAILING ADDRESS (*Street, City, State, ZIP*) - Optional	**8. DATE OF SUBMISSION (*YYMMDD*)**

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