Contract DA19-129-AMC-366(N)

FINAL REPORT

Maximum Hourly Durations of High and Low Temperatures

Prepared At
Indiana State University
Terre Haute, Indiana

Mrs. Jane Westbrook, Project Officer
Mr. Edward J. Corbett, Contract Officer
Dr. John C. Hook, Principal Investigator

Contract DA19-129-AMC-366(N)

Final Report

Summary: A method for predicting the most probable duration of high and low temperatures from the absolute maximum and absolute minimum was developed by the U.S. Army Natick Laboratories. The method is applicable for any temperature, any month, any place in the world. It was the purpose of this contract to make extensive tests of the method and make modifications if necessary.

The tests were conducted using actual data on temperature durations from United States (including Alaska) and Canadian stations for January and July of 1961, 1962, and 1963 and from fifteen other stations all over the world for July for as long as they had been keeping records of durations. The tests were made by comparing the actual durations with those predicted by the model.

For low temperatures (-40°F, -30°F, -20°F) the prediction method performs almost perfectly. The coefficient of correlation between the actual and predicted temperature durations was above .90 for all years and for all temperatures tested.

For high temperatures (110°F, 100°F, 90°F) the method has a tendency to overpredict the durations. This can be remedied by assuming a maximum value of 20 hours duration for temperatures of 110° and 100° and above, and by using the predicted values for a mean year or for one year in five for temperatures of 90° and above. For temperatures of 80° and above there is close agreement between the actual and predicted temperature durations.

Contract DA19-129-AMC-366(N)

Final Report

Introduction:

When working in a science like Climatology, it is usually necessary for an investigator to rely on data gathered by others. The need for continent-wide or world-wide information and records of considerable length make the material gathered by any one individual of limited value in most studies. On the other hand, the data gathered by others may not be directly applicable to the particular problem under investigation. When this occurs, further manipulation of the data to obtain the required information is sometimes possible. This is the situation with temperature durations.

For certain design and testing criteria, the duration of extreme temperatures would seem to have some significance. For example, a lubricant might be able to withstand temperatures of 110 degrees Fahrenheit for a period of an hour or two but fail if such a high temperature continued for a much longer period. Or some article of clothing might give adequate protection if the temperature fell to twenty degrees below zero for only a brief period, but be completely inadequate if it remained at that level for say, twenty-four hours. Data on the world-wide distribution of the duration of extreme temperatures is not readily available. For most climatic stations, such records have not even been compiled. If one is to work with temperature durations, therefore, some method must be developed to obtain them from other readily available data.

Such a method was developed by Mrs. Jane Westbrook of the U.S. Army Natick Laboratories and was described by her in a paper presented at the annual meeting of the Association of American Geographers, Miami, Florida, in April, 1962. The method was further elaborated in a paper by Mrs. Westbrook and John Hook presented at the Association meetings in Syracuse, New York, in April, 1964.

The basis of Mrs. Westbrook's method is a prediction model in the form of a nomograph. (Actually, there are two nomographs, one for high temperatures and one for low temperatures. These nomographs are included in this report as Appendix I.) With the aid of the nomographs it is possible to predict the probability of a temperature duration at or above a certain value for any month of the year. The data necessary are the absolute maximum and the absolute minimum temperatures ever recorded at that station. Such data are readily available in the British Air Ministry publication "Tables of Temperature, Relative Humidity and Precipitation for the World," and in various publications of the U.S. Weather Bureau. The absolute maximum and absolute minimum temperatures are reduced to a standard scale of 100; the desired temperature is taken as a percentage of the range, the nomograph entered and the probable value of the duration read from the scale therein.

The prediction model was constructed in an empirical way, using data on temperature durations and absolute temperature range from one hundred United States stations. It is applicable to any station in the world for any temperature.

Preliminary tests were conducted with the model in 1963 and then the method was used to construct a series of maps depicting the duration of specific temperatures for the entire world. As these maps were evaluated by various regional experts, some doubt arose as to the validity of some of the durations depicted. It was deemed advisable to conduct further tests on the model and make modifications of it, if possible, while still retaining its general nature. This work was conducted under contract DA19-129-AMC-366(N).

<u>The Test Data</u>: In constructing the world maps of temperature durations, the absolute temperature range of over one thousand stations were used, of which some 275 were in North America. Data on the actual durations of January and

July temperatures for the years 1961, 1962 and 1963 for 63 of these stations in the United States (including Alaska) and Canada were available. Air Weather Service also furnished data on the maximum duration of July temperatures for 15 stations from throughout the world. These stations had records ranging in length from two to seventeen years.

The Effect of the Length of the Station Record on the Predicted and Observed Durations: In the construction of the world maps of temperature durations and in conducting the tests of the prediction model, it was necessary to use climatic records of varying length. One aspect of this investigation, therefore, was to determine how accurately records of 25 years, ten years, and five years in length reflect the absolute maximum and the absolute minimum recorded during a period of 50 years. Data were obtained from the Climatic Summary of the United States (Bulletin W), U.S. Department of Agriculture, Weather Bureau. The stations were chosen because they had records of more than fifty years. In selecting samples, the 50 years and the 25 years immediately preceding 1930 (the most recent data in bulletin W) were chosen. The 10-year and five-year periods were randomly selected from the 50-year data.

The records for 25 years are essentially the same as the 50-year records. For the January high temperature, the mean is 70° for the 50-year period and 69° for the 25-year period. The difference in the means of the two periods for both the high and low July temperatures were also one degree (50 year July high 104°; 25 year July high 103°; 50 year July low 49°; 25 year July low 50°). The difference in the January low temperatures was a little greater, -13° for the 50-year period, -9° for the 25-year one. Tests of the differences between the means and the difference between the variance in the two series show that there is no statistically significant difference between them.

The difference between the 50-year, 10-year, and 5-year records are shown in Table I.

TABLE I

Differences Between 50-year, 10-year and 5-year Records

	Mean °F			Standard Deviation °F		
	50 yr.	10 yr.	5 yr.	50 yr.	10 yr.	5 yr.
Ab. Max. Jan.	70	67	66	11	9	9
Ab. Min. Jan.	-13	-8	-5	18	18	18
Ab. Max. July	104	101	100	5	5	5
Ab. Min. July	49	51	53	8	8	8

The five-year and ten-year reeords give very similar results, the biggest departure between the two being three degrees in the mean value for the absolute minimum for January.

The greatest departure between the mean values of the five- and fifty-year records is again found in the absolute minimum for January, in this case, eight degrees. For the January maximum and the July maximum and minimum, the five-year records were within four degrees of the 50-year record.

In terms of temperature durations, a comparison of the values obtained using the mean values from the 5-year and 50-year records is shown in Table II.

TABLE II

A Comparison of Temperature Durations Computed Using Mean Values of 5-year and 50-year Records

		Predicted Temperature Duration (Hours)			
Temperature	Length of Record	One Year in Two	One Year in Five	One Year in Ten	One Year in 25
0 °F	5-year record	0	0	5	12
	50-year record	0	8	10	52
90° F	5-year record	7	10	11	30
	50-year record	9	14	18	85
80° F	5-year record	38	95	150	300
	50-year record	39	98	160	325

The predicted temperature durations based on the 5-year and 50-year records are practically identical except for some difference in the one year in twenty-five category. This similarity is due in part to the closeness of the 5-year and 50-year records and is also due to the way the prediction model works. The length of the prediction is a function of two variables, the absolute minimum temperature and the temperature range. With a 5-year record both of these values tend to be smaller than with a 50-year record, and the predicted durations can be very similar. Omaha, Nebraska furnishes an excellent example of this point. The data and computations for Omaha are shown in Table III.

TABLE III

Computation of Temperature Durations of 80° for July for Omaha, Using 5-year and 50-year Records

5 year July Max.	99
July Min.	62
Range	37

$$\%\ \text{of Temp. Range} = \frac{\text{Given Temp.} - \text{Min. Temp.}}{\text{Range}}$$

$$\%\ \text{of Temp. Range} = \frac{80-62}{37} = \frac{18}{37} = 49\%$$ – This is the value used to enter nomograph.

	1/2	1/5	1/10	1/25
Predicted Durations	70	175	240	700

50 year July Max.	109
July Min.	50
Range	59

$$\%\ \text{of Temp. Range} = \frac{80-50}{59} = \frac{30}{59} = 51\%$$

	1/2	1/5	1/10	1/25
Predicted Durations	57	168	220	683

A comparison of the predicted temperature durations for some other stations that showed a considerable difference in their five-year and fifty-year records are shown in Table IV.

TABLE IV

A Comparison of Temperature Durations Computed Using 5-year and 50-year Records for Certain Specific Stations

Station	Temperature and Month	Length of Record	Ab. Max.	Ab. Min.	Predicted Duration (Hours): One Year in Two	One Year in Five	One Year in Ten	One Year in 25
Harve, Mont.	-20°	5 yr.	61	-39	3	10	13	60
	January	50 yr.	61	-57	12	28	40	110
Helena, Mont.	-20°	5 yr.	55	-32	0	6	8	45
	January	50 yr.	63	-42	4	12	15	70
Williston, N.D.	-20°	5 yr.	50	-38	4	11	14	62
	January	50 yr.	52	-49	12	22	38	110
St. Paul, Minn.	-20°	5 yr.	51	-26	0	0	5	12
	January	50 yr.	51	-41	7	13	18	78
Sacramento, Cal.	100°	5 yr.	105	48	0	4	5	8
	July	50 yr.	114	47	7	10	12	30
	90°	5 yr.	105	48	9	15	21	125
	July	50 yr.	114	47	16	43	64	350
	80°	5 yr.	105	48	38	95	150	325
	July	50 yr.	114	47	65	185	235	455
San Francisco, Cal.	80°	5 yr.	84	63	7	10	12	32
	July	50 yr.	98	47	18	46	71	367
Omaha, Neb.	90°	5 yr.	99	62	9	13	16	70
	July	50 yr.	109	50	12	30	45	258
	80°	5 yr.	99	62	70	175	240	700
	July	50 yr.	109	50	57	168	220	683

Even with these extreme cases, the predicted durations seem to be of the same order of magnitude, except for variations in the one year-in-twenty-five and in the predictions for 80° for Sacramento.

There is a high correlation between the five-year and fifty-year records, and if greater precision in the predicted duration is desired, the five-year records can be adjusted using regression equations. These regression equations are presented in Table V. Because the five-year records and the ten-year records are so similar, these equations could also be used to adjust ten-year records.

TABLE V

Regression Equations to Predict 50-year Temperature Extremes from 5-year Records

Month	r (5-year and 50-year records)	Regression Equation
January Maximum	.93	$X_c = .80Y + 18.3$
January Minimum	.97	$X_c = .99Y - 7.7$
July Maximum	.75	$X_c = .65Y + 39.4$
July Minimum	.88	$X_c = .86Y + 3.7$

where X_c = 50-year value
Y = 5-year value

Testing the Prediction Model: Low Temperatures: The method was tested by comparing the actual temperature durations as recorded at specific stations with the durations predicted by the model. The results of the low temperature comparisons are shown in the following tables.

TABLE VI

A Comparison of Predicted Durations with Actual Durations (1961-63) of -40° F and Below (Hours)-January

Station	Actual Duration		Predicted Duration	
	Shortest	Longest	1 yr. in 2	1 yr. in 25
Barter Island, Alaska	0	8	0	28
Fairbanks, Alaska	0	39	8	80
McGrath, Alaska	0	13	8	79

TABLE VII

A Comparison of Predicted Durations with Actual Durations (1961-63) of -30° F and Below (Hours)-January

Station	Actual Duration		Predicted Duration	
	Shortest	Longest	1 yr. in 2	1 yr. in 25
Barrow, Alaska	4	51	10	95
Barter Island	2	71	7	75
Bethel	0	2	2	55
Fairbanks	2	91	15	138
Kotzebue	0	11	1	53
McGrath	18	117	15	141
Port Arthur, Canada	0	6	0	27

TABLE VII (Con't.)

Station	Actual Duration		Predicted Duration	
	Shortest	Longest	1 yr. in 2	1 yr. in 25
Regina	0	17	8	78
Winnipeg	3	13	4	59
Duluth, Minn.	0	7	0	27
International Falls	6	13	4	60
Bismark, N.D.	0	2	0	45
Huron	0	2	0	9
La Crosse, Wis.	0	1	0	58
Helena, Mont.	0	3	0	27

With temperature durations of -40° F and below and -30° F and below, the actual durations observed during the three years 1961-63 were within the range of durations predicted by the model in every single case.

The nomograph was used to predict the probable temperature durations for four classes of years, i.e. the durations that would be expected in one year in two (an average year), one year in five, one year in ten, and one year in twenty-five. Since the values from twenty-five-year records are so close to those derived from fifty-year records, the one year in twenty-five can be considered in most cases as a maximum value. Also, since the one year in two is an average year, it would be expected that half the values would be greater than this value, but that half of them would be less. Tables VI and VII indicate that the shortest duration recorded at a station is in many cases less than the value predicted for a mean year.

The coefficient of correlation between the actual duration of -30°F and that of the class of year that was closest to the actual duration was computed for the fifteen stations in Table VII for each individual year, 1961, 1962, and 1963. The values of the coefficient of correlation were as follows: for 1961, .97; for 1962, .96; and for 1963, .99.

TABLE VIII

A Comparison of Predicted Durations with Actual Durations (1961-63) of -20°F and Below (Hours)-January

Station	Actual Duration: Shortest	Actual Duration: Longest	Predicted Duration: 1 yr. in 2	Predicted Duration: 1 yr. in 25
Barrow, Alaska	93	195	22	177
Barter Island	24	181	16	155
Bethel	0	57	11	103
Fairbanks	28	138	30	210
King Salmon	0	16	5	88
Kotzebue	11	128	12	110
McGrath	43	132	32	219
Nome	0	27	11	109
Edmonton, Canada	0	14	14	132
Calgary	0	16	10	89
Port Arthur	9	18	7	74
Montreal	0	3	0	16
Regina	11	36	15	138
Winnipeg	22	39	12	114
Colorado Springs, Colo.	0	1	0	11
Denver	0	12	0	9
Pueblo	0	7	0	16
Rockford, Ill.	0	3	0	11
Des Moines, Iowa	0	4	0	21
Waterloo	0	7	0	42
S. Ste. Marie, Mich.	0	3	5	68
Duluth, Minn.	12	31	6	70
International Falls	18	40	12	115
Minneapolis	4	15	0	50
Rochester	0	17	4	61
Grand Is., Neb.	0	7	0	12
North Platte	0	3	0	10
Bismark, N.D.	7	11	8	79
Fargo	9	15	3	58
Huron, S.D.	11	12	0	40
Rapid City	0	9	0	11
Sioux Falls	5	6	0	11
Green Bay, Wis.	0	13	4	61
La Crosse	0	13	10	85
Madison	0	10	0	20
Milwaukee	0	4	0	9
Casper, Wyo.	0	16	4	63
Cheyenne	0	31	2	56
Sheridan	0	16	0	50
Billings, Mont.	0	6	0	18
Gr. Falls	0	19	0	44
Helena	0	16	5	66
Missoula	0	11	0	15

A comparison of the predicted durations and actual durations for 1961-63 of -20°F are shown in Table VIII. Here there are four stations (underlined in the table) where the actual duration was somewhat longer than the predicted duration. The greatest difference between the two values is at Barter Island, Alaska, where the longest observed duration of -20° F is 26 hours longer than that predicted by the model. This amounts to an underprediction of some 17% and can probably best be explained in terms of some new records being set in these years. Otherwise, the observed durations are well within the limits predicted by the model. Again, the coefficients of correlation between the actual durations of -20° and that of the class of year that was closest to the actual duration was computed for the 43 stations in Table VIII for the years of 1961, 1962, and 1963. The following values were obtained: for 1961, .98; for 1962, .97; for 1963, .99.

It must be concluded, therefore, that in predicting the duration of low temperatures the model performs nearly to perfection.

<u>Testing the Prediction Model: High Temperatures</u>: The high temperature phase of the model was tested in the same manner as the low temperature phase described above.

Table IX shows the results of the test of durations of 110° or higher. In this case, as with the low temperature durations, the actual durations are well within the range predicted by the model. With Dhahran, Saudi Arabia, there is a tendency for the model to over-predict for one year in twenty-five. The durations of 110° and above listed in Table IX are the longest on record in the world. The longest recorded is the 7-hour duration for Dhahran and durations of 110° much longer than this do not appear to be physically possible. That is, the records indicate that such high temperatures cannot be maintained after sunset and therefore durations as long as twenty-four hours should not be expected.

TABLE IX

A Comparison of Predicted and Actual Durations of 110°F or Higher-World-wide Stations-July

Station	Length of Record-Yrs.	Longest Duration-Hrs.	Predicted Durations: 1 yr. in 2	1 yr. in 5	1/10	1/25
Dhahran, Saudi Arabia	14	7	6	9	11	24
Ben Guerir, Morocco	11	6	0	4	5	8
Yuma, Ariz.	3	6	5	8	9	15
Las Vegas, Nev.	3	6	0	1	4	7
Phoenix, Ariz.	3	5	4	7	8	10
Khartoum, Sudan	2	5	0	0	3	5
Port Lyautey, Morocco	17	3	0	0	3	5
Tripoli, Libya	15	3	0	4	5	8

The tendency for the model to overpredict for long durations is more pronounced in Table X. The durations of 100° (Table X) are like 110° in that such temperatures cannot be maintained very long after sunset. Table XI, the durations of 100° for 1961-1963 also shows the same tendency. On the other hand, for shorter durations of these temperatures, the model predicts in a most satisfactory way.

TABLE X

Longest Recorded Durations of 100°F or Higher; World-Wide Stations (over 10 hours) - July

Station	Length of Record-Yrs.	Longest Duration-Hrs.	Predicted Durations: 1 yr. in 2	1 yr. in 5	1/10	1/25
Dhahran, Saudi Arabia	14	16	40	110	160	325
Khartoum, Sudan	2	15	7	10	11	24
Ben Guerir, Morocco	11	12	9	13	17	75
Tripoli, Lybia	15	12	9	15	20	100
Port Lyautey, Morocco	17	12	7	10	11	29
Las Vegas, Nev.	3	12	6	9	10	22
Phoenix, Ariz.	3	12	13	32	47	271
Yuma, Ariz.	3	11	14	36	52	301

TABLE XI

A Comparison of Predicted Durations with Actual Durations (1961-1963) of 100° F and Above (Hours)-July-U.S. Stations

Station	Actual Duration		Predicted Duration			
	Shortest	Longest	1 yr. in 2	1 yr. in 5	1/10	1/25
Birmingham, Ala.	0	2	3	6	7	10
Little Rock, Ark.	0	2	4	7	8	12
Albuquerque, N.M.	0	3	0	3	5	7
Okla. City, Oka.	0	7	5	8	9	14
Abilene, Texas	0	5	5	8	9	17
Austin	0	4	4	7	8	12
Dallas	0	6	0	5	6	8
El Paso	0	7	0	5	6	8
Phoenix, Ariz.	5	12	13	32	47	271
Yuma	6	11	14	36	52	301
Fresno, Calif.	4	7	8	12	15	58
Sacramento	0	9	7	10	12	32
Boise, Idaho	0	3	5	8	9	17
Las Vegas, Nev.	8	12	6	9	10	22
Portland, Ore.	0	5	1	5	6	8
Salt Lake City, Utah	0	5	0	3	5	7
Pueblo, Colo.	0	1	0	1	4	7
Sioux City, Iowa	0	2	4	7	8	12
Dodge City, Kansas	0	1	2	6	7	9
Omaha, Neb.	0	3	4	7	8	11
Bismark, N.D.	0	3	5	8	9	15

The following are the reasons for the overpredictions. First, the model works on the assumption that the duration of a temperature is independent of its actual value. For most temperatures this is a valid assumption and is the reason that the same prediction model can be used for any temperature. However, as the data on the actual durations show, there are limits to the duration of very high temperatures (100° and above) set by the ability of the earth's atmosphere to retain heat after sunset. Secondly, the model assumes that the variability of temperature durations from one year to another is independent of the temperature and of the season. That this is not strictly correct was indicated in the analysis of the length of station records. There (Table I) it was shown that the standard deviation of the absolute maximum temperature for January varied from 9° to 11°, depending on the length of the record, while the standard deviation of the July absolute maximum was only 5°. This difference in variability of maximum temperatures would be reflected in variability in durations as well. Another measure of the variability of temperature is a comparison of the average daily high temperature of a station and the absolute maximum for the month. If these two values are close it indicates that the temperatures are quite uniform from year to year. Table XII lists the mean values of these temperatures for the 63 stations used in the tests of the high temperature phase of the model. This comparison shows that the difference between the average daily high temperature and the absolute maximum temperature is 10.2° less in July than in January. In other words, there is less variability from year to year in the July temperatures than in January temperatures. Temperature variability measured in the above way is also related to latitude. When the difference between the average daily high temperature and the absolute maximum temperature for July of 73 stations chosen from all over the world was correlated with their latitude, the coefficient of correlation was .73. This means the lower the latitude, the lower will be the variation in temperature from year to year. It would be expected that this variation in temperature would also be reflected in variations in durations. It seems, therefore, that the unusual temperatures and durations that were predicted and observed in the low temperatures (as indicated by the one year in twenty-five predictions) are not to be expected in July high temperatures and durations especially in low latitudes.

TABLE XII

A Comparison of the Average Daily High Temperature and Absolute Maximum Temperature and the Average Low Temperature and the Absolute Minimum Temperature for January and July (Mean of 63 U.S. and Canadian Stations)

	January	July
Mean Average Daily High	43.5	86.4
Mean Absolute Maximum	72.6	105.3
Mean Difference	29.1	18.9
Mean Average Daily Low	26.4	65.6
Mean Absolute Minimum	-9.5	50.0
Mean Difference	35.9	15.6

For temperature durations of 110° and above and 100° and above the tendency for the model to overpredict can be corrected easily and without changing the general nature of the model itself. Tables IX, X, and XI indicate that for durations of these temperatures of under 20 hours, the model works satisfactorily. For stations where the prediction is greater than 20 hours, 20 hours should be substituted as a maximum duration.

The actual and predicted durations of 90° and above are shown in Tables XIII and XIV. Temperatures at this level are possible for a period of 24 hours or more; at Dhahran a duration of 141 hours has been recorded and at Phoenix one of 39 hours has been observed. The model still overpredicts the long durations, however. For durations of 24 hours or more, the most realistic values are given by the one year in two predictions. This is also true for most stations with durations less than twenty-four hours, but there are some at which the actual values are greater. In only one case, however, is the one year in five prediction exceeded by the observed durations. (Pueblo, Colorado, and there the difference is only one hour) Most of these observations are for three years only, but recently data from two of the stations (Dallas and Des Moines) based on ten year records became available and the values are essentially the same for the 90° durations. To summarize, for durations of 90° and above of over twenty-four hours, the most realistic values given by the model are those for one year in two. This is also true for values under twenty-four hours, but some stations will have actual durations that are longer than those predicted. If more conservative estimates are desired, the one year in five predictions should be used.

TABLE XIII

Longest Recorded Durations of 90° F or Higher (over 15 Hrs.)
World-Wide Stations - July

Station	Length of Record-Yrs.	Longest Duration-Hrs.	Predicted Durations (Hrs.) 1 yr. in 2	1 yr. in 5	1/10	1/25
Dhahran, Saudi Arabia	14	141	225	400	450	575
Phoenix, Ariz.	3	39	65	185	235	455
Khartoum, Sudan	2	21	22	55	100	275
Yuma, Ariz.	3	20	65	185	235	455
Ben Guerir, Morocco	11	19	35	85	135	300
Port Lyautey, Morocco	17	18	19	53	75	250
Tripoli, Libya	15	18	40	110	160	325
Las Vegas, Nevada	3	18	13	34	50	287
Dallas, Texas	3	16	11	25	38	216

TABLE XIV

A Comparison of Predicted Durations with Actual Durations
(1961-1963) of 90° and Above-July-U.S. Stations

Station	Actual Duration (Hrs.) Shortest	Longest	Predicted Duration (Hrs.) 1 yr. in 2	1 yr. in 5	1/10	1/25
Portland, Me.	0	7	8	13	16	64
Boston, Mass.	0	9	9	15	21	102
Albany, N.Y.	2	8	8	12	15	61
Buffalo, N.Y.	0	6	2	6	7	9
Syracuse	2	8	7	10	12	34
Providence, R.I.	0	7	6	9	10	22
Wash., D.C.	6	10	11	22	34	191
Louisville, Ky.	5	7	11	22	33	183
Baltimore, Md.	6	9	12	30	44	254
Columbus, Ohio	0	7	10	19	28	154
Philadelphia, Pa.	0	9	10	17	24	126
Pittsburgh, Pa.	0	5	8	12	14	55
Scranton, Pa.	0	6	5	8	9	13
Norfolk, Va.	2	8	11	23	34	195
Richmond, Va.	5	9	10	20	29	159
Charleston, W.Va.	0	2	10	19	26	142
Birmingham, Ala.	5	11	14	37	53	304
Mobile, Ala.	4	9	12	29	43	244
Jacksonville, Fla.	6	10	16	44	65	352
Key West, Fla.	2	7	12	27	40	232
Miami, Fla.	4	6	7	9	10	22
Tampa	6	8	8	12	15	63
Atlanta, Ga.	0	7	11	21	31	173
Wilmington, N.C.	7	9	10	17	23	117
Charleston, S.C.	7	9	13	32	46	266
Nashville, Tenn.	5	8	12	26	38	220
Little Rock, Ark.	9	11	16	44	66	354
New Orleans, La.	4	8	13	34	50	28[illegible]

TABLE XIV (Con'd.)

Station	Actual Duration (Hrs.) Shortest	Longest	Predicted Duration (Hrs.) 1 yr. in 2	1 yr. in 5	1/10	1/25
Albuquerque, N.M.	6	11	10	20	30	166
Okla. City, Okla.	9	12	15	41	59	334
Abilene, Texas	6	12	16	43	63	347
Austin, Texas	7	11	15	41	60	337
Dallas, Texas	9	16	11	25	38	216
El Paso, Texas	9	14	11	25	38	216
Phoenix, Ariz.	16	39	65	185	235	455
Yuma, Ariz.	18	20	65	185	235	455
Fresno, Cal.	9	14	22	54	88	413
Sacramento, Cal.	9	11	16	43	64	350
San Francisco, Cal.	0	3	5	8	9	16
Boise, Idaho	7	10	12	28	42	239
Helena, Mont.	0	7	6	9	10	21
Missoula, Mont.	5	7	7	10	12	35
Las Vegas, Nevada	17	18	13	34	50	287
Reno, Nevada	4	8	8	12	14	51
Portland, Ore.	0	9	10	17	23	117
Salt Lake City, Utah	9	11	9	13	16	71
Spokane, Wash.	0	9	10	17	24	125
Pueblo, Colo.	8	12	8	11	14	48
Chicago, Ill.	0	9	10	17	24	123
Indianapolis, Ind.	1	4	10	19	27	142
Des Moines, Iowa	15	19	12	27	40	230
Sioux City, Iowa	14	19	11	23	35	200
Dodge City, Kansas	15	20	11	21	32	177
Detroit, Mich.	12	19	10	16	22	112
Duluth, Minn.	0	10	9	14	17	80
Minneapolis, Minn.	9	12	10	20	28	155
Kansas City, Mo.	17	44	14	40	58	332
Omaha, Neb.	16	20	12	30	45	258
Bismark, N.D.	8	14	11	22	32	182
Madison, Wis.	11	15	11	21	31	172

Table XV shows the comparison of the actual and predicted durations of 80° for July. At this temperature, the model predicts some very long durations, but very long durations have also been observed. The observed durations are within the range of durations predicted by the model and the tendency to overpredict is not present. In other words, for temperatures of 80°, the model performs in a satisfactory manner.

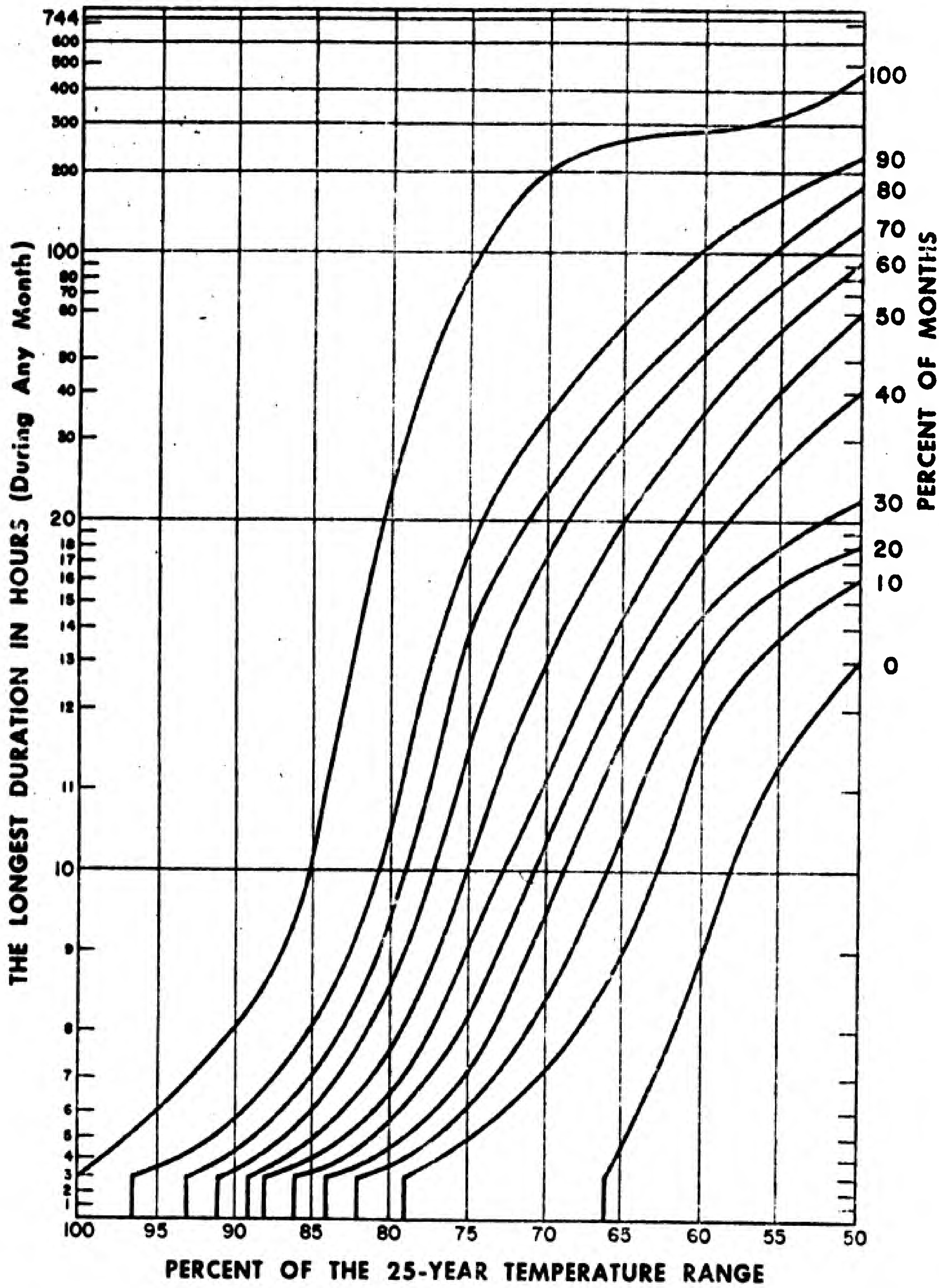
TABLE XV

Longest Recorded Durations of 80° F or Higher During July (over 40 Hours)

Station	Length of Record-Yrs.	Longest Duration-Hrs.	Predicted Duration 1 yr. in 2	1 yr. in 5	1/10	1/25
Dhahran, Saudi Arabia	14	744	600	690	700	744
Key West, Fla.	3	707	154	322	380	710
Yuma, Ariz.	3	592	203	380	430	690
Khartoum, Sudan	2	355	80	250	275	500
Phoenix, Ariz.	3	350	235	410	460	710
Las Vegas, Nevada	3	186	46	133	190	633
Miami, Fla.	3	159	75	205	255	465
Tripoli, Libya	15	119	140	300	375	550
Dallas, Texas	3	116	65	185	235	455
Kangnung, Korea	12	108	40	110	160	320
Tampa, Fla.	3	90	80	215	265	470
Ben Guerir, Morocco	11	86	125	300	350	500
Dakar, Senegal	3	65	41	115	165	325
Port Lyautey, Morocco	17	47	90	225	300	500
Kansas City, Mo.	3	44	80	215	265	470

APPENDIX I

PROBABILITY OF TEMPERATURE DURATIONS ABOVE STATED LEVELS



PROBABILITY OF TEMPERATURE DURATIONS BELOW STATED LEVELS