Engineering Weather Data Handbook (2 Feb 2015)

INTRODUCTION

Background**.** The data in this handbook were compiled by the 14th Weather Squadron (14 WS), formerly the Air Force Combat Climatology Center (AFCCC), at the request of the Air Force Civil Engineer Support Agency (HQ AFCESA). Sites were identified by AFCESA, US Army Corps of Engineers (USACE), and the Naval Facilities Engineering Command (NAVFACENGCOM). Final selection of sites was based upon availability of climatological data. Most are located at military installations supporting airfield operations, or at local airports/airfields. Department of Defense agencies and DoD contractors may obtain data for additional sites by providing site coordinates to the climatological services section via the Support Assistance Request form on the 14 WS web site.

The information in Engineering Weather Data (EWD) is organized by location. The following sections describe each of the products contained in EWD.

CLIMATE SUMMARY

Location Information**.** This section contains a summary table which includes site name, location, elevation (above mean sea level), World Meteorological Organization (WMO) number or Station ID, period of record (POR), and average (atmospheric) pressure not corrected to sea level (higher elevations result in lower pressures). The WMO number is a unique number assigned to every location in the world that takes and transmits regular weather observations. The Station ID is a combination of a station's network type (denotes the network the station belongs to) and platform ID (represents the source of the observation). The POR is the time frame over which the data used to compute the statistics in this handbook was compiled.

Design Values**.** Design values are provided for dry bulb temperature, wet bulb temperature, and humidity ratio at specific percentile frequencies of occurrence.

The old EWD summer design values of 1, 2.5, and 5 percent were based on the warmest four months of the year. In the United States this was standardized as June through September. The new design values of 0.4, 1, and 2 percent are based on the entire year. The old winter design values of 99 and 97.5 percent were based on the three coldest months of the year (December through February). The new winter design values of 97.5, 99.6 and 99 percent are based on the entire year. In other words the new design values are **annual** values not **seasonal** values.

In general, for mid-latitude locations with continental climates (hot summer – cold winter), there are some *generalizations* that can be made about the differences between the old and new values. The new 0.4% annual value is comparable to the old 1% seasonal value. The new 1% annual value is usually about a degree cooler than the old 2.5% seasonal value. The new 2% annual value is similar to the old

5% seasonal value. The new 99.6% and 99% annual values are generally cooler than the old 99% and 97.5% seasonal values; however there is more variability between stations.

The new design values were instituted for several reasons. At some locations, the warmest or coldest months of the year do not fall into the months listed above. It is easier to compare locations that are in tropical or marine climates where there is less seasonal variability. It is also more straightforward to compare Southern Hemisphere locations. Finally, this is the same convention used by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) in their 1997 Handbook of Fundamentals.

Dry Bulb Temperature:

Median of Extreme Highs (or Lows). The dry bulb temperature extreme high (or low) is determined for each calendar year of the POR along with the coincident values for wet bulb temperature, humidity ratio, wind speed, and prevailing wind direction. Median values are determined from the distribution of extreme highs (or lows).

0.4%, 1.0%, 2.0%, 97.5%, 99.0%, and 99.6% Occurrence Design Values. Listed is the dry bulb temperature corresponding to a given annual cumulative frequency of occurrence and its respective mean coincident values for wet bulb temperature, humidity ratio, wind speed, and prevailing wind direction. This represents the dry bulb threshold which exceeded its respective percent of time, taking into account the entire POR. For example, the 1.0% occurrence design value temperature has been exceeded only 1% of the time during the entire POR. All the observations occurring within one degree of the design value are grouped, and the coincident mean values for wet bulb temperature, humidity ratio, and wind speed are calculated. The prevailing wind direction (the 'mode' of the wind direction distribution) is also calculated.

Mean Daily Range. The mean daily range (difference between daily maximum and daily minimum temperatures) is the average of all daily dry bulb temperature ranges for the POR.

Wet Bulb Temperature:

Median of Extreme Highs for wet bulb temperature is the highest annual extreme wet bulb temperature averaged over the POR. The corresponding mean coincident values are determined the same way as for dry bulb temperature. **0.4%, 1.0 %, 2.0%** occurrence wet bulb temperature design values and the corresponding mean coincident values for dry bulb temperature are determined the same way as for dry bulb temperature.

Humidity Ratio:

Median of Extreme Highs for humidity ratio is the highest annual extreme averaged over the POR. The corresponding mean coincident values are determined the same way as for dry bulb temperature. Design values are provided for "Humidity Ratio" at the **0.4%, 1.0%, and 2.0%** occurrence and the corresponding mean coincident values for dry bulb temperature, vapor pressure, wind speed, and wind prevailing direction.

Air Conditioning/Humid Area Criteria:

These are the number of hours, on average, that dry bulb temperatures of 93 ºF (34 ºC) and 80 ºF (27 ºC) and wet bulb temperatures of 73 ºF (23 ºC) and 67 ºF (19 ºC) are equaled or exceeded during the year.

Other Site Data:

This information is provided *for general reference only and should NOT be used as the basis for design.* There are some locations for which this data is not available. In these cases, that portion of the table will be left blank.

Weather Region. There are eleven weather regions developed by the Department of Energy. They are defined by the range of cooling-degree days and heating-degree days.

Ventilation Cooling Load Index. The VCLI is a two-part index which defines the total annual cooling load for ventilation air by calculating sensible heat load separately from the latent heat load (moisture). The results are expressed in ton-hours per cubic feet per minute per year of latent and sensible load. Values for sensible heat load are calculated by comparing the outdoor temperature to indoor conditions (75 ºF and 60% relative humidity [RH]), and calculating how much energy is required to bring the outdoor air to the indoor temperature. The latent load is calculated similarly. Separate calculations are made for each hour of the year, and them summed to form the annual VCLI (Harriman 1997).

Average Annual Freeze-Thaw Cycles. This is simply the average number of times per year that the air temperature first drops below freezing and then rises above freezing, regardless of the duration of either the freezing or thawing. The number of cycles is summed per year, and averaged over the entire POR. Days with high temperatures or low temperatures at 32 °F (0 ºC) are not counted for a freeze-thaw cycle. A cycle is counted only when the temperature drops below freezing (31 °F [-0.5 ºC] or colder) or goes above freezing (33 °F [0.5 ºC] or warmer).

Other Values. The following are derived from sources other than the 14 WS. Engineers and architects should contact the organizations listed below for current values, including background information and complete guidelines for use of these data elements.

Groundwater**:**

The National Groundwater Educational Foundation 601 Dempsey Road Westerville OH
(800) 551-7379

Note**:** Average groundwater temperature parallels long-term average air temperature, because soil at a depth of 50 feet (15 meters) does not undergo significant temperature change over the course of a year. Soil temperature at 50 feet stays slightly warmer than average annual air temperature by about 2.5 degrees Fahrenheit (1.4 degrees Celsius).

Rain Rate:

International Plumbing
Code BOCA International
4051 West Flossmoor
Road Country Club Hills
IL 60478
(708) 799-2300

Frost Depth, Basic Wind Speed, Ground Snow Loads:

ANSI/ASCE 7-95 American Society of Civil Engineers 1015 15th Street NW, Suite 600 Washington DC 20005
(800) 548-2723

Note**:** Frost depth penetration data was obtained from TI 809-01, Load Assumptions for Buildings (1986) which is published by the Army Corps of Engineers. Wind and snow load data are provided by the American Society of Civil Engineers (1995); where snow load data was not available from ASCE, TI-809-01 (1986) was used. However, since the completion of this project, a new version of TI-809-01 has also been completed. Many of the new snow loads have changed.

Suggestions for Use. The dry bulb, wet bulb, and humidity ratio values shown are peak load conditions and are used for sizing mechanical equipment. Design guidance determines the level of occurrence applied.

The 0.4% Dry Bulb Temperature value is seldom used for sizing conventional comfort control systems, but is sometimes appropriate for mission-critical systems where equipment failure due to high heat would be unacceptable. Using the 0.4% value for equipment sizing requires that the engineer consider its operation at less-than-peak design conditions. In the past, oversized cooling equipment has been incapable of modulating during the more common range of operating conditions, yielding comfort control problems. Also, over-sized equipment cycles on and off more frequently, increasing maintenance costs and failing to remove enough moisture to maintain humidity control.

Similar cautionary notes apply to the extreme low dry bulb temperature. Heating equipment designed for extreme conditions must be carefully evaluated to ensure that they will modulate properly to maintain comfort at less extreme outdoor temperatures that occur 99.6% of the hours during the year.

The mean coincident value for humidity at the 0.4% peak dry bulb temperature is not the highest moisture value, and must not be used for design of humidity control systems. The mean coincident value is the arithmetic average of all the moisture levels which occur when the dry bulb temperature is high. However, the highest moisture values typically occur when the dry bulb temperatures are lower.

High wet bulb temperature is used for sizing cooling towers and other evaporative equipment.

Peak humidity ratio is used for sizing dehumidification systems. Peak moisture conditions usually represent a higher enthalpy (total heat) than peak dry bulb conditions. Consequently, engineers use the peak moisture condition to cross-check operation of a system which may be primarily intended to control temperature.

Coincident wind speed allows the engineer to accurately estimate latent loads due to infiltration of humid air in the summer and infiltration of dry air during the winter.

Cautionary Note: The same precautions that apply to heating and cooling equipment also apply to dehumidification and humidification systems. Oversized equipment may not control properly under typical operating conditions without special attention from the engineer.

ASHEVILLE RGNL NC	
Latitude = 35.44 N	Station ID = ICAO_KAVL
Longitude = 82.54 W	Elevation = 2165 Feet
Period of Record = 1983 To 2012	Average Pressure = 27.82 inches Hg

Design Criteria Data

	Mean Coincident (Average) Values				
Dry Bulb Temperature (T)	**Design Value (°F)**	**Wet Bulb Temperature (°F)**	**Humidity Ratio (gr/lb)**	**Wind Speed (mph)**	**Prevailing Direction (NSEW)**
Median of Extreme Highs	91	72	96	8.2	NNW
0.4% Occurrence	88	71	97	8.3	N
1.0% Occurrence	86	71	98	8.2	N
2.0% Occurrence	84	70	96	8.1	NNW
Mean Daily Range	21	-	-	-	NNW
97.5% Occurrence	24	22	14	8.5	NNW
99.0% Occurrence	19	17	10	10.6	NNW
99.6% Occurrence	14	12	8	11.9	NNW
Median of Extreme Lows	7	6	5	13.9	NNW

Wet Bulb Temperature (T_{wb})	**Design Value (°F)**	**Dry Bulb Temperature (°F)**	**Humidity Ratio (gr/lb)**	**Wind Speed (mph)**	**Prevailing Direction (NSEW)**
Median of Extreme Highs	76	85	125	7.3	N
0.4% Occurrence	74	83	118	7	N
1.0% Occurrence	73	81	115	6.8	N
2.0% Occurrence	72	80	112	6.6	N

Humidity Ratio (HR)	**Design Value (gr/lb)**	**Dry Bulb Temperature (°F)**	**Vapor Pressure (in. Hg)**	**Wind Speed (mph)**	**Prevailing Direction (NSEW)**
Median of Extreme Highs	134	80	0.83	4.5	N
0.4% Occurrence	126	77	0.78	4.5	S
1.0% Occurrence	119	76	0.74	5.3	NNW
2.0% Occurrence	118	76	0.73	4.5	NNW

Air Conditioning/ Humid Area Criteria	**Threshold**	**T ≥ 93°F**	**T ≥ 80°F**	**Twb ≥ 73°F**	**Twb ≥ 67°F**
	# of Hours	10	486	130	1349

Other Site Data

Weather Region	Rain Rate 100 Year Recurrence (in/hr)	Basic Wind Speed 3 sec gust @ 33 ft 50 Year Recurrence (mph)	Ventilation Cooling Load Index (Ton-hr/cfm/yr) Base 75°F-RH 60% Latent + Sensible
7	3.5	90	2.1 + 0.5
Ground Water Temperature (°F) 50 Foot Depth*	Frost Depth 50 Year Recurrence (in)	Ground Snow Load 50 Year Recurrence (lb/ft²)	Average Annual Freeze-Thaw Cycles (#)
57.8	N/A	15	66

*Note: Temperatures at greater depths can be estimated by adding 1.5 °F per 100 feet additional depth.

Figure 1 – Climate Summary table for Asheville NC (page 1)

Average Annual Climate

Explanation of Graph. The graph shows the monthly mean temperature, dewpoint, and precipitation. The bar graph representing precipitation uses the scale on the right side of the chart (inches or centimeters). Lines of temperature and dew point use the scale on the left side of the chart (degrees Fahrenheit or Celsius). These charts have fixed maximum and minimum values on their axes for easy comparison between different sites. The precipitation chart is capped at a maximum of 15 inches (45 centimeters) per month. A few sites may exceed this value; but to keep the graph readable, a fixed maximum value was used. There are a number of sites for which accurate precipitation data was not available. If this is the case, then no bars are printed on the chart.

Suggestions for Use:

This graph displays the average behavior of weather over a single year. An architect can compare rainfall patterns at one station with another to evaluate differences in gutter and drain sizing, and also the relative importance of water resistance for the exterior envelope. An engineer can compare the temperature and moisture patterns to understand the relative importance of sensible heat loads vice latent loads at this location.

With averages displayed by month, it is relatively easy to comprehend seasonal variations of each variable, and also understand which specific months are likely to be hot or cold; humid or dry, or have high precipitation. This can be helpful for mission planning, as well as for planning construction and building operation.

Cautionary Note: This graph displays averages, not extreme values. Data shown should not be used to size equipment or building envelopes for peak loads. Peak load data appears on page 1 of each station record in this handbook.

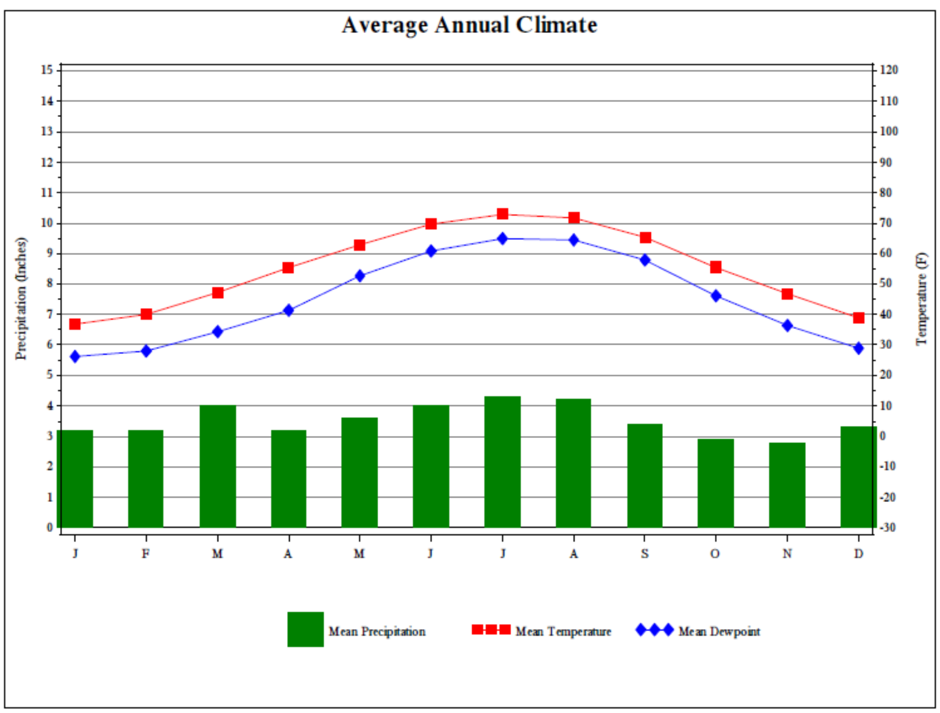


Figure 2 – Average Annual Climate graph for Asheville NC (page 2)

LONG TERM PSYCHROMETRIC SUMMARY

Explanation of Graph:

The graph displays the joint cumulative percent frequency of temperature and humidity ratio. Hourly observations are binned into groups of 5 ^{o}F and 10 grains per pound (gr/lb) (or 3^{o}C and 1.5 grams per kilogram [g/kg]), centered on each value of temperature or humidity ratio. For example, the 70 ^{o}F temperature bin collects all observations between 67.5 ^{o}F and 72.5^{o}F. The bin is depicted as a gridline on the chart; the vertical lines represent the temperature bins and the horizontal lines represent the humidity ratio bins. The intersection of temperature and humidity ratio lines represent a further sub-setting of the observations into groups meeting both temperature and humidity ratio criteria. For example, the intersection of the 70 ^{o}F bin line and the 40 gr/lb bin line represent the observations when temperature was between 67.5 ^{o}F and 72.4 ^{o}F and the humidity ratio was between 35 gr/lb and 44 gr/lb. Thus, a joint-frequency table is created for all temperature and humidity ratio bin combinations.

Suggestions for Use:

This graphic displays the long-term history of temperature and moisture at each station (a total of 262,800 hourly observations if the POR is 30 years and if the data is complete over that period). The engineer can use this graph to ascertain the most common temperature and moisture conditions which will be encountered over the operating life of mechanical equipment.

It is often useful to calculate the behavior of the proposed system at "most-common" conditions, in addition to the traditional peak design calculations. This will help ensure that the selected equipment and controls are capable of modulation and control at all points of operation rather than simply at extreme conditions.

Cautionary Note: The psychrometric graph is intended as a visual tool only. Its purpose is to allow quick visual comparison between climates at different locations. Extrapolation of data directly from the graph is not advised due to the approximate plotting routine used to generate the graph from the binned data. This is evident where values of humidity appear past their saturation point. This discrepancy between the actual data and the graph is the result of the plotting routine used to generate the graph and not from errors in the original hourly data used to create the binned summary.

The contours on this chart represent the areas containing 99%, 97.5%, 95%, 80%, and 50% of all observations (cumulative percent frequency or percentiles). The contours are centered on the most frequently occurring bins (50% contour), spreading outward until almost all observations (99%) are grouped. Contours are defined by calculating a percent frequency for each bin (relative to the others), and then accumulating these percent frequencies (from most frequent to least frequent) until the 50% value is passed, and thus the first set of bins is grouped. The accumulating continues until the 80% value is passed, and the second group of bins is grouped. This continues until the 95%, 97.5%, and 99% values are passed.

Thus, the least frequent (most extreme) bins, which when accumulated amount to less than 1% of the total observations, are outside of the 99% contour. Any bins outside the 99% contour thus have either not occurred, or have occurred so infrequently that they should not be taken into consideration for sizing equipment.

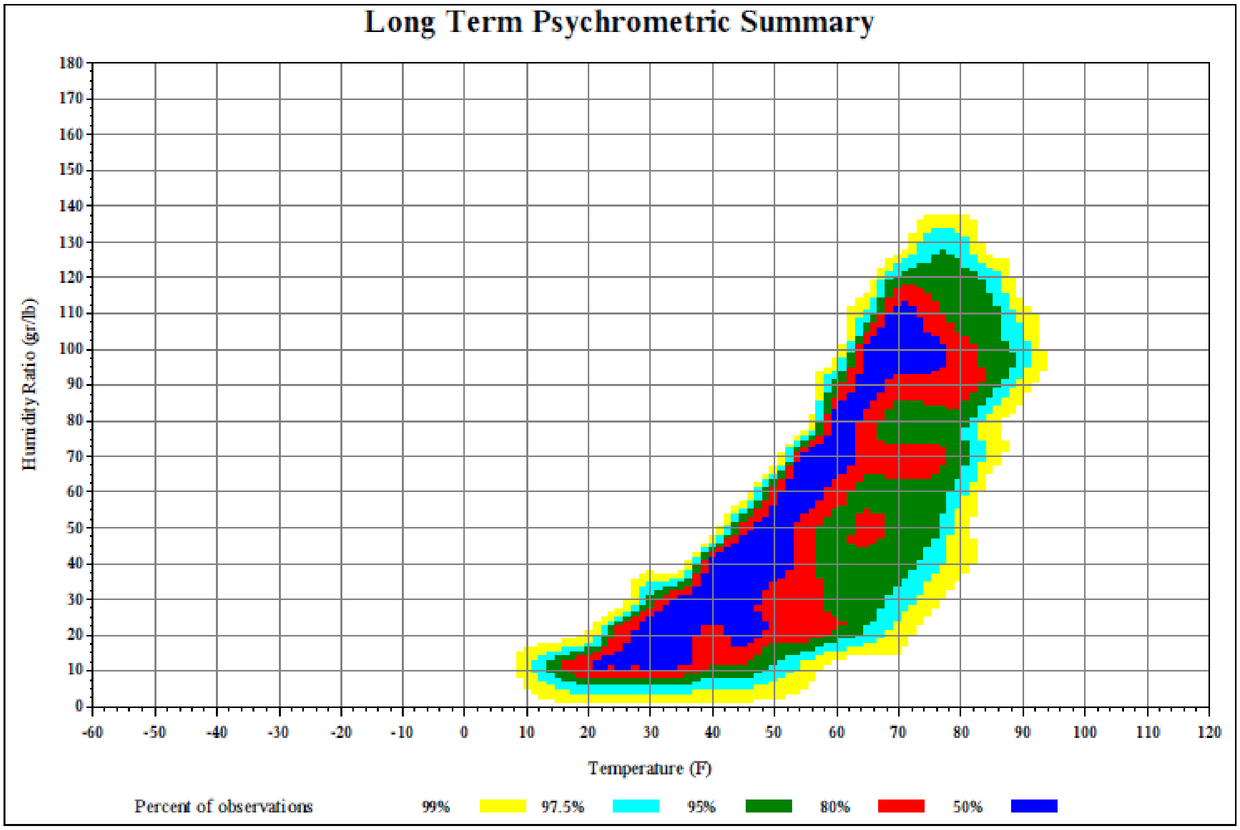


Figure 3 – Long Term Psychrometric Summary chart for Asheville NC (page 3)

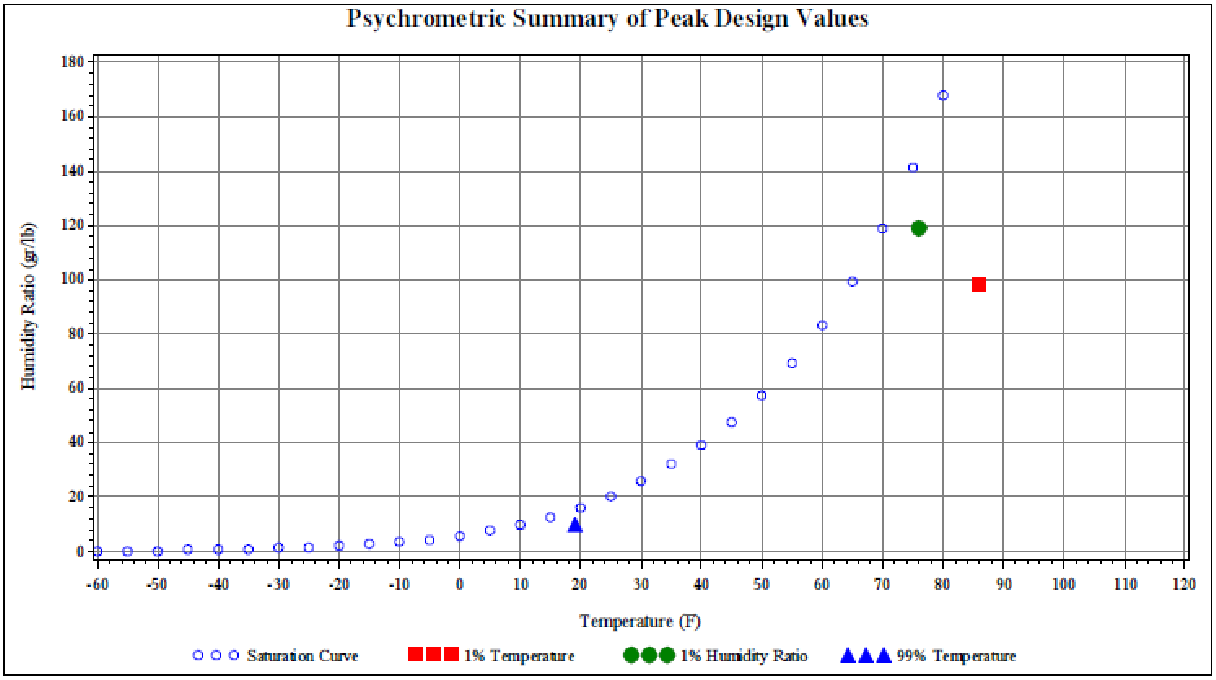
PSYCHROMETRIC DISPLAY OF DESIGN VALUES

Explanation of Chart. Similar to the Long Term Summary, this chart depicts the saturation curve (when RH = 100%) along with peak design values. The design values are calculated as in the table on Page 1, but this chart shows their relationships graphically, depicting their position relative to each other and relative to the saturation curve.

Above and to the left of saturation curve, RH would be greater than 100 percent (not possible). The area below and to the right of the curve (including the points on the curve itself) represent the area where RH is less than or equal to 100 percent, and thus where all observations occur. Note that since the humidity ratio is a function of pressure, and pressure varies with elevation, different sites will have different saturation curves.

The dry bulb temperature is the vertical coordinate on this scatter plot, and the humidity ratio is the horizontal coordinate. Peak design values are depicted by the red square (1.0% Dry Bulb Temperature), the green circle (1.0% Humidity Ratio), and the blue diamond (99% Dry Bulb Temperature).

The table below the chart shows the exact values of 99% dry bulb temp, 1.0% humidity ratio, and 1.0% dry bulb temperature, along with calculated values of enthalpy, mean coincident wet bulb temperature, and humidity ratio (as applicable). The value of enthalpy coincident to each temperature/humidity ratio is created using the psychometric functions provided by the Linric Company, Bedford, New Hampshire. The dry bulb temperature and humidity ratios are used to calculate enthalpy using the Linric algorithms.



	(°F) / (gr/lb)	MCDB (°F)	MCWB (°F)	MCDP (°F)	MCHR (gr/lb)	Enthalpy (btu/lb)
1.0% Dry Bulb	86.0		71		98.0	36.0
99.0% Dry Bulb	19.0				10.0	6.1
1.0% Humidity Ratio	119.0	76.0	71.6	69.9		36.9

Figure 4 – Psychrometric Summary of Peak Design Values chart and table for Asheville NC (page 4)

BINNED TEMPERATURE DATA

Explanation of Tables. Identical to those in AFM 88-29, these tables show the number of hours that temperatures in 5 °F (3 °C) bins occur during a given month, and during 8-hour periods during the days of that month. The 8-hour periods are based upon a 24-hour clock and displayed in Local Standard Time (LST). The total numbers of observations (hours) in each temperature bin are summed horizontally in the “Total Obs” column for the month. The mean coincident wet bulb temperature is the mean value of all those wet bulb temperatures that occur coincidentally with the dry bulb temperatures in the particular 5-degree temperature interval. At the upper or warmer end of the mean coincident wet bulb distribution, the values occasionally reverse their trend because the highest wet bulb temperatures do not necessarily occur with the highest dry bulb temperatures. There are thirteen such tables, one for each month, and one representing the overall annual summary.

Suggestions for Use. Binned summaries are used by many different technical disciplines for different purposes. They are useful in making informal estimates of energy consumption by cooling and heating equipment, and for gaining a general understanding of patterns of temperature and moisture at different times of the day, month, and year.

Cautionary Note: Do not use these binned summaries to calculate moisture loads. These particular summaries are based on the dry bulb temperature. After each of the one-hour observations has been placed into a dry bulb BIN, the average humidity ratio is calculated for all observations in each BIN. Consequently, dry bulb BINs underestimate the magnitude of dehumidification and humidification loads, because the averaging calculation "flattens" the peaks and valleys of humidity ratios. The amount of the underestimation varies according to the desired humidity control level.

Dry-Bulb Temperature Hours For An Average Year

	January					February					March				
Temperature Range (°F)	**01 To 08 LST**	**09 To 16 LST**	**17 to 00 LST**	**Total Obs**	**MCWB (°F)**	**01 To 08 LST**	**09 To 16 LST**	**17 to 00 LST**	**Total Obs**	**MCWB (°F)**	**01 To 08 LST**	**09 To 16 LST**	**17 to 00 LST**	**Total Obs**	**MCWB (°F)**
95/ 99															
90/ 94															
85/ 89															
80/ 84		0		0	55							0	0	0	59.6
75/ 79		0	0	0	63.2		0	0	0	59		5	1	6	58.5
70/ 74		1	0	1	58.4		2	0	2	57.8		16	6	22	55.8
65/ 69		2	0	2	54.5		4	1	5	54.1	0	17	10	27	54.1
60/ 64	1	11	5	17	53.1	2	16	7	25	51.5	5	33	25	63	52.1
55/ 59	5	19	11	35	49.8	5	25	17	47	48.3	14	37	34	85	49.7
50/ 54	10	26	20	56	46.4	12	30	29	71	45.5	28	40	44	112	46.5
45/ 49	18	37	33	88	41.7	21	37	35	93	41	43	39	45	127	41.9
40/ 44	21	32	33	86	37.9	23	26	31	80	37.7	35	21	27	83	37.8
35/ 39	41	46	47	134	33.6	39	36	42	117	33.5	48	24	30	102	33.9
30/ 34	49	35	45	129	29	51	28	33	112	29.2	40	11	18	69	29.2
25/ 29	46	21	31	98	24.2	40	12	19	71	24.3	26	3	6	35	24.6
20/ 24	25	8	11	44	19.9	18	4	6	28	19.9	6	1	1	8	20
15/ 19	19	6	10	35	15.5	10	2	3	15	15.5	3	1	1	5	15.6
10/ 14	10	2	2	14	10.9	3	1	1	5	10.8	1	0	0	1	10.4
5/ 9	3	1	1	5	6.1	1	0	0	1	6.1	0		0	0	6.4
0/ 4	0	0	1	1	1.1	0	0	0	0	1.2	0			0	2
-5/ -1	1	0	0	1	-3.5	0			0	-2					
-10/ -6	0	0	0	0	-8.7										
-15/-11	0	0	0	0	-12.5										
-20/-16	0			0	-15.3										

Caution: This summary reflects the typical distribtion of temperature in a typical year. It does not reflect the typical mositure distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Figure 5 –- Monthly (Jan- Mar) Dry Bulb Temperature Hours for Asheville NC (page 5)

ANNNUAL TEMPERATURE SUMMARY

Explanation of Chart. This chart shows a week-by-week summary of dry bulb temperatures for the given site. The observations are grouped into seven-day periods (approximate calendar weeks). For example, observations from 1-7 January from all years are grouped, 8-14 January are grouped, and so on, overlapping the end of one month and beginning of the next month where necessary. For each of the seven-day periods, the following statistics are shown.

1% Temperature is the dry bulb temperature that is exceeded one percent of the time during that calendar week.

MCWB @ 1% Temp is the mean of wet bulb temperatures coincident with 1% dry bulb temperatures during the same week

Mean Max Temp is the daily maximum dry bulb temperature, averaged by week over the POR.

Mean Min Temp is the daily minimum dry bulb temperature, averaged by week over the POR.

99% Temp is the daily dry bulb temperature that is at or above this value 99 percent of the time, or below this value one percent of the time.

Note: The information in this chart is calculated on a weekly basis; information on a climate summary (Data Set Page 1) is calculated on an annual basis.

Suggestions for Use. The weekly 1% and 99% temperatures are useful for understanding the probable temperature extremes that can occur during a given week of the year. The weekly dry bulb temperatures are useful for understanding the change of seasons at a given location. The display is helpful for mission planning and construction project planning.

Cautionary Notes:

Designers. The values displayed here are based on the 30-year record. It is important that designers NOT base equipment selection on the “highest” or “lowest” recorded temperature at the station. That error would result in selecting equipment extremely costly to install, which would operate inefficiently for all but the very hottest or coldest single hour in 30 years. See the design criteria data page (Page 1) in this handbook for appropriate maximum and minimum temperatures for sizing equipment.

Construction and Operation Planners. The mean maximum and minimum temperatures shown for each week seldom occur in the same year. Keep in mind these are mean values useful for understanding the typical range of temperatures in a given week. The difference does NOT represent the actual day-night temperature swing in a given week.

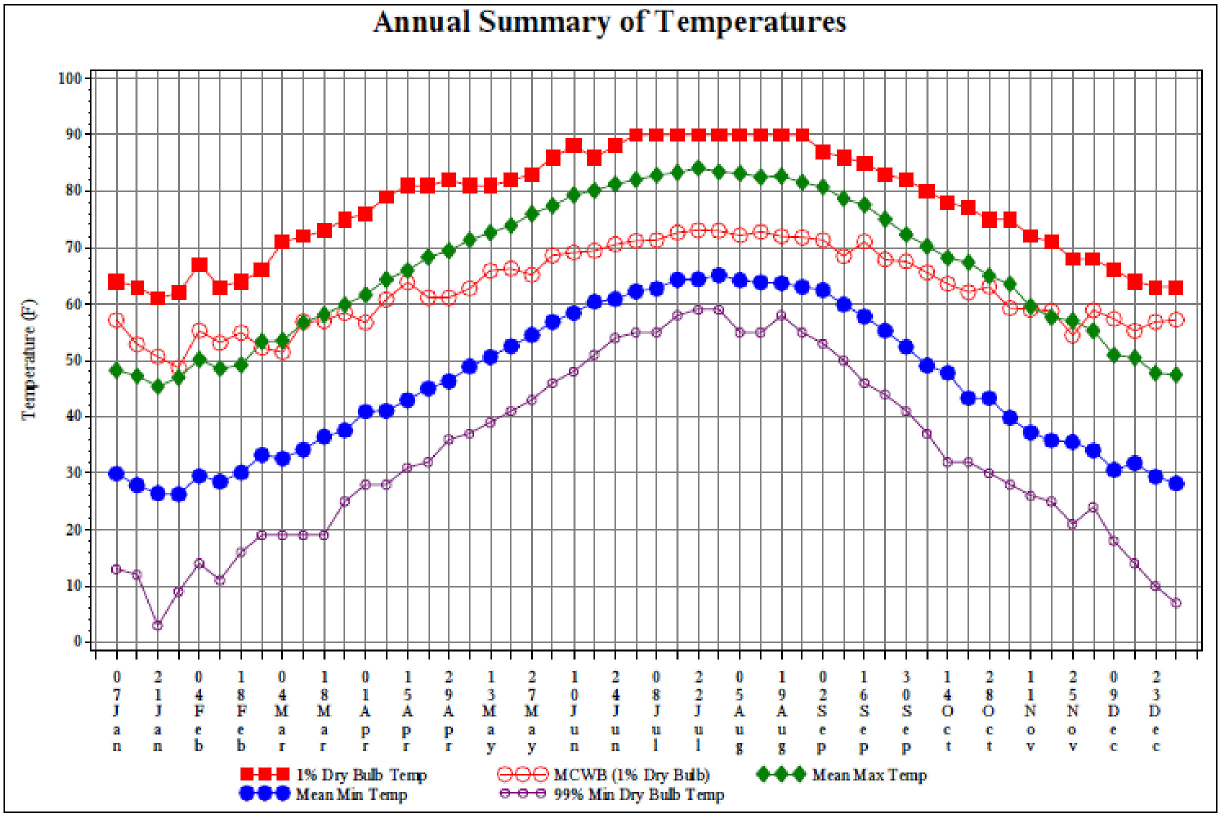


Figure 6 – Annual Summary of Temperature graph for Asheville NC (page 10)

ANNUAL DRY BULB TEMPERATURE AND HUMIDITY SUMMARY

Explanation of Chart. Similar to the annual temperature summary, this chart depicts mean maximum and minimum values of humidity ratio, plus the 1% maximum humidity ratio, along with its mean coincident dry bulb temperature, summarized by calendar week. The chart uses two vertical axes: On the left are the humidity ratio values and on the right is a temperature scale for the mean coincident dry bulb temperature.

Suggestions for Use. Weekly humidity ratios are useful for understanding the change of seasons at a given location, and the probable high and low moisture levels during a given week of the year. The display is helpful for planning humidity-controlled storage projects, and for understanding factors contributing to atmospheric corrosion. Humidity also affects the deterioration rate of building materials and weathering of military equipment and structures exposed to the elements.

Cautionary Notes:

Designers. The values displayed here are based on the 30-year record. It is important that designers NOT base equipment selection on the “highest” or “lowest” recorded humidity at the station. That error would result in selecting oversized equipment, which would increase costs and may result in control problems at other than extreme conditions. Use design values on Data Set Page 1 for equipment sizing.

Construction and Operation Planners. The high and low humidity ratios shown for each week seldom occur in the same year. Keep in mind that these are mean values that are useful for understanding the typical range of humidity ratio in a given week. The difference does NOT represent the actual day-night humidity ratio swing in a given week.

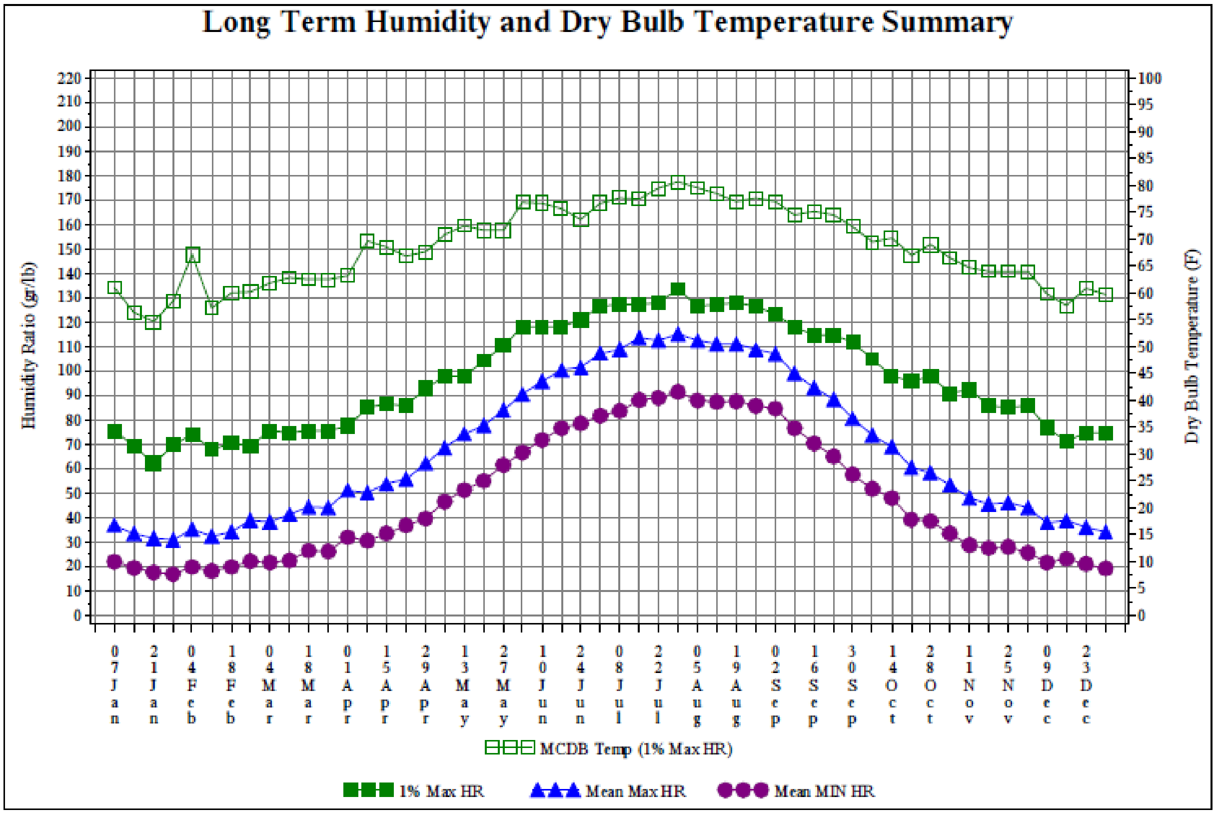


Figure 7– Humidity and Temperature Summary graph for Asheville NC (page 11)

LONG TERM HUMIDITY AND DRY BULB TEMPERATURE SUMMARY

Explanation of Tables. These tables show the values for the Long Term Humidity and Dry Bulb Temperature Summary graph (pages 10 and 11).

Long Term Humidity and Dry Bulb Temperature Summary

Week Ending	1.0% Temp (°F)	MCWB@ 1% Temp (°F)	Mean Max Temp (°F)	Mean Min Temp (°F)	99% Temp (°F)	1.0% HR (gr/lb)	MCDB@ 1% HR (°F)	Mean Max HR (gr/lb)	Mean Min HR (gr/lb)
7-Jan	64	57.1	48.3	29.9	13	75.6	61.1	37	22.1
14-Jan	63	52.8	47.2	27.9	12	69.3	56.4	33.6	19.5
21-Jan	61	50.7	45.3	26.4	3	62.3	54.7	31.8	17.7
28-Jan	62	48.7	46.9	26.3	9	70	58.6	31	17
4-Feb	67	55.3	50.1	29.5	14	74.2	67.2	35.3	20
11-Feb	63	53.1	48.6	28.5	11	67.9	57.3	32.4	18.3
18-Feb	64	54.9	49.2	30.1	16	70.7	60	34.2	20
25-Feb	66	52.3	53.4	33.2	19	69.3	60.3	39	22.3
4-Mar	71	51.5	53.5	32.6	19	75.6	61.9	38.2	21.8
11-Mar	72	56.9	56.7	34.2	19	74.9	62.9	41.4	22.7
18-Mar	73	57	58.1	36.5	19	75.6	62.6	44.6	26.6
25-Mar	75	58.4	59.9	37.6	25	75.6	62.5	44.3	26.3
1-Apr	76	56.7	61.7	40.9	28	77.7	63.3	51.3	32.1
8-Apr	79	60.8	64.4	41	28	85.4	69.8	50.4	30.7
15-Apr	81	63.8	66	42.9	31	86.8	68.5	53.9	33.7
22-Apr	81	61.1	68.3	45	32	86.1	66.9	55.9	37
29-Apr	82	61.1	69.5	46.3	36	93.1	67.7	62.3	39.7
6-May	81	62.8	71.3	48.9	37	98	70.9	68.8	46.6
13-May	81	65.9	72.7	50.6	39	98	72.6	74.4	51.5
20-May	82	66.3	73.9	52.5	41	104.3	71.7	77.9	55.2
27-May	83	65.2	76	54.5	43	110.6	71.7	84.1	61.6
4-Jun	86	68.6	77.4	56.8	46	118.3	76.9	90.6	66.8
10-Jun	88	69.2	79.3	58.4	48	118.3	76.8	95.8	72
17-Jun	86	69.5	80.1	60.4	51	118.3	75.8	100.5	76.8
24-Jun	88	70.6	81.3	60.9	54	121.1	73.7	101.6	78.7
1-Jul	90	71.2	82	62.2	55	126.7	76.8	107.4	81.8
8-Jul	90	71.3	82.8	62.7	55	127.4	77.8	109.1	83.9
15-Jul	90	72.7	83.3	64.3	58	127.4	77.5	113.8	88.3
22-Jul	90	73.1	84.1	64.4	59	128.1	79.5	112.7	89.1
29-Jul	90	73	83.4	65.1	59	133.7	80.7	115.2	91.6
5-Aug	90	72.2	83.1	64.2	55	126.7	79.6	112.6	88
12-Aug	90	72.8	82.5	63.8	55	127.4	78.5	111.3	87.5
19-Aug	90	72	82.7	63.7	58	128.1	77.1	111.2	87.7
26-Aug	90	71.8	81.6	63	55	126.7	77.7	108.9	85.9
2-Sep	87	71.3	80.7	62.5	53	123.2	77	107.2	84.8
9-Sep	86	68.5	78.7	59.9	50	118.3	74.6	99.1	76.7
16-Sep	85	71.1	77.6	57.8	46	114.8	75.2	93.3	70.5
23-Sep	83	67.9	75.1	55.3	44	114.8	74.6	88.5	65.1
30-Sep	82	67.6	72.3	52.4	41	112	72.4	80.7	57.8
7-Oct	80	65.6	70.3	49.1	37	105	69.5	73.8	52
14-Oct	78	63.6	68.1	47.8	32	98	70.2	69.2	48.1
21-Oct	77	62.1	67.3	43.3	32	95.9	67.1	60.6	39.4
28-Oct	75	63.1	65	43.3	30	98	69	58.4	38.7
4-Nov	75	59.3	63.6	39.8	28	91	66.6	53.5	33.7
11-Nov	72	59	59.6	37.2	26	92.4	64.8	48.3	28.9
18-Nov	71	58.8	57.7	35.8	25	86.1	64.1	45.7	27.7
25-Nov	68	54.4	57	35.5	21	85.4	64.1	46.2	28.1
2-Dec	68	58.9	55.2	34	24	86.1	64	44.3	25.7
9-Dec	66	57.4	50.9	30.6	18	77	59.9	38.1	21.7
16-Dec	64	55.2	50.5	31.8	14	71.4	57.7	38.9	23.3
23-Dec	63	56.8	47.8	29.4	10	74.9	60.9	36.2	21.2
31-Dec	63	57.2	47.5	28.2	7	74.9	59.7	34.4	19.4

F*igure 8 – Data Table for the Long Term Humidity and Dry Bulb Temperature Summary graph for Asheville NC*

BUILDING ENVELOPE LOADS

Explanation of Charts:

Cooling degree-days are derived by multiplying the number of hours that the outdoor temperature is above 65 °F (18 ºC) times the number of degrees of that temperature difference. For example, if one hour was observed at a temperature of 78 °F, that observation adds 13 degree-hours to the annual total. The sum of the degree-hours is divided by 24 to yield degree-days.

Heating degree-days are calculated similarly, against an inside temperature of 65 °F. So a one-hour observation of 62 °F adds 3 degree-hours to the annual total. Heating degree-days are summed separately from the cooling degree-days. Hot and cold hours do not cancel each other out, as both heating and cooling conditions may occur over the course of a given day.

Suggestions for Use. Degree-days are used to estimate the sensible heat and sensible cooling loads on the building envelope. Degree-day loads can be used to estimate the annual energy consumption of a building, provided that the loads from ventilation and infiltration air are also considered.

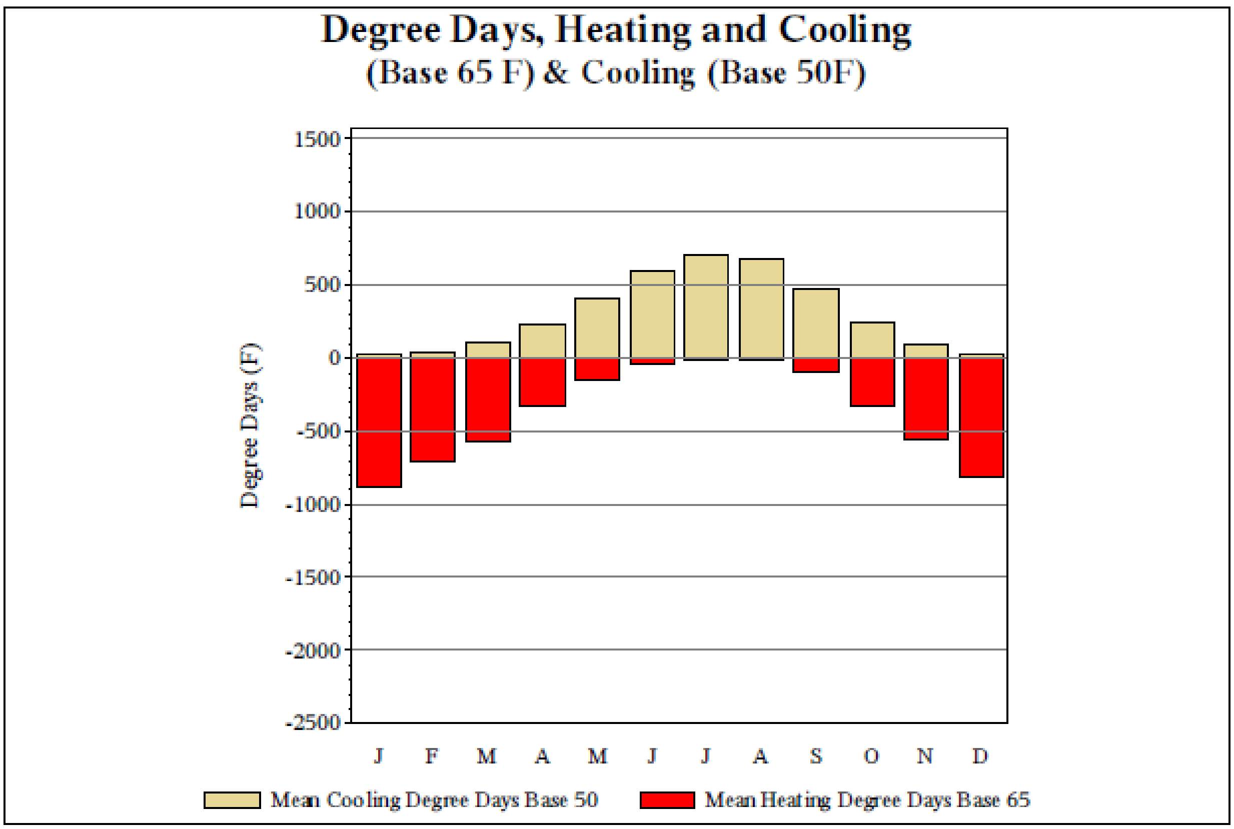


Figure 9 – Degree Days, Heating and Cooling graph for Asheville, NC (page 13)

Month	Mean Cooling Degree Days (°F) Base 50	Mean Cooling Degree Days (°F) Base 65	Mean Heating Degree Days (°F) Base 65
JAN	24.9	0.5	875
FEB	38	1.2	705.6
MAR	111	11	563.3
APR	236.4	42.5	329.3
MAY	413.9	92.1	157.6
JUN	590.4	181.8	42.1
JUL	708.2	255	11.8
AUG	674.1	225.5	16.6
SEP	469.1	111.8	98.8
OCT	239.7	32	326.4
NOV	97.3	5.6	553.9
DEC	34.2	0.9	809.7
ANN	3637.2	959.9	4490.1

Figure 9 – Values for Degree Days, Heating and Cooling graph for Asheville, NC (page 13)

VENTILATION AND INFILTRATION LOADS

Explanation of Charts:

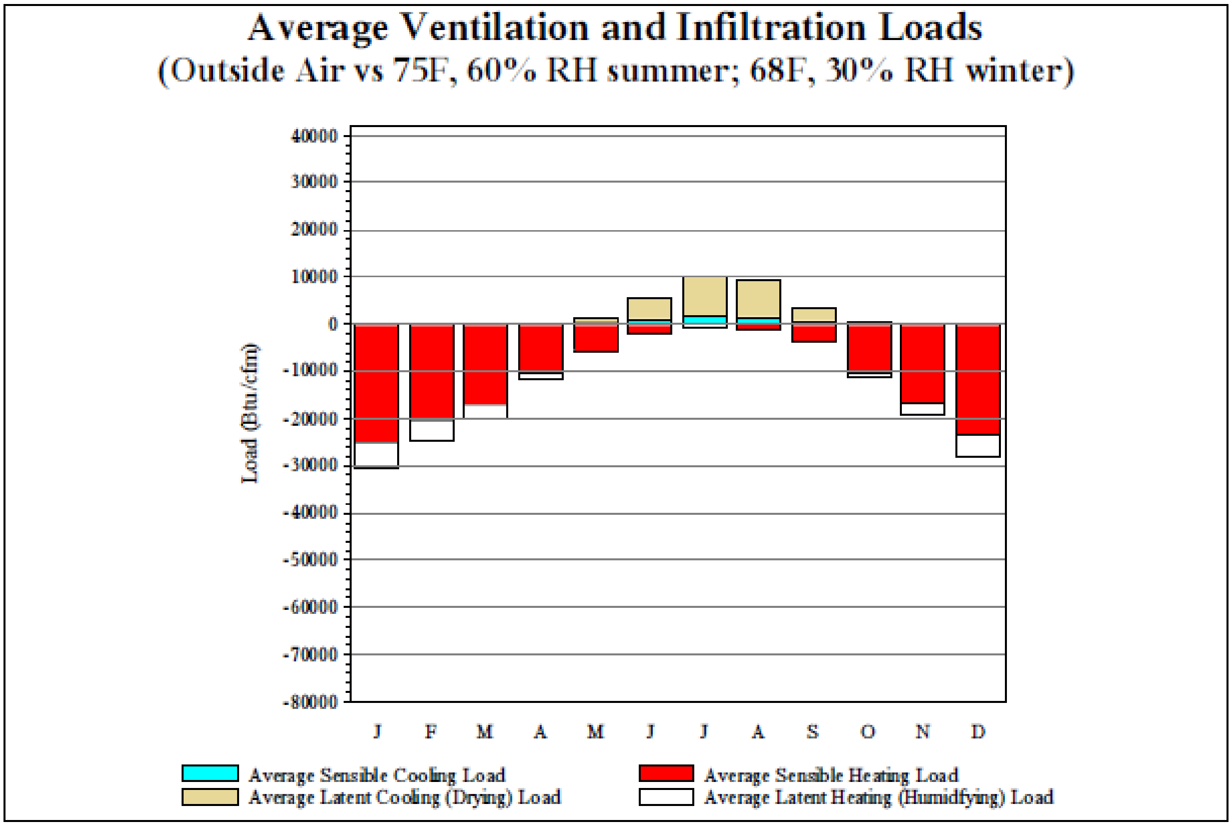
The graph and table display the independent loads imposed by heating, cooling, humidifying, and dehumidifying outside air as it is brought into a building. The calculation assumes that air inside the building is maintained at 68 ºF (20 ºC)/30% RH during the winter and 75 ºF (24 ºC)/60% RH during the summer. For the purposes of these calculations, when the outside air is within that range of temperature and moisture, any incoming air is assumed not to impose any load.

These values are calculated with the methodology used to calculate the annual VCLI Index on page one, except that values on this page are computed by month, and the result is displayed as British thermal units (Btu) per cubic foot per minute (cfm) rather than as ton-hours per cfm per year. The heating and humidifying loads are shown as negative values. Cooling and dehumidifying loads are displayed as positive values.

Suggestions for Use. Bringing fresh ventilation air into a building or allowing air to infiltrate into buildings through cracks imposes heating, cooling, dehumidification, and humidification loads on the mechanical system. This display helps the architect, engineers, and operating personnel understand the nature and magnitude of those loads on an annual basis. It also shows how the loads vary from month to month throughout the year.

Comments. These calculations are based on the load created when one cubic foot of fresh air is brought into the building each minute. The results of the calculation include the moisture load or deficit, and the sensible heat load or deficit created by that cubic foot of air during each month of the year. Note that most months have both a load and a deficit for temperature and moisture. The monthly deficit and load do not “cancel” from the perspective of the mechanical system, because temperature and moisture loads will often occur at different times of the day.

Cautionary Note: The values displayed here assume that the inside air is maintained at 68 °F/30% RH during the winter and at 75 °F, 60% RH during the summer. If the inside conditions are held in a different range of temperature or moisture, the loads will be different. For example, in calculating loads for humidity-controlled, but unheated storage, the loads vary according to the change in both temperature and humidity, since the inside temperature varies, but the inside humidity is held constant. For estimating loads in that or similar applications, the engineer may obtain better results from using the average maximum weekly humidity data shown on sample pages 11 and 12.



Month	Average Sensible Cooling Load (Btu/cfm)	Average Sensible Heating Load (Btu/cfm)	Average Latent Cooling Load (Btu/cfm)	Average Latent Heating Load (Btu/cfm)
JAN	0	-25084	2	-5473
FEB	0	-20467	0	-4425
MAR	11	-16872	2	-3024
APR	140	-10451	55	-1342
MAY	362	-5649	949	-105
JUN	1129	-1999	4351	0
JUL	1792	-822	8458	0
AUG	1462	-1068	7805	0
SEP	505	-3863	2855	-11
OCT	54	-10494	357	-641
NOV	2	-16607	47	-2519
DEC	0	-23380	5	-4721
ANN	5457	-136756	24886	-22261

Figure 10 – Average Ventilation and Infiltration Loads graph and table for Asheville NC (page 14)

SOLAR RADIATION DATA

Explanation of Charts:

This data is reproduced courtesy of the National Renewable Energy Laboratory (NREL). The data were first published in their *Solar Radiation Data Manual for Buildings* (1995). The user should refer to that publication for a complete description of how to use this data.

The site used in each station record is the nearest NREL-published site available within a 1.5º latitude radius from the desired location. Therefore, some sites may be several miles away, and in some cases the NREL location may be in a neighboring state. Caution should be used when the nearest site available is not in the same city as the desired location, as significant differences in cloud climatology can exist over short distances.

When this handbook was prepared, the only sites available from NREL were the 50 states, Puerto Rico, and Guam. These pages are blank at locations where solar radiation data is not available. For these locations, users may wish to contact NREL directly to obtain advice concerning data not published in the NREL solar radiation data manual.

Suggestions for Use. The solar data presented here can be used for calculating solar radiation cooling loads on building envelopes, and also for estimating the value of solar illumination for daylighting calculations. Again, the user should refer to the *Solar Radiation Data Manual for Buildings* for a complete description of how to use this data.

Cautionary Note: The data source for the NREL reports comes from the National Solar Radiation Database — not the data set used to calculate peak design values and other monthly temperature and moisture data in this handbook. The two data sets will differ for many reasons, including different periods of record, measurement locations, sampling methodology and frequency, and differences in calculation methodology. Consequently, the user should expect differences in degree-days, min/max temperatures, and humidities between this data and that calculated by the 14WS. For design criteria, use the temperature and moisture values presented on the Design Criteria Data page of this handbook. These were calculated more recently, and used a longer POR. Also, they are taken from records at DoD locations rather than from civilian locations near — but not always identical to — the military data collection points.

Average Annual Solar Radiation - Nearest Available Site
Source: National Renewable Energy Laboratory, Golden CO, 1995

Station Information		Shading Geometry in Dimensionless Units	
City, State, WBAN	ASHEVILLE, NC 03812	Window:	1.000
Lat, Lon, Elev	35.43N 82.53W 2169ft	Overhang:	0.405
Press, Stn_Type	13.7psia Secondary	Vert Gap:	0.290

AVERAGE INCIDENT SOLAR RADIATION (Btu/sq.ft./day) Percentage Uncertainty = 9

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ.	Global	790	1040	1360	1700	1830	1910	1830	1670	1410	1200	860	700	1360
	Std.Dev.	62	83	113	137	92	147	152	112	110	109	76	54	37
	Minimum	630	910	1110	1370	1710	1660	1580	1490	1170	1020	690	560	1290
	Maximum	900	1240	1550	2040	2080	2200	2150	1880	1630	1420	990	780	1450
	Diffuse	320	410	530	650	780	850	850	780	640	440	340	290	580
Clear Day	Global	1110	1440	1880	2290	2530	2600	2520	2300	1930	1500	1130	980	1850
NORTH	Global	220	280	350	440	530	590	560	470	390	310	230	200	380
	Diffuse	220	280	350	420	480	520	500	450	390	310	230	200	360
Clear Day	Global	210	260	330	430	570	680	620	490	380	300	220	190	390
EAST	Global	510	650	800	970	1000	1020	990	900	770	710	540	450	780
	Diffuse	260	340	430	520	580	610	610	560	470	370	290	240	440
Clear Day	Global	790	980	1180	1340	1390	1400	1360	1290	1150	960	780	700	1110
SOUTH	Global	1180	1210	1120	950	750	680	700	830	990	1230	1180	1120	1000
	Diffuse	360	420	480	520	530	540	550	550	520	450	380	330	470
Clear Day	Global	2020	1980	1720	1270	920	790	840	1100	1480	1790	1900	1930	1470
WEST	Global	530	660	810	960	960	990	940	890	810	740	560	470	780
	Diffuse	270	340	430	520	580	620	610	560	480	380	290	240	440
Clear Day	Global	790	980	1180	1340	1390	1400	1360	1290	1150	960	780	700	1110

Average Annual Solar Radiation - Nearest Available Site
Source: National Renewable Energy Laboratory, Golden CO, 1995

AVERAGE TRANSMITTED SOLAR RADIATION (Btu/sq.ft./day) FOR DOUBLE GLAZING Percentage Uncertainty = 9														
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ.	Unshaded	530	720	970	1230	1330	1390	1330	1210	1020	840	580	460	970
NORTH	Unshaded	150	190	240	300	350	390	370	320	270	210	160	140	260
	Shaded	140	180	220	270	320	350	340	290	250	200	150	130	240
EAST	Unshaded	350	460	560	690	710	730	700	640	540	490	370	310	550
	Shaded	320	420	510	620	630	640	620	560	480	450	340	290	490
SOUTH	Unshaded	880	880	760	600	450	410	430	520	660	880	880	840	680
	Shaded	860	830	630	430	340	350	350	380	510	790	860	830	590
WEST	Unshaded	360	460	570	680	680	700	660	630	580	520	390	320	550
	Shaded	340	430	520	610	600	620	590	560	520	480	360	300	490

AVERAGE INCIDENT ILLUMINANCE (klux-hr) FOR MOSTLY CLEAR AND MOSTLY CLOUDY CONDITIONS Percentage Uncertainty = 9											
				March					June		
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	32	71	87	75	39	35	77	100	98	74
	M. Cloudy	18	42	53	47	24	21	51	71	71	50
NORTH	M.Clear	9	14	15	14	10	22	16	17	17	16
	M. Cloudy	8	14	16	15	9	12	16	19	19	16
EAST	M.Clear	73	66	19	14	10	65	77	42	17	16
	M. Cloudy	24	33	18	15	9	25	44	33	19	16
SOUTH	M.Clear	30	65	79	68	36	10	21	38	38	21
	M. Cloudy	13	32	42	37	18	9	19	31	31	19
WEST	M.Clear	9	14	15	61	76	10	16	17	42	74
	M. Cloudy	8	14	16	34	31	9	16	19	33	44
M. Clear	(% hrs)	35	39	38	36	35	38	43	36	29	29

				Sept					Dec		
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	18	61	86	84	57	12	43	56	41	9
	M. Cloudy	10	35	55	56	35	7	24	31	24	6
NORTH	M.Clear	7	14	17	16	14	5	10	11	10	4
	M. Cloudy	5	13	18	18	13	3	10	11	9	3
EAST	M.Clear	46	74	40	16	14	38	48	11	10	4
	M. Cloudy	13	32	28	18	13	10	20	11	9	3
SOUTH	M.Clear	12	46	68	67	43	30	78	93	76	26
	M. Cloudy	6	23	39	41	24	8	28	35	28	7
WEST	M.Clear	7	14	17	44	73	5	10	13	50	34
	M. Cloudy	5	13	18	30	35	3	10	12	21	9
M. Clear	(% hrs)	25	41	39	37	37	38	38	38	40	40

Figure 11 – Average Annual Solar Radiation data for Asheville, NC (page 15-16)

WIND SUMMARY (pages 17-18)

Explanation of Charts:

These charts depict the frequency of different wind direction and wind speed combinations. The observations are binned into the sixteen cardinal compass directions and six speed categories (Calm, 1-5 knots, 6-14 knots, 15-24 knots, 25-34 knots, and greater than 34 knots). The frequency of direction and the tick marks indicating that value lie along each 'spoke' of the wind chart. The wind speed bins for each direction are color-coded by the legend at the bottom of the chart.

To determine the percent frequency of a particular wind direction, look for the tick mark bounding the outer edge of a colored (wind speed) area. In the case of the first wind speed bin (1-5 knots), the percent frequency is simply the value of the tick mark on the outer edge of the 1-5 knot region. The edge of the calm area is the 0 tick mark. For the higher speed bins (6-14 knots or greater), subtract the earlier spoke values from the value shown to get the frequency for the speed bin in question.

The values for percent frequency have been summed by direction, so to determine the total percent frequency for all speeds from a particular direction, look up the tick mark (or interpolated value) bounding the outermost colored area along that spoke. That tick mark represents the total percent frequency of wind from that direction.

Sample Wind Summary Chart. The wind summary charts are prepared by three-month seasons, over all hours (December, January, February for northern hemisphere winter or southern hemisphere summer; March, April, May for northern hemisphere spring or southern hemisphere fall, and so on). See the following sample wind summary chart for an example of determining percent frequencies.

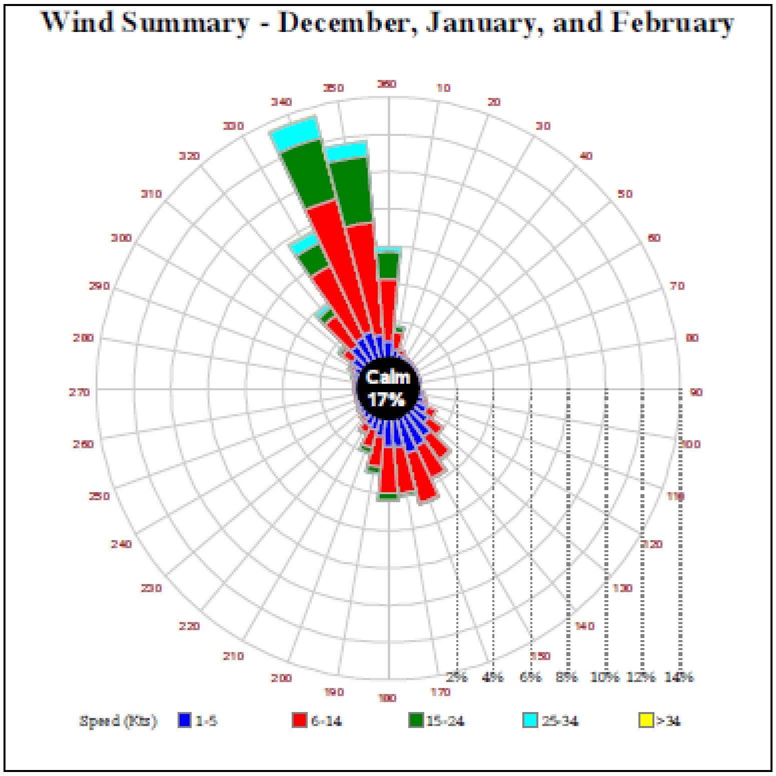


Figure 12 – Wind Summary Wind Rose for Dec-Feb for Asheville NC

From the above sample wind summary chart, the percent frequency of wind between 1-5 knots and from the north (N) is about 3%. The percent frequency of wind between 6-14 knots and from the northwest (NW) is about 5% (7% - 2%). The percent frequency of all wind speeds from the south (S) is about 12%. The percent frequency of all wind directions from the west through north (W, WNW, NW, NNW, and N) is about 38% (5% + 7% + 8% + 8% + 10%, respectively). It is easy to determine that wind speeds greater than 34 knots almost never occur (or are such a small frequency from any direction), because the colored area (yellow) is not shown or is indistinguishable because it is so small.

The percent of time the wind is calm is indicated in the center of the chart, in this sample case, 10%. When the outermost value from each of the 16 directions are summed and added to the percent calm the result is 100% (allowing for rounding). Occurrences of variable wind direction are omitted from the sample before computing percent frequency by direction.

Suggestions for Use. Knowing the probable wind speed and direction in a particular season can be helpful in construction and mission planning as well as in designing structures which must face severe wind-driven rain or drifting snow. Engineers designing heating and air conditioning systems, which draw fresh air from the weather and exhaust-contaminated building air can use these data to minimize the potential for cross-contamination between supply and exhaust air streams. Also, when accumulation on roofs of drifting snow is likely, this information can be helpful for locating inlet and exhaust ducts so they are less likely to be covered by snowdrifts.

Cautionary Note: The wind currents around any building are strongly affected by the geometry of the building and the topography of the site as well as any surrounding buildings. The wind data used for these wind summaries are typical of flat and open airfields, where there are no obstructions near the observation point.

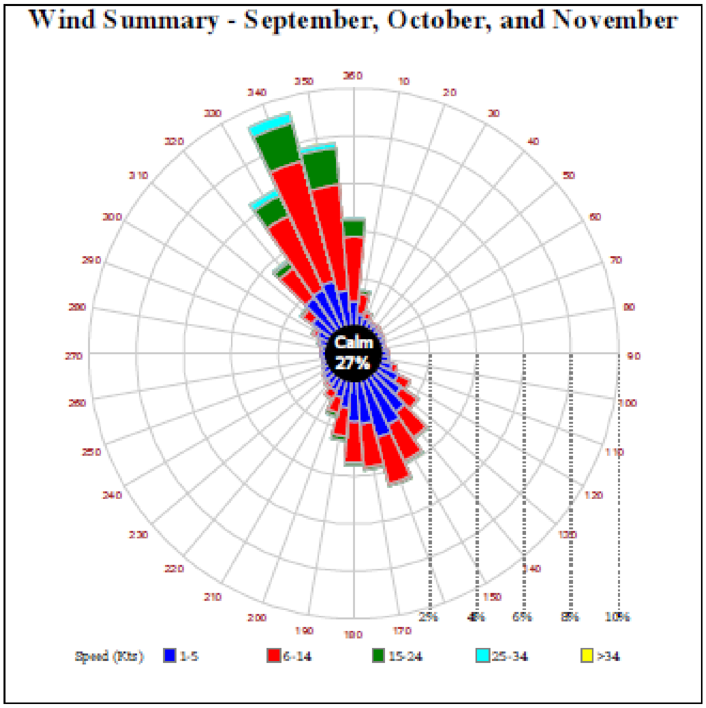


Figure 13 – Wind Summary Wind Rose for Sep – Nov for Asheville NC (page 17)

REFERENCES AND SUPPORTING INFORMATION

Section A—References

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Section B— Abbreviations and Acronyms

Btu/lb—British thermal units per pound of air (enthalpy)

Btu/sq ft/day—Btu per square foot per day (solar radiation)

cm—centimeter (frost depth)

cm/hr—centimeters per hour (rain rate)

gr/lb—grains per pound (humidity ratio, grains of water vapor per pound of air)

gr/kg—grams per kilogram (humidity ratio, grams of water vapor per kilogram of air)

in Hg—inches of mercury (atmospheric pressure)

in—inches (frost depth)

in/hr—Inches per hour (rain rate)

kBtu/cfm —Thousands of Btu per cubic foot per minute (sensible or latent heating or cooling loads)

klux-hr—Thousands of lux-hours (average incident illuminance)

lb/sq ft—pounds per square foot (snow load)

mb Hg—millibars of mercury (atmospheric pressure)

mph—miles per hour (wind speed)

ton-hrs/cfm/yr—ton-hours of load per cubic foot per minute per year (Btu÷12,000)

SUMMARY OF CHANGES

Date of revision: 2 Feb 2015

-- Added Summary of Changes page

-- Updated 14WS web address URL in the Introduction paragraph

-- Added Station ID explanation to the Location Information paragraph

-- Changed the title of ANNUAL DRY BULB TEMPERATURE AND HUMIDITY SUMMARY to LONG TERM HUMIDITY AND DRY BULB TEMPERATURE SUMMARY

-- Updated the images to the most current images