AD 711366

AFCRL-70-0332
JUNE 1970
ENVIRONMENTAL RESEARCH PAPERS, NO. 323

AEROSPACE INSTRUMENTATION LABORATORY PROJECT 8624

**AIR FORCE CAMBRIDGE RESEARCH LABORATORIES**

L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

# Unusual Extremes and Diurnal Cycles of Desert Heat Loads

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# Abstract

Diurnal cycles of high temperature during which equipment must operate, and long-term temperature extremes and cycles which equipment must withstand without irreversible damage, are provided for the revision of MIL-STD-210A, "Climatic Extremes for Military Equipment." The high temperature during which the equipment should be operable was selected from a companion study. The still higher temperatures that the equipment must withstand on standby for periods of 2 to 25 years without irreversible damage are new. The areas studied for these extremes included Death Valley, Calif., and stations in French West Africa. The operational upper 1-percent extreme in the hottest month in the worst location is 120°F; the associated diurnal cycle has an amplitude of 29 F°. The withstanding upper 10-percent extreme is 128°F for a 2-year planned life, increasing to 133°F for a 25-year planned life.

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## Unusual Extremes and Diurnal Cycles of Desert Heat Loads

### 1. INTRODUCTION

Military Standard 210A, "Climatic Extremes for Military Equipment," is being revised and scientific studies are needed on which to realistically specify the hottest situations. Equipment should be operable most of the time in the hottest areas of the world during the hottest times of the year, and be able to withstand the onslaught of the heat without irreversible damage. It has been convenient to tag the geographical areas of importance by mapping probabilities of high temperatures on a world-wide basis for the hottest month of the year (Bennett et al, 1964; Tattelman, Sissenwine, and Lenhard, 1969).

Assuming that no place on earth is to be excluded from military operations during the hottest times of the year and that 1 percent inoperability is acceptable, we can limit our study of extreme heat to the French West African Sahara Desert and Death Valley, California, where the 1 percentile is about 120°F (Tattelman, 1969, Figure 12). Other areas in the Sahara and Middle East are only slightly cooler.

Although not expected to operate in temperatures over 120°F, equipment should withstand, without damage, unusual temperature extremes in these deserts, levels that are reached with only a 10 percent probability during the field life of equipment. The higher temperatures for this design philosophy must be specified.

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(Received for publication 2 June 1970)

Hot extremes are always included in a well pronounced diurnal cycle. The daily maximums last only a couple of hours. However, they are accompanied by strong sunshine that causes equipment to attain temperatures considerably higher than the free-air values on which climatology maps are based. For this reason the hot extreme of temperature for both operating and withstanding need to be shown in realistic diurnal cycles with solar radiation. The cycle should also include the windspeed, which might serve 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 can lead to special design problems.

This study does not examine alternative methods for estimating heat stress. Specifically, it does not provide cycles of greatest solar insolation. Solar insolation is known to be higher at high-elevation deserts (and other elevated topography) than it is in the near-sea-level (below sea level up to about 1000 ft), hot deserts mentioned. However, standard free-air temperatures are not as high. The assumption is made herein that equipment will, in general, reach higher temperatures in the hottest locations than in the sunniest locations; therefore, the high thermal-stress cycles developed herein are linked to instrument shelter free-air temperatures, a worldwide standard.

## 2. DATA

For extreme heat the climate of stations in the Sahara Desert would be the best for analysis, but records of hourly observations and annual extremes were not available. For most of the Sahara only average and absolute monthly maximum and minimum temperatures were available (Meteorological Office, 1958). For Death Valley, California, year by year extremes are available from 1911 on. Also available are daily records of maximum and minimum temperatures that will be useful in determining the diurnal cycle.

Frequency distributions of temperatures, one or more observations per day, in the summer months for El Golea, Fort Flatters, In Amenas, Adrar, In Salah, and Ouallen, Algeria; Punta Penasco and Sonora, Mexico; Belize, British Honduras; Yuma, Arizona; and the 59-year record of daily maximum and minimum temperatures for Death Valley, California, were obtained from ETAC.

## 3. DIURNAL CYCLES FOR OPERATIONS

As stated, typical locations for models of extreme temperature cycles are French West Africa and Death Valley, California. Because records for those areas are incomplete with respect to the diurnal cycle and associated measures of radiation, windspeed, and moisture, it was deemed desirable to study Yuma, Arizona. While not as extremely hot as Death Valley, Yuma is one of the hotter deserts near sea level and has a substantially long record of hourly observations that can be studied in depth. Patterns discerned by such a study can then be extrapolated for analysis of more extreme locations.

### 3.1 Yuma, Arizona

The July hourly observations of temperature at the U. S. Weather Bureau station, Yuma, Arizona, for 1942 to 1968, and daily maxima and minima, were provided by ETAC. Except for those of July 1942, when the daily record was completed only between the hours of 0500 and 1700 LST, the observations are for all 24 hours.

The distribution of all temperatures in July is shown in Figure 1. The mean and standard deviation for the hours of 0000, 0600, 1200, and 1800 are:

| Time | Mean (°F) | SD (F°) |
|---|---|---|
| 0000 | 87.6 | 3.74 |
| 0600 | 82.2 | 4.09 |
| 1200 | 100.0 | 4.60 |
| 1800 | 103.0 | 4.99 |

For the four time periods above, the average of hourly standard deviations, $\hat{\sigma}$, is estimated as 4.36 F°.

The diurnal maximum and minimum have mean and standard deviations as follows:

| | Mean (°F) | SD (F°) |
|---|---|---|
| Maximum | 107.2 | 4.56 |
| Minimum | 80.1 | 4.26 |

The mean diurnal range is 27.1 F°.

It should be noted that the average of the standard deviations of daily maximum and daily minimum temperatures, 4.41 F°, does not differ greatly from the estimate for hourly temperatures, 4.36 F°. Apparently, if hourly observations of temperature are unavailable for a desert station, hourly standard deviations can be reasonably well estimated from the mean of the standard deviations of the maximum and minimum temperatures.

The 1-percentile of the hourly July temperatures obtained from Figure 1 is 111°F. Because of the large diurnal cycle in the desert, the problem of determining the extreme high temperature duration is to determine the typical cycle associated with the 1-percentile. In the period 1961 to 1968 there were 20 days during which the temperature rose to 111°F or higher. For these select days, the median maximum is 111°F and the median minimum is 83.5°F; the average temperature of each hour

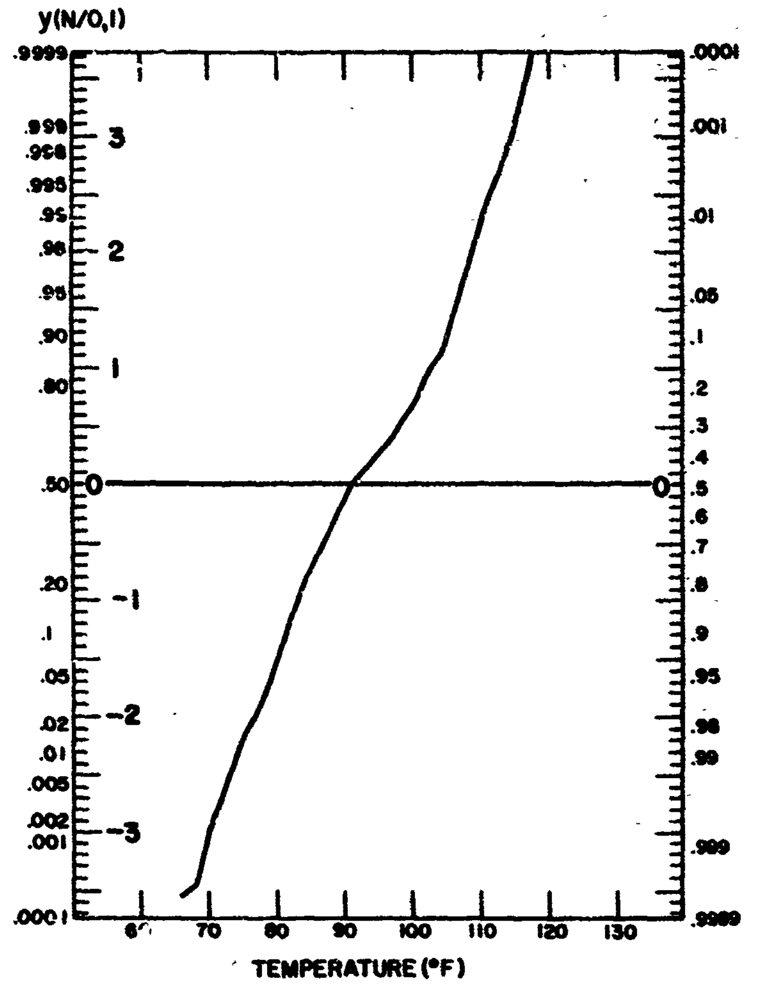


Figure 1. Yuma, Ariz., July Frequency Distribution of Temperature, Based on 1949-1967 Records of Hourly Observations Supplied by ETAC

is shown in a diurnal cycle in Figure 2. The mean diurnal range is 27.5 F° for these 20 hottest days, about the same as it is for the whole population of July days. However, hourly means and standard deviations for the 20 hottest days differ considerably from those for the month:

| Time | Mean (°F) | SD (F°) |
|---|---|---|
| 0000 | 92 | 2.88 |
| 0600 | 83 | 2.67 |
| 1200 | 104 | 2.16 |
| 1800 | 109 | 1.89 |

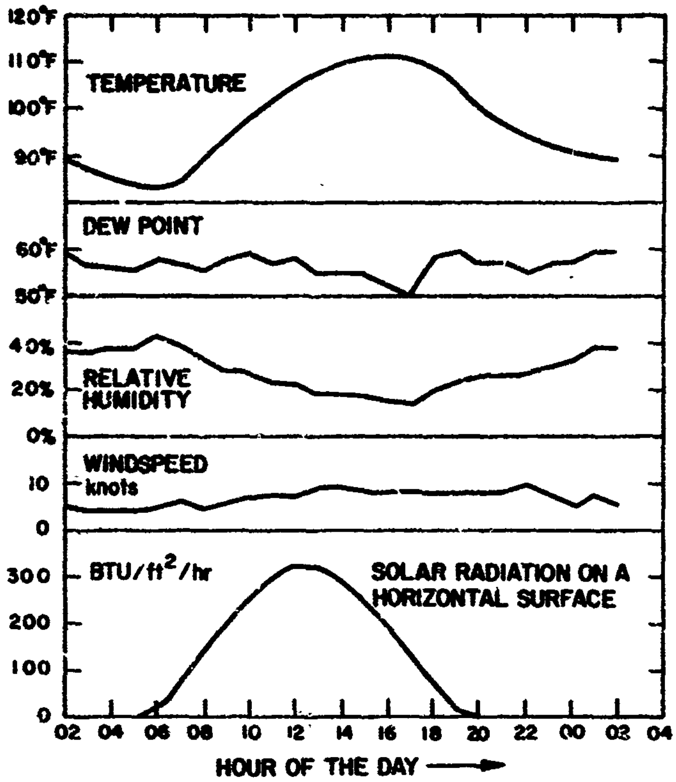


Figure 2. Yuma, Ariz., July Typical Diurnal Cycles of Temperature, Dew Point, Relative Humidity, Windspeed, and Solar Radiation Associated With Maximum Daily Temperature Equal to or Exceeding 111°F, Based on 1961-1968 Data

The average standard deviation of 2.4 F° is considerably lower than the population value of 4.4 F°. Evidently, the 1 percent hottest days are very similar to one another and can provide a reliable diurnal cycle to be associated with the 1-percent value of 111°F.

The median hourly dew points for the same 20 hottest July days are shown in Figure 2. The overall median is 57°F. The large diurnal temperature range yields a pronounced diurnal cycle of relative humidity that is out of phase with the smaller cycle of dew point.

The windspeed has a median value of 7 knots. The anemometer levels were known to be 20 to 27 ft above ground. While varying in the narrow limits of 4 to 9 knots, the wind still appears to have a diurnal cycle with maximum speed in the afternoon and minimum in the early morning.

Data are available (U. S. Army, 1957 to 1968) for direct and indirect solar radiation at all wavelengths absorbed by a horizontal surface with an Eppley pyrheliometer. In July at Yuma the noon value is 325 BTU/ft$^2$/hr, decreasing to zero at 2000 and remaining at zero until 0500 the following morning. Temperature cycles for the hottest day and for 1 and 2 days before and after each of the 20 hot days were studied.

Table 1 gives the ratio of the departure of each hourly temperature from the 1-percentile value (111°F for Yuma) to the diurnal amplitude of temperature of the hottest day (27.5 F° for Yuma). It also gives the ratio of windspeed departure from an anchor value to that anchor value, likewise solar radiation. At Yuma the anchor value for windspeed is 8 knots and for solar radiation 325 BTU/ft$^2$/hr. These relationships are considered typical of even hotter near-sea-level deserts, and are provided as patterns of diurnal cycles of such locations in periods of extreme heat.

Table 1. Hourly Ratio of Temperature Departure From the 99-percentile Value to the Diurnal Amplitude on the Hottest Days (Max ≥ 99-percentile). The table also includes hourly departure of windspeed and solar radiation from an anchor value, and its ratio to that anchor value

| Item | Hour of the Day | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Temperature, hottest day | .84 | .88 | .88 | .93 | .98 | 1.00 | .96 | .84 | .62 | .47 | .35 | .24 | .13 | .04 | .04 | 0 | .02 | .07 | .20 | .40 | .49 | .58 | .67 | .73 |
| 1 day before | .80 | .87 | .94 | 1.02 | 1.02 | 1.05 | .98 | .84 | .65 | .54 | .40 | .33 | .26 | .14 | .11 | .07 | .11 | .14 | .22 | .40 | .51 | .58 | .69 | .76 |
| 1 day after | .76 | .80 | .87 | .87 | .94 | .94 | .91 | .80 | .65 | .54 | .40 | .31 | .24 | .14 | .11 | .11 | .11 | .22 | .31 | .44 | .56 | .67 | .78 | .84 |
| 2 days before | .87 | .93 | .98 | 1.00 | 1.02 | 1.09 | .98 | .87 | .73 | .58 | .47 | .36 | .31 | .24 | .20 | .08 | .14 | .18 | .29 | .49 | .58 | .62 | .73 | .74 |
| 2 days after | .87 | .89 | .93 | .93 | .96 | .98 | .94 | .84 | .73 | .62 | .51 | .32 | .53 | .27 | .22 | .20 | .22 | .27 | .34 | .51 | .64 | .69 | .76 | .86 |
| Windspeed, hottest day | .38 | .36 | .38 | .38 | .38 | .38 | .38 | .38 | .38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .38 |
| Radiation, hottest day | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .94 | .77 | .57 | .35 | .20 | .08 | 0 | 0 | .20 | .35 | .57 | .77 | .94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

### 3.2 Death Valley, California

The USWB records (on Form 1009) provide daily maximum and minimum temperatures at Death Valley, Calif., for the period 1911 to 1968. As for hourly summer temperatures, the only known record was made by thermograph in 1949 by the U. S. National Park Service at Death Valley National Monument. Court (1952) made a study of this limited record to obtain durations of daily maximum and near maximum temperatures in the diurnal cycle, treating it, as he practically had to, as a case study. The record is insufficient to yield a direct statistical estimate of the 1-percentile value in the warmest month, with hourly details of the associated diurnal cycle. The cycle during a day on which 1-percentile extremes occur must be estimated by indirect means (described below).

## 4. OPERATIONAL EXTREMES

From the available data, frequency distributions of the 59 years of July daily maximum and minimum temperatures are provided in Figure 3.

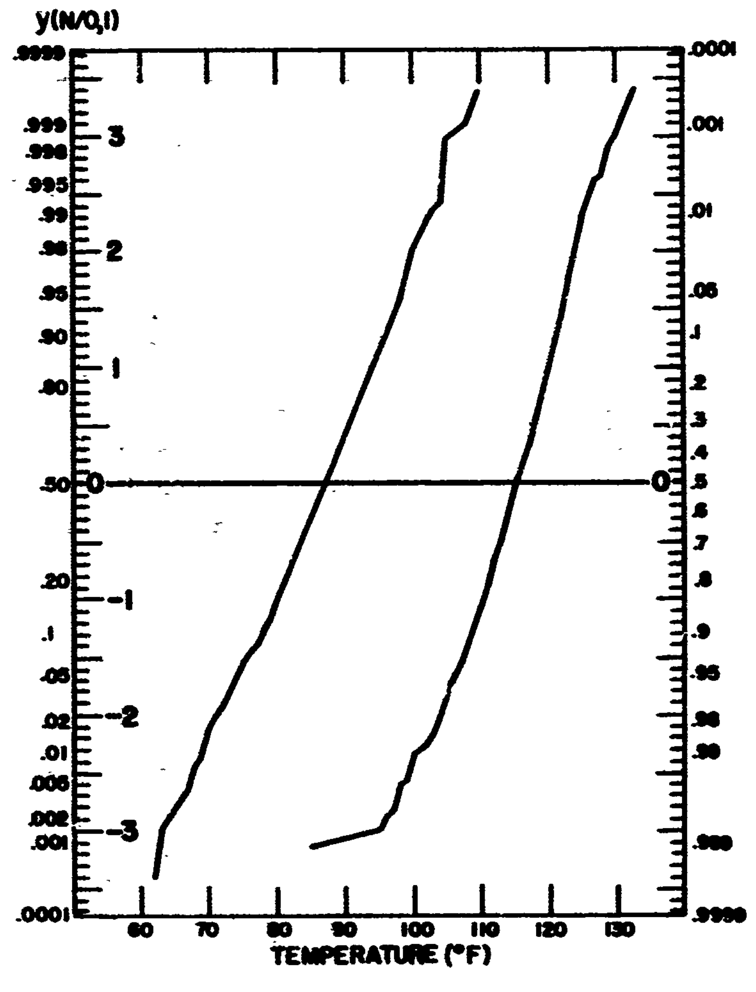


Figure 3. Death Valley, Calif., July Temperatures, Based on 1911-1969 Records of Daily Maximum and Minimum

The diurnal maximum and minimum temperatures have mean and standard deviations as follows:

| | Mean (°F) | SD (F°) |
|---|---|---|
| Maximum | 115.4 | 7.99 |
| Minimum | 87.9 | 7.56 |

The mean daily range is 27.5 F°, about the same as for Yuma, but the estimated standard deviation of hourly temperatures, averaging 7.78 F°, is much greater than that at Yuma.

From studies of daily maximum (Court, 1949) and duration (Court, 1952), Tattelman, Sissenwine, and Lenhard (1969) estimated the 1-percentile for Death Valley to be 123°F. As noted in the introduction, a value of 120°F was selected as the maximum temperature in the cycle for high-temperature operations (Memo from JCS to Secretary of Defense, Subject: Military Standard MIL-STD-210A, Climatic Extremes for Military Equipment, JCSM-502-69, 12 August 1969).

To better restore the diurnal cycle that is typical for days attaining 120°F, the microfilm record was searched for the maximum and minimum temperatures for each day that the temperature equalled or exceeded 120°F in July of 1911 to 1927 (1922 missing). The median maximum was found to be 120°F, the median minimum was 91°F. Thus, the range was 29 F° for Death Valley's hottest days compared with Yuma's 27.5 F°. It is concluded that the Yuma cycle (Table 1) can be used to establish the Death Valley cycle to accompany the 1-percent value (Table 2a) for the hottest days, 1 day before or after, and 2 days before or after. For the sake of symmetry and intuitive impressions of the rise and decline of extreme temperatures, these values were smoothed to the values in Table 2b.

## 5. WITHSTANDING EXTREMES

The record for Death Valley is assumed as typical of extremely hot deserts. The microfilm yielded the highest temperature in each of 57 years from 1911 to 1968 (1 year incomplete). Their distribution fits the Gumbel distribution very well (Figure 4) and, through theory (Gringorten, 1963g), yields the following estimates of risk for given planned lifetimes:

| | Planned Life (years) | | | | |
|---|---|---|---|---|---|
| Probability (%) | 1 | 2 | 5 | 10 | 25 |
| 1 | 131°F | 133°F | 134°F | 135°F | 137°F |
| 10 | 127 | 128 | 130 | 131 | 133 |
| 25 | 125 | 127 | 123 | 129 | 131 |
| 50 | 124 | 125 | 127 | 128 | 130 |

For the withstanding problem, the 10-percentiles are used as the maximum 1600 LST temperatures and the associated diurnal cycle is estimated (Table 1).

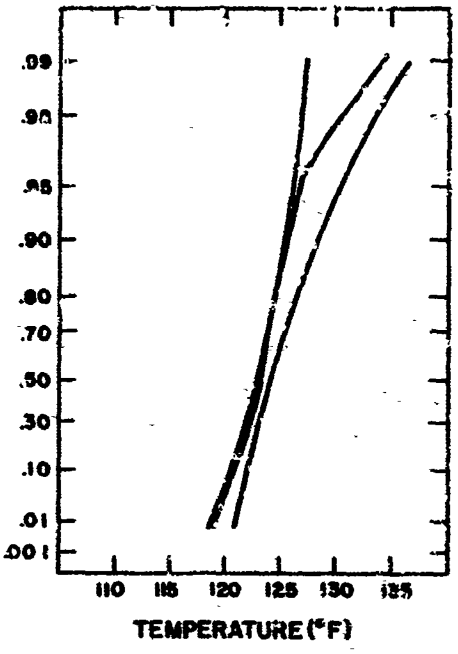


Figure 4. Death Valley, Calif., Annual High Temperature Extreme Frequency Distribution for Years 1911-1968. The outer curves are the 95 percent envelope, drawn on extreme probability paper (Gringorten, 1963b)

Before this estimate can be made, it is necessary to establish the typical diurnal amplitude for each planned life.

The whole 59-year record for Death Valley, Calif., was searched for the maximum and minimum temperature for each day that the maximum reached or exceeded 120°F. For the following maxima, the median of the minima were:

| Max (°F) | Median min (°F) | No. of occurrences |
|---|---|---|
| 120 | 91 | 150 |
| 121 | 93 | 91 |
| 122 | 92 | 82 |
| 123 | 89 | 63 |
| 124 | 90 | 30 |
| 125 | 98 | 15 |
| 126-134 | 89 | 18 |

There is no indication that the minimum temperature can be associated with the maximum, except that it is close to 91°F whenever the maximum temperature equals or exceeds 120°F. Hence, the associated minimum is assumed to be 91°F and the diurnal amplitude (as used in Table 2c) becomes as follows:

| Max (°F) | Amplitude (F°) |
|---|---|
| 128 | 37 |
| 130 | 39 |
| 131 | 40 |
| 133 | 42 |

## 6. ESTIMATING ASSOCIATED HUMIDITY

Figure 2 shows that for the selected sample of July days at Yuma the hourly dew point has an overall median of 57°F. Data tabulated (Met. Off., 1958) for African stations that have average daily maximum temperatures for July equal to or greater than 113°F, much like Death Valley, shows relative humidities as follows:

| Station | Lat | Long | Alt (ft) | R H (%) 0700 | R H (%) 1300 |
|---|---|---|---|---|---|
| Aarur | 27°52'N | 0°17'W | 938 | 30 | 19 |
| Aculef | 27°04'N | 0°44'W | 902 | 29 | 18 |
| In Salah | 27°12'N | 2°22'E | 919 | 29 | 16 |
| Ouallene | 24°38'N | 1°14'E | 1135 | 15 | 7 |
| Reggan | 26°43'N | 0°09'E | 876 | 16 | 7 |
| Timimoun | 29°15'N | 0°14'E | 981 | 26 | 15 |
| Araocane (June) | 18°54'N | 3°33'W | 935 | 26 (0800) | 16 (1800) |
| | | | Median | 26% | 16% |

For temperatures of 92°F at 0700 and 116°F at 1300, typical for these times, the median RH's give dew points of 52° and 59°F respectively; the relative humidities for Reggan and Ouallene give dew points of about 38°F at both times.

Data obtained during a Death Valley expedition (Sissenwine et al, 1951) shows that the humidity varied from a relatively moist condition (45° to 50°F dew points) at places like the National Monument and Cow Creek to very dry conditions over desert dunes near Stove Pipe Wells; over the desert dunes on 10 and 11 Aug 1950, some 12 afternoon observations (1200 to 1700 hours) gave a median dew point of 19°F and a relative humidity of 4 percent.

Since a low moisture content causes the most critical drying during the hot extreme condition, a rounded-value 20°F dew point was chosen for the MIL-STD-210B, yielding the relative humidities in Table 2d.

## 7. ESTIMATING ASSOCIATED WINDSPEED

At Yuma, Arizona, July windspeeds on the hottest days are approximately 8 knots from 1000 to 2300 LST and 5 knots at other times. The anemometer height during the periods of record was 20 to 2' ft above the ground.

At Death Valley, California (1961 to 1959), the wind recorder at 1.5 to 2.0 ft height was read once daily to give the 24-hr movement of air across the evaporation

Table 2. Death Valley, Calif., July Temperature (°F) Diurnal Cycles Restored by Estimation (see text) for Days When Maximum Temperature Equals or Exceeds the 1-percentile (120°F)

| Item | Hour of the Day | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| **Table 2a. Temperature Cycles, Estimated by Using Ratios for Yuma (Table 1)** | | | | | | | | | | | | | | | | | | | | | | | | |
| Hottest Day | 95 | 94 | 94 | 92 | 91 | 90 | 91 | 95 | 101 | 106 | 110 | 112 | 116 | 119 | 119 | 120 | 119 | 118 | 114 | 108 | 105 | 102 | 100 | 98 |
| 1 day before | 96 | 94 | 92 | 89 | 89 | 88 | 91 | 95 | 100 | 104 | 108 | 110 | 112 | 116 | 117 | 118 | 117 | 116 | 113 | 108 | 105 | 103 | 99 | 97 |
| 1 day after | 97 | 96 | 94 | 94 | 92 | 92 | 93 | 96 | 100 | 104 | 108 | 111 | 113 | 116 | 117 | 117 | 117 | 113 | 111 | 107 | 103 | 100 | 97 | 95 |
| 2 days before | 94 | 92 | 91 | 90 | 89 | 87 | 91 | 94 | [illegible] | 103 | 106 | 109 | 111 | 113 | 114 | 117 | 116 | 115 | 111 | 105 | 103 | 101 | 98 | 96 |
| 2 days after | 94 | 93 | 92 | 92 | 91 | 91 | 92 | 95 | 98 | 101 | 105 | 107 | 110 | 112 | 113 | 114 | 113 | 112 | 110 | 105 | 101 | 99 | 97 | 94 |
| **Table 2b. Smoothed Cycles - Operational Temperatures** | | | | | | | | | | | | | | | | | | | | | | | | |
| Hottest Day | 95 | 94 | 93 | 92 | 91 | 90 | 91 | 95 | 101 | 106 | 110 | 112 | 116 | 118 | 119 | 120 | 119 | 118 | 114 | 108 | 105 | 102 | 100 | 98 |
| 1 day before or after | 96 | 95 | 93 | 92 | 91 | 90 | 92 | 96 | 100 | 104 | 108 | 111 | 113 | 116 | 117 | 118 | 117 | 115 | 112 | 108 | 104 | 101 | 98 | 96 |
| 2 days before or after | 94 | 93 | 92 | 91 | 90 | 89 | 91 | 95 | 98 | 102 | 105 | 108 | 110 | 112 | 114 | 116 | 115 | 113 | 111 | 105 | 102 | 100 | 98 | 96 |
| **Table 2c. Withstanding Temperature Cycles** | | | | | | | | | | | | | | | | | | | | | | | | |
| 2-year extreme | 97 | 96 | 96 | 94 | 92 | 91 | 92 | 97 | 105 | 110 | 115 | 119 | 123 | 126 | 127 | 128 | 127 | 125 | 121 | 113 | 110 | 106 | 103 | 101 |
| 5-year extreme | 97 | 96 | 96 | 94 | 92 | 91 | 92 | 97 | 106 | 112 | 117 | 120 | 125 | 128 | 129 | 130 | 129 | 127 | 122 | 114 | 111 | 107 | 104 | 102 |
| 10-year extreme | 97 | 96 | 96 | 94 | 92 | 91 | 92 | 97 | 106 | 112 | 117 | 121 | 126 | 129 | 130 | 131 | 130 | 128 | 123 | 115 | 111 | 108 | 104 | 102 |
| 25-year extreme | 98 | 96 | 96 | 94 | 92 | 91 | 92 | 98 | 107 | 113 | 118 | 122 | 128 | 131 | 131 | 133 | 132 | 130 | 125 | 116 | 112 | 108 | 105 | 102 |
| **Table 2d. Associated Values** | | | | | | | | | | | | | | | | | | | | | | | | |
| Relative Humidity (dp=20°F) | 6% | 7 | 7 | 8 | 8 | 8 | 8 | 6 | 6 | 5 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 5 | 6 | 6 | 6% |
| Windspeed (mph) | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 6.1 |
| Solar Radiation ($BTU/ft^2/hr$) | 0 | 0 | 0 | 0 | 0 | 22 | 83 | 155 | 233 | 288 | 332 | 360 | 360 | 288 | 233 | 155 | 83 | 22 | 0 | 0 | 0 | 0 | 0 | 0 |

pan. On 35 days when the maximum temperature reached or exceeded 120°F, the recorded movement had a median of 55 miles, thus giving an average windspeed of 2.3 mph. Table 2d gives the windspeeds by hour, restored by using the ratios as determined for Yuma, and corrected to an anemometer height of 10 ft by the so-called power law

$$\frac{V_{10}}{V_2} = \left(\frac{10}{2}\right)^{0.17}$$

to give an average speed of 8.2 mph. The exponent of 0.17 is considered typical for average winds (Shellard, 1962).

## 8. ESTIMATING ASSOCIATED RADIATION

The report of Sissenwine et al (1951) gives an average (or typical) noontime radiation on a horizontal surface at Death Valley, California, between 20 July and 12 August with clear skies, of 1.376 Langleys/min = 82.5 Langleys/hr. At Yuma, Arizona, the July Eppley Pyrheliometer records yielded a noontime average of 88.0 Langleys/hr. Since the latitudinal effect would be very much less, this difference is probably due to increased absorption of radiation by the atmosphere over Death Valley. The elevation of Death Valley is 178 ft below sea level compared to Yuma's elevation of 206 ft above sea level.

The absorption of solar radiation is related to the thickness (by mass) of air that is penetrated, making the following relation acceptable as an initial assumption for solar radiation at pressure, p:

$$I = I_o \cdot e^{-ap} \tag{1}$$

where $I_o$ is the solar constant for radiation on a horizontal surface above the atmosphere, 1.95 Langleys/min (117 Langleys/hr). Solving Eq. (1) with Yuma's I of 88.0 Langleys/hr, the standard atmosphere pressure of 1006 mb for 206 ft yields an a of $2.833 \times 10^{-4}$ $mb^{-1}$. Solving Eq. (1) using that a for Death Valley at -200 ft (approximately), where standard pressure is 1020 mb, yields a noontime radiation of 87.6 Langleys/hr. Since this is much higher than the 82.5 given by Sissenwine et al (1951), it must be explained by another factor. The most obvious is the moisture content in the lowest 3000 or 4000 ft of the atmosphere.

Now, assume that the parameter, a, for pressure greater than 900 mb, typical of hot deserts, will be given by:

$$\frac{I_1}{I_2} = \frac{e^{-ap_1}}{e^{-ap_2}} \; . \tag{2}$$

Then, for Yuma and Death Valley:

$$I_1 = 88.0 \qquad I_2 = 82.5$$

$$p_1 = 1006 \qquad p_1 = 1020 \; .$$

Solving for a, the value of 0.00464 $mb^{-1}$ is obtained.

The hottest locations in the Sahara desert are all at about 1000 ft altitude. The standard atmospheric pressure is 977 mb for that altitude. Solving Eq. (2) for 977 mb and an a of 0.00464 $mb^{-1}$ yields 100.8 Langleys/hr or 369 BTU/$ft^2$/hr. This value is just 9 BTU/$ft^2$/hr higher than the value previously assumed in this kind of work. The value of 360 BTU/$ft^2$/hr (97.6 Langleys/hr) is, therefore, recommended for retention as the peak radiation in the desert on a horizontal surface. The proportions of radiation in other hours are taken from Table 1 for Yuma to give the hourly radiation in Table 2d.

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Unclassified

Security Classification

**DOCUMENT CONTROL DATA - R&D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author) Air Force Cambridge Research Laboratories (CRE) L. G. Hanscom Field Bedford, Massachusetts 01730 | 2a. REPORT SECURITY CLASSIFICATION Unclassified<br>2b. GROUP |

3. REPORT TITLE

UNUSUAL EXTREMES AND DIURNAL CYCLES OF DESERT HEAT LOADS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific. Interim.

5. AUTHOR(S) (First name, middle initial, last name)

Irving I. Gringorten
Norman Sissenwine

| | | |
|---|---|---|
| 6. REPORT DATE June 1970 | 7a. TOTAL NO. OF PAGES 20 | 7b. NO. OF REFS 10 |

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| 8a. CONTRACT OR GRANT NO.<br>b. PROJECT, TASK, WORK UNIT NOS. 8624-01-01<br>c. DOD ELEMENT 62101F<br>d. DOD SUBELEMENT 681000 | 9a. ORIGINATOR'S REPORT NUMBER(S) AFCRL-70-0332<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ERP No. 323 |

10. DISTRIBUTION STATEMENT

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| 11. SUPPLEMENTARY NOTES TECH, OTHER | 12. SPONSORING MILITARY ACTIVITY Air Force Cambridge Research Laboratories (CRE) L. G. Hanscom Field Bedford, Massachusetts 01730 |

13. ABSTRACT

Diurnal cycles of high temperature during which equipment must operate, and long-term temperature extremes and cycles which equipment must withstand without irreversible damage, are provided for the revision of MIL-STD-210A, "Climatic Extremes for Military Equipment." The high temperature during which the equipment should be operable was selected from a companion study. The still higher temperatures that the equipment must withstand on standby for periods of 2 to 25 years without irreversible damage are new. The areas studied for these extremes included Death Valley, Calif., and stations in French West Africa. The operational upper 1-percent extreme in the hottest month in the worst location is 120°F; the associated diurnal cycle has an amplitude of 29 F°. The withstanding upper 10-percent extreme is 128°F for a 2-year planned life, increasing to 133°F for a 25-year planned life. (K)

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Unclassified

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| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| High temperature extremes | | | | | | |
| Design criteria | | | | | | |

Unclassified

Security Classification

AFCRL-70-0332
JUNE 1970
ENVIRONMENTAL RESEARCH PAPERS, NO. 323

# UNUSUAL EXTREMES AND DIURNAL CYCLES OF DESERT HEAT LOADS

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Norman Sissenwine

## Errata

Table 1, which gives ratios of hourly departures from the maximum of temperature, windspeed and solar radiation to the daily maximum, should be corrected, to show the last line as follows:

| Hour of the Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Radiation, hottest day | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.95 | 0.76 | 0.55 |
| Hour of the Day | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Radiation, hottest day | 0.35 | 0.18 | 0.07 | 0 | 0 | 0.07 | 0.18 | 0.35 |
| Hour of the Day | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Radiation, hottest day | 0.55 | 0.76 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Hence, there will be a correction to Table 2d to give the solar radiation ($BTU/ft^2/hr$) at Death Valley, as follows:

| Hour of the Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Solar Radiation | 0 | 0 | 0 | 0 | 0 | 18 | 86 | 162 |
| Hour of the Day | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Solar Radiation | 234 | 295 | 335 | 360 | 360 | 335 | 295 | 234 |
| Hour of the Day | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Solar Radiation | 162 | 86 | 18 | 0 | 0 | 0 | 0 | 0 |

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