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Wind Speed Distribution Changes With Height at Selected Weather Stations

Jack W. Reed

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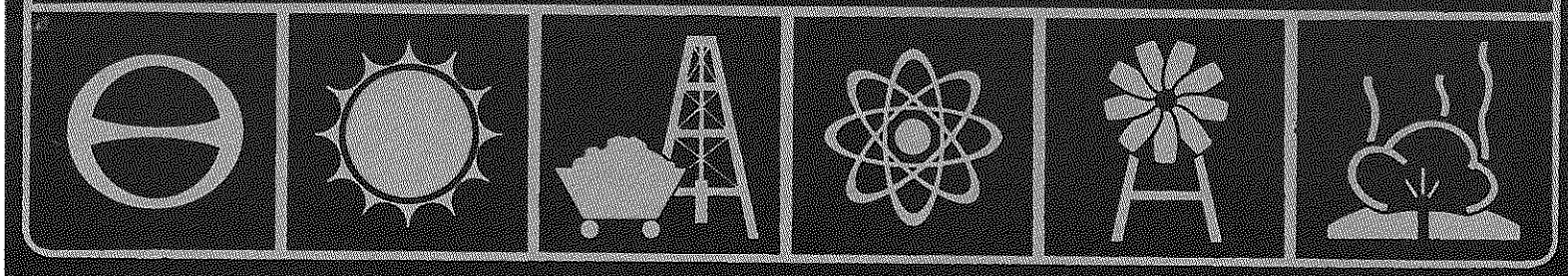

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ABSTRACT

Ten-year records of hourly wind speed observations at 15 selected weather stations have been smoothed to correct for observer bias. Records were adjusted to a constant, final anemometer height over level airfield terrain at nine stations where the anemometer was moved during the period of record. The anemometer adjustment scheme is described for each location, since the anemometer exposure change and date of change were unique for each location. Finally, wind speed distribution curves and tables of synthesized time series at final anemometer height and at 10 m, 20 m, and 50 m above ground have been prepared. These homogenized series should be useful for various analyses of wind power systems.

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WIND SPEED DISTRIBUTION CHANGES WITH HEIGHT AT SELECTED WEATHER STATIONS

Introduction

A major problem with long-term wind records, needed for assessing site wind-power characteristics is that anemometer location and height were often changed every few years. International standard anemometer exposure is remote from obstructions, such as buildings, trees, or hills, and the sensor is mounted 10 m above ground. There has been little attempt to conform to this standard at most United States Weather Bureau (now National Weather Service) observing sites. Expedience, in various forms, has dominated in placing these anemometers. As a result, it is often difficult to make interstation comparisons, particularly for wind-power estimates.

In earlier years of recording (generally before the early 1960's), the highest available mounting point was often used in a attempt to minimize the effects of local obstructions and in hopes of obtaining a representative free-flow observation for use in weather map analysis. Since most observing stations were located at airports, the anemometer often was found on top of large hangars. Frequently it was on a mast extending above the control tower, possibly 20 to 40 m above the ground. Sometimes a site was selected atop the airport terminal which housed the weather station, to minimize signal cable length.

Concern for actual wind conditions during landings with high-performance jet transports led to a policy change in the early 1960's that caused most anemometers to be moved onto the airfield. They were placed approximately 6.5 m (20 ft) above gound, representative of jet transport landing conditions, and without need for a formidable and hazardous mast. Thus the 10-m "standard" observation has been made, if at all, only by some specialized agencies or research projects in such limited numbers as to be inadequate for wind-power climatological assessment. Any assumption by users that standard 10-m observations were taken needs to be examined.

Recent observations, made since the general shift to locations at 6.5-m height near a primary runway, do provide a relatively homogeneous geographic data bank. Over such flat terrain it is likely that simple extrapolation methods are adequate for wind estimates at greater heights which concern many wind-turbine power planners. It may be assumed that wind speed increases in proportion to the one-seventh power of height above ground[1] for useful wind speeds when neutral thermal stability probably occurs as a result of mechanical mixing of the air.

Curves in Figure 1 show that the simple law is adequate for extrapolation above 10 m over flat terrain, by comparison with the more complicated logarithmic law which accounts for the size of surface roughness elements.

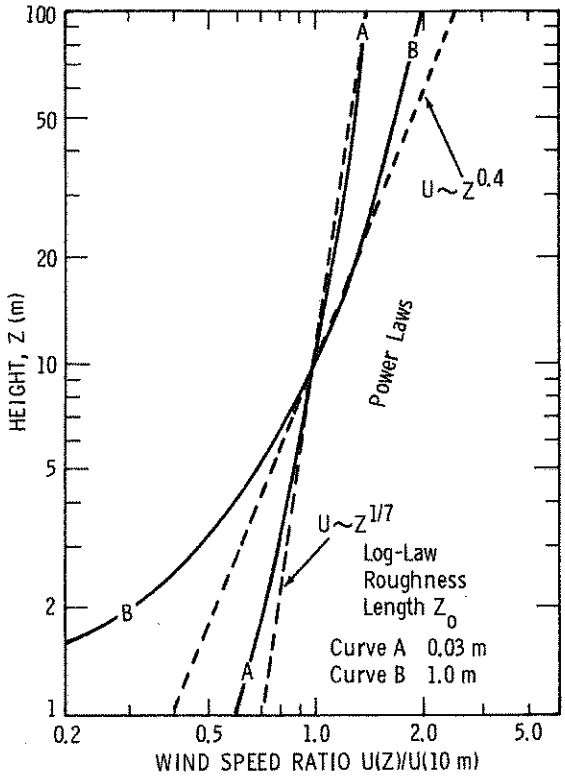

Figure 1

Wind Speed vs Height, Comparison of Logarithmic and Power Laws

With another policy change permanent archive records were reduced to three hourly weather observations beginning in 1965. Hourly reports which are still made for airways monitoring are no longer archived in computer accessible form. For purposes of exploring wind speed distribution functions (and especially at the extremes), these homogeneous exposure data since 1965 are only equivalent to 44 months of hourly observations. Recent analyses by Corotis[2] have shown that only two or three statistically independent observations can be expected during each day, but it is not yet determined how this affects wind power time-series calculations.

For meteorological studies for wind power at Sandia Laboratories, it was felt that a long record of hourly observations was required. A 10-yr series was needed to span possible sunspot cycles as well as provide significant occurrence frequencies for high-wind-speeds. In consequence, a magnetic tape record of complete hourly weather observations for 10 yrs (usually through 1964) for fifteen stations was obtained from the NOAA National Climatic Center (NCC) Asheville, NC.

Station selections were made primarily to represent major U.S. wind-power climate zones, as derived from Reed's[3] national map of available wind power. A second criterion was to select stations near sites of particular interest to wind-power development projects under consideration at the time. Collaboration with the NCC and reference to statistical tabulations by Reed[4]

identified the station which appeared to best meet the multiple criteria of location, representative wind power potential, and record length and quality. It was not considered feasible to conduct a cumbersome but objective site selection process in the hopes of evading the many questions and shortcomings that could arise. Once an analysis scheme was developed and some results were produced, records from other stations could be fed to the computer to satisfy specific needs.

Stations selected for detailed evaluation are listed in Table I with record periods and pertinent anemometer history notes. Several station histories were not specific about anemometer location with respect to buildings, hangars, runways, etc. U.S. Navy records for Corpus Christi, TX and San Nicolas Island, CA do not show the date, but only the year, of a change in anemometer location. Records from Nantucket Shoals, MA (68 mos.), Cape Hatteras, NC (93 mos.), and Eniwetok, Marshall Islands (78 mos.) do not span a full 10 yrs. Their interesting locations made necessary a compromise with record length requirements.

Anemometer Height Changes

Anemometer height changes during a record period must not be ignored in wind-power evaluation. For an extreme example, at San Nicolas Island, the shift from 21.9 m to 4.0 m in 1963 might be expected to reduce wind speeds by a factor of about $(21.9/4.0)^{1/7} = 1.28$, and reduce the annual wind power (speed cubed) estimate by a factor of 2.1. Rather than assume the one-seventh power law for speed correction for this detailed study, actual speed distributions were compared between eras of constant anemometer height at each location. In this way, specific local influences could possibly be identified and corrected.

The methodology employed to generate a homogeneous 10-year time series for the final anemometer height (over open flat airfield terrain) almost necessarily assumed that climatic wind distributions were the same in both anemometry eras, before and after each change. This assumption introduces a possibility for error that will be analyzed in a later report, in consideration of inter-annual wind variability. More important, there are more windy months early in the year before a random anemometer change date, and more light winds later in the year after a change. Consequently, the assumption that the wind distribution is the same before and after a change is not strictly valid. It was decided that introducing this possible bias was preferable to reducing both sample sizes by deleting observations made during a year of change.

The cumulative probability function (CPF) was graphed for each anemometry era. An example is shown in Figure 2 for Corpus Christi, TX. It was assumed that if at some fraction of the time at the first site the observed wind speed was below S_1 knots, and that for the same fraction of the time at the second site the wind was below S_2 knots, then a speed of S_1 knots before the change corresponds to a speed of S_2 knots after the change. In fact, these occurrences would not correlate perfectly, but the scatter has been ignored. Next, the ratio of speeds at the two levels was calculated at each speed integer on the lower curve. Results were graphed as shown by Figure 3.

TABLE I

Stations Selected for Detailed Wind Power Analyses

Station	Record Period Start	Record Period Stop	Anemometer Height (m)	Anemometer Height (ft)	Remarks	Station Selection Criteria
Corpus Christi, TX	1/1/55	12/31/60*	19.2	63	Atop control tower roof	Gulf coast winds
	1/1/61*	12/31/64	6.7	22	Near runway 13R-31L	
Albuquerque, NM	1/1/55	2/4/60	14.6	48	Atop airport adm. bldg.	Sandia VAWT Lab
	2/5/60	12/31/64	7.0	23	Near E-W runway	
Memphis, TN	1/1/55	7/22/58	16.8	55	Atop airport adm. bldg.	Southeast U.S., light winds
	7/23/58	12/31/64	6.7	22	(Near runway?)**	
Dodge City, KS	1/1/55	4/12/61	17.7	58	Atop airport adm. bldg.	High plains winds
	4/13/61	12/31/64	6.1	20	(Near runway?)**	
Nantucket Shoals, MA	4/1/57	12/4/62	61.0	200	Radio mast, top deck, Texas Tower	Atlantic offshore winds
Cleveland, OH	1/1/55	1/30/56	17.1	56	Atop mun. airport adm. bldg.	NASA Lewis Lab and turbine
	1/31/56	6/25/59	26.8	88	Atop int'l airport term. bldg.	
	6/26/59	12/31/64	6.1	20	(Near runway?)**	
Fargo, ND	1/1/55	6/26/61	26.2	86	Atop airport adm. bldg.	Northern plains winds
	6/27/61	12/31/64	6.1	20	(Near runway?)**	
Lubbock, TX	1/1/55	12/31/64	20.7	68	Atop airport term. bldg.	High plains winds, Texas Tech turbine project
Oklahoma City, OK	1/1/55	12/31/64	4.0	13	Near N-S runway	Plains winds, university turbine projects
Cheyenne, WY	1/1/55	10/2/57	22.3	73	Atop airport bldg.	Western high plains.
	10/3/57	12/31/64	10.1	33	(Near runway?)**	
Great Falls, MT	1/1/55	8/1/59	22.9	75	Atop airport adm. bldg.	Mountainous and windy
	8/2/59	12/31/64	7.0	23	(Near runway?)**	
Tatoosh Is., WA	1/1/55	12/31/64	19.5	64	Atop USWB office	Pacific coastal winds
Eniwetok, Marshal Is.	1/1/60	6/30/69	----	Unkn	----	Tradewinds, ERDA site
San Nicolas Is., CA	1/1/60	6/30/63*	21.9	72	Atop control tower	Pacific coastal winds
	7/1/63*	12/31/69	4.0	13	800 ft SE of opns bldg.	
Cape Hatteras, NC	3/1/57	12/31/64	9.8	32	At USWB bldg. in Buxton	Atlantic coastal winds

*Exact date of anemometer relocation not recorded.

**Final location not specified but it probably was near a runway.

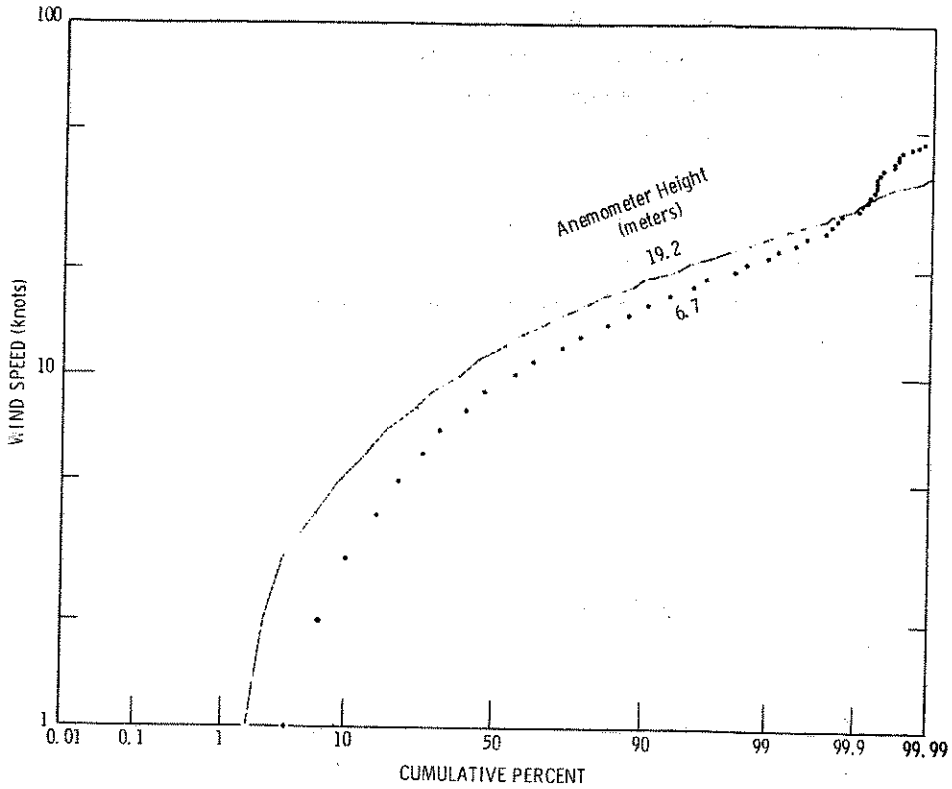

Figure 2. Wind Speed Distributions at Corpus Christi, TX

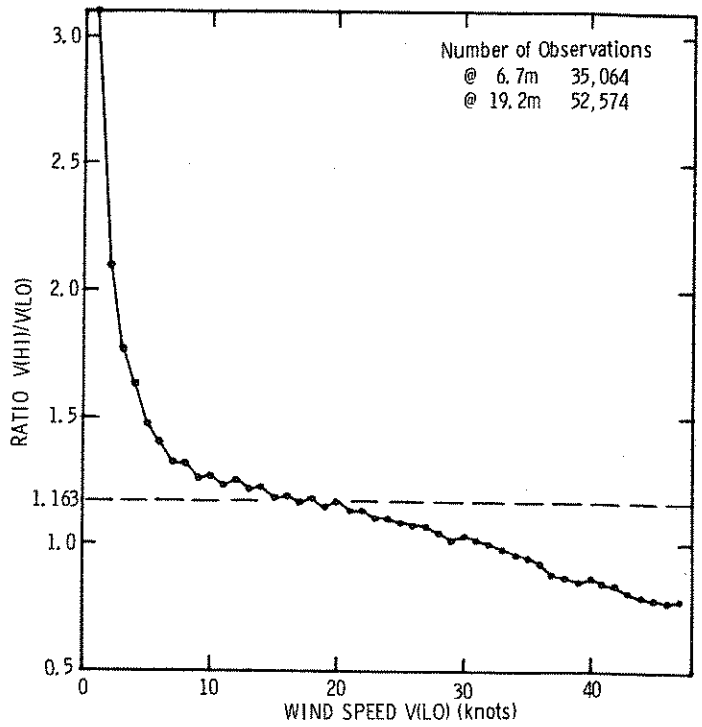

Figure 3. Wind Speed-Height Ratios at Corpus Christi

For reference purposes, the ratio obtained from the one-seventh power law has been shown. As the next section will demonstrate, there are various deviations from this power law result. Each station thus needs individual analysis in order to obtain an appropriate function for adjusting early era records and synthesizing a homogeneous long-time series of observations.

In most cases very low wind speeds have correspondingly large ratios. These conditions are of little concern to wind turbine applications, so relatively crude functional relationships have been adopted for height adjustments at speeds below about 5 knots.

Station Wind Records

Corpus Christi, TX

This station was selected as representative of the breezy Gulf Coast of Texas.[3] Wind speed distributions for 19.2-m and 6.7-m heights were shown in Figure 2. In general, both distributions give a relatively smooth curve on this log-normal graph. Both are curves, however, and not straight lines as would be required for a log-normal distribution. On the other hand, a log-normal distribution could be quite reasonably fit to 60 to 80 percent of the data in a range of importance to wind-power studies.

Figure 3 shows that very light winds are magnified with height although the upper level speed is not great. There is an approach to the one-seventh power law relationship at 10 to 20 knots,* as might be expected. There is, however, a decay so that high speed winds at low level appeared to correspond to lower winds aloft. This result was not repeated in other station records. Returning to Figure 2, this crossover is seen to result from an irregular hump of high probability for speeds over 30 kt from the low anemometer. There was a possibility that these high winds came from a specific direction where the control tower anemometer was protected. Original records showed, however, that some 20 hrs of exceptionally strong winds (over 35 kt) were observed during the passage of Hurricane Carla (struck Port LaVaca, 100 km northeast of Corpus Christi) on September 10-12, 1961. This storm considerably distorted the entire 6.7-m speed distribution.

It is generally accepted that winds in tropical disturbances distort the normal wind-speed distribution. This must be considered at low-latitude coastal stations where hurricanes may strike. Such storm wind occurrences cannot legitimately be deleted from a statistical sample, but they do pose problems for wind energy assessment. They may contribute an exceptional amount of wind power to station averages, but most typical wind turbines would be secured during hurricane threats.

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*Archived wind-speed data were recorded in integer knots (nautical miles per hour, abbreviated kt), so this measure has been preserved in calculation. Easy conversion to metric standard meters per second is obtained from dividing knots by 2 (with -2.9% error).

This special case must be considered whenever semitropical or tropical coastal station analyses are conducted.

For the present analyses, it will be assumed that when wind speeds at 6.7-m height exceed 20 kt, the one-seventh power law is valid for extrapolation to higher levels. At lower speeds, the ratio curve is approximated by linear relationships between the three points shown in Table II. For comparisons with other studies, the apparent exponent for relating wind speed to height is listed in Table III for low-level winds of 5, 10, and 20 kts.

TABLE II

Linear Approximators for Wind Speed Ratio Functions

	End Points of Linear Segments					
	I		II		III	
	Low-Level Speed	Ratio	Low-Level Speed	Ratio	Low-Level Speed	Ratio
Corpus Christi	0	2.000	8	1.270	≥20	1.163
Albuquerque	All	1.060				
Memphis	0	1.269	27	1.047		
Dodge City	0	1.450	≥15	1.164		
Cleveland I	All	1.158				
Cleveland II	All	1.236				
Fargo	2	1.500	30	1.232		
Cheyenne	3	0.850	≥25	1.120		
Great Falls	All	1.184				
San Nicolas Island	8	1.175	29	1.124		

TABLE III

Observed Wind Speed - Height Relation Exponents

$$u_2/u_1 = (Z_2/Z_1)^a$$

	$a = \ell n(u_2/u_1)/\ell n(Z_2/Z_1)$				
	Anemometer Heights (meters)		Low-Level Speed, u_1 (knots)		
Station	Z_1	Z_2	5	10	20
Corpus Christi	6.7	19.2	0.37	0.23	0.15
Albuqerque	7.0	14.6	0.09	0.10	0.11
Memphis	6.7	16.8	0.23	0.19	0.14
Dodge City	6.1	17.7	0.29	0.22	0.16
Cleveland I	6.1	17.1	0.02	0.12	0.16
Cleveland II	6.1	26.8	0.24	0.20	0.17
Fargo	6.1	26.2	0.28	0.23	0.22
Cheyenne	10.1	22.3	(-0.23)	(-0.05)	0.11
Great Falls	7.0	22.9	0.14	0.20	0.17
San Nicolas Island	4.0	21.9	0.12	0.11	0.10

Albuquerque, NM

This station was selected for proximity to Sandia's Vertical Axis Wind Turbine (VAWT) laboratory. It is probably representative of many inhabited valley regions in the mountainous west. Wind speed distributions for 14.6 and 7.0-m anemometer heights are shown in Figure 4, and the curve of speed ratios versus 7.0-m speed is shown in Figure 5. Very low speeds are more frequent at the higher level. Also, the speed increase with height is not so great as the one-seventh law would indicate for speeds below about 25 kt. These conditions probably both result from the fact, stated in Table I, that the higher measuring site was atop the airport terminal, where considerable wind resistances could be expected from the building and nearby trees.

In adjusting the 14.6-m distribution to 7.0 m, very low speed winds may be neglected. A speed-correction factor of 1.06 has been adopted from the data, rather than 1.11 which was obtained from the one-seventh law. Errors from under-correcting for speeds above about 25 kt may be safely ignored, as they affect only 0.3 percent of this data series.

Memphis, TN

This station was selected to represent conditions in the generally light-wind regions of the Southeast.[3] Wind speed distributions for 6.7 and 16.8-m observing heights are compared in Figure 6, and speed ratios are graphed in Figure 7. These data are quite well-behaved in following the one-seventh power law. Early siting on the airport administration building did not appear to seriously influence these data. At very low speeds the increase with height is larger, as could be expected. The small slope of the ratio curve was used for the linear adjustment function, as defined by two points in Table II.

Dodge City, KS

This station is representative of the high-wind-power region of the western High Plains.[3] Wind speed distributions for 6.1 and 17.7 m are shown in Figure 8, along with the total distribution that ignores the anemometer height change. Speed ratios for the two heights are shown in Figure 9. A one-seventh power law approximation appears valid for low-height wind speeds above about 15 kt. At lower speeds a linear approximation of the ratio will be assumed for data adjustment (from two points shown in Table II).

Cleveland, OH

This station was selected for proximity to the NASA Plumbrook wind-turbine test site. The Cleveland anemometer was moved twice during the 10-yr record, so three distribution curves are shown in Figure 10, for 6.1, 17.1, and 26.8 m. Two ratio curves, in relation to the lowest 6.1 m observations, are shown in Figure 11. The 13-mo. record at 17.1 m showed reduced speeds at low speeds with a dip on the ratio curve, similar to the effect noted at Albuquerque. The new building and anemometer mount, established at 26.8 m in 1956 shows an opposite effect: a speed-up beyond what the power law gives. Both data sets show an approach to one-seventh

power law dependence for speeds above 10 to 15 kt, so this relationship will be assumed valid for all adjustments of this station record. Resulting errors at speeds below 10 kt will not affect wind power analyses, because of the low-power production level.

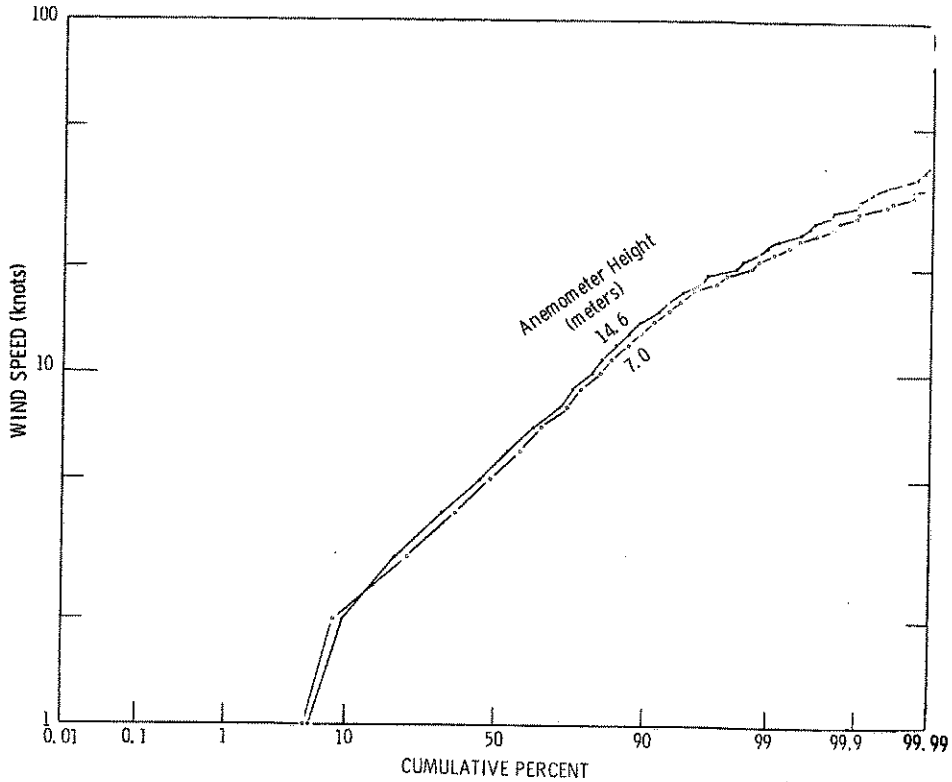

Figure 4. Wind Speed Distributions at Albuquerque, NM

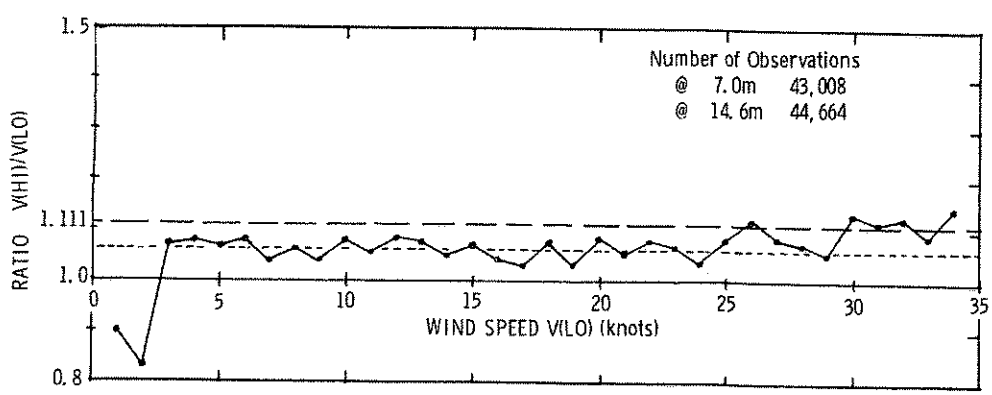

Figure 5. Wind Speed - Height Ratios at Albuquerque

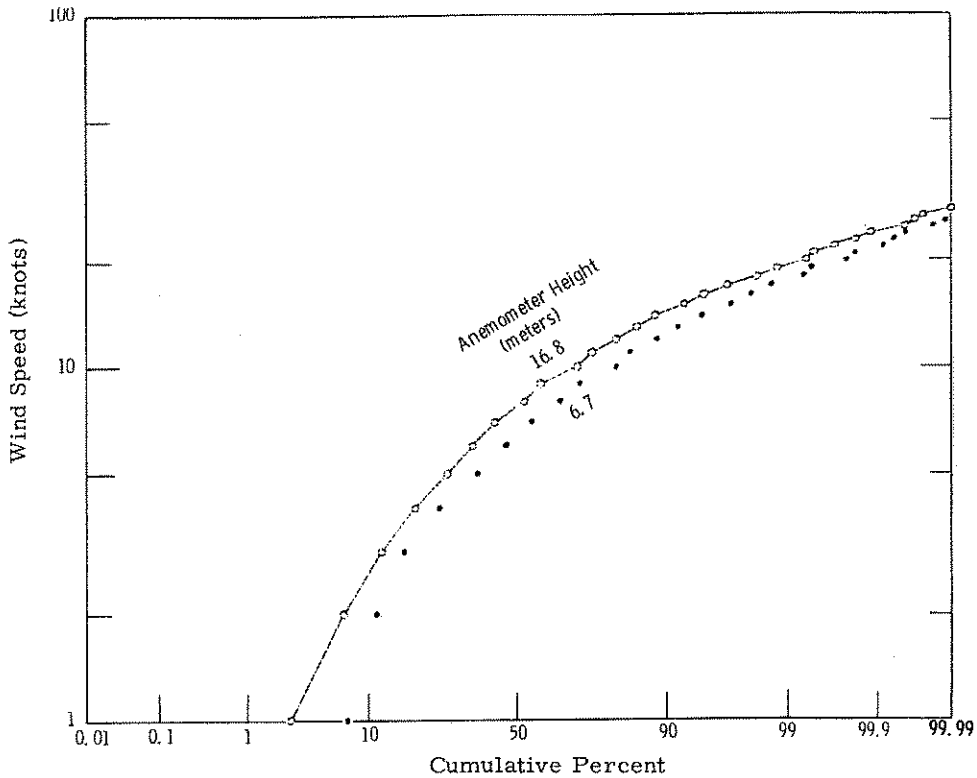

Figure 6. Wind Speed Distributions at Memphis, TN

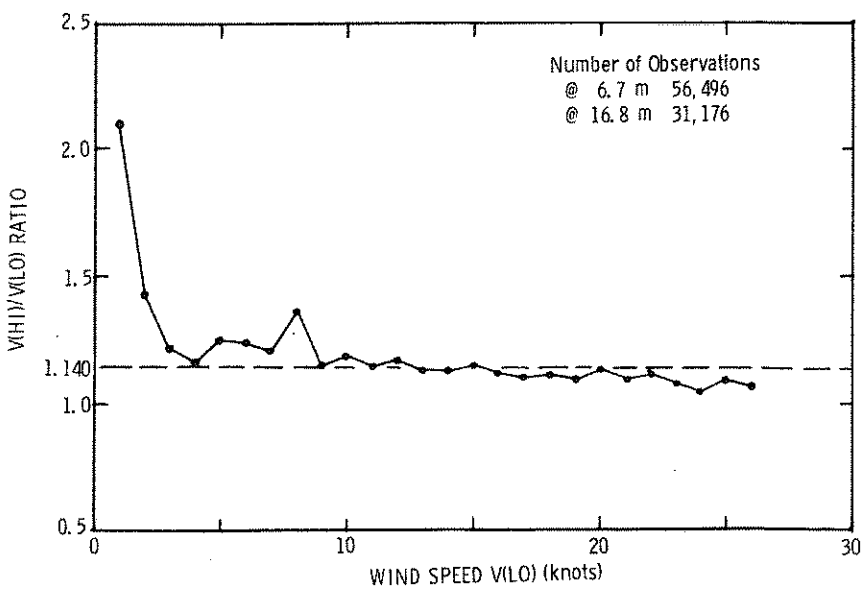

Figure 7. Wind Speed - Height Ratios at Memphis

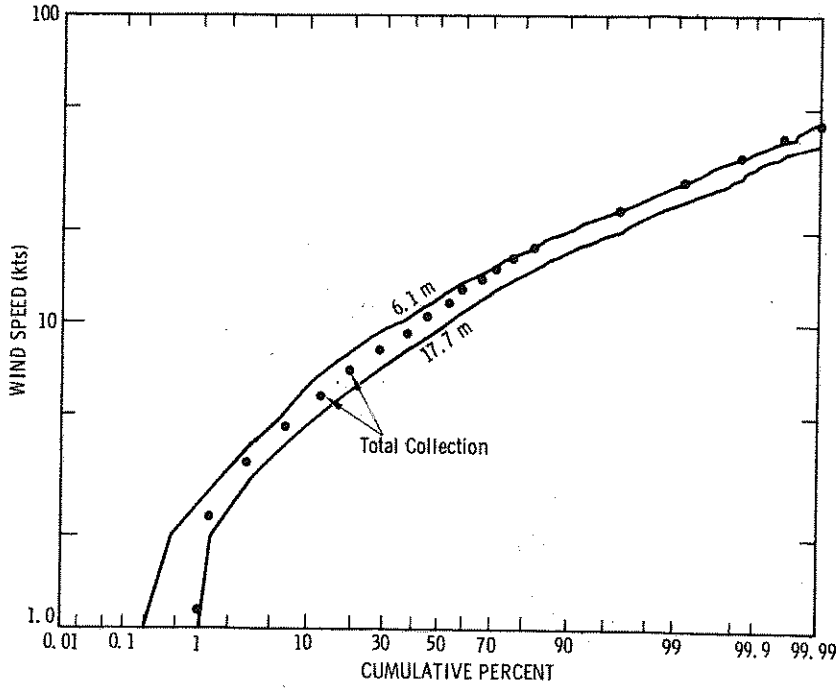

Figure 8. Wind Speed Distributions at Dodge City, KS

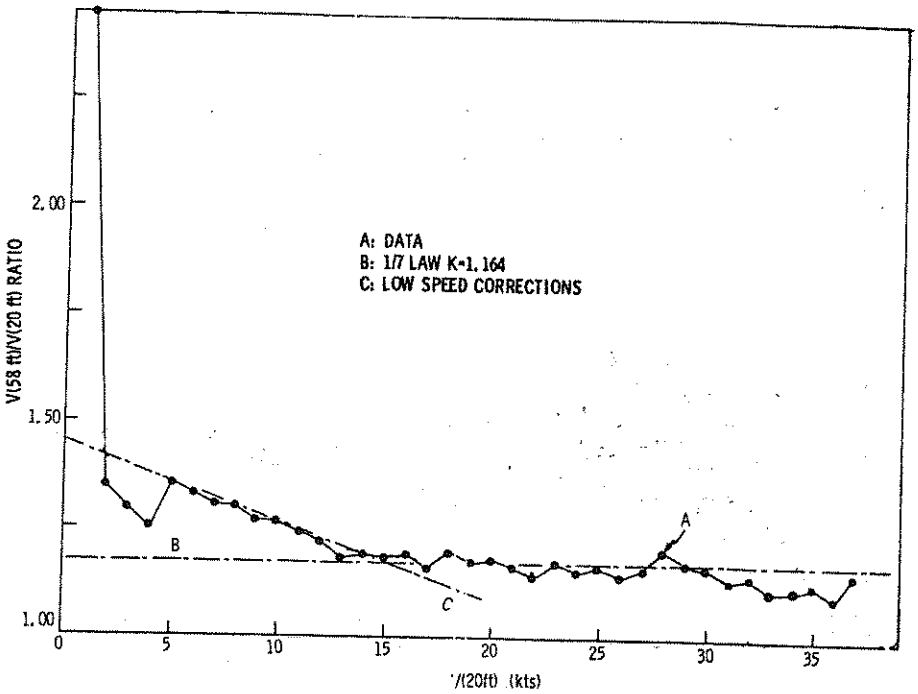

Figure 9. Wind Speed - Height Ratios at Dodge City

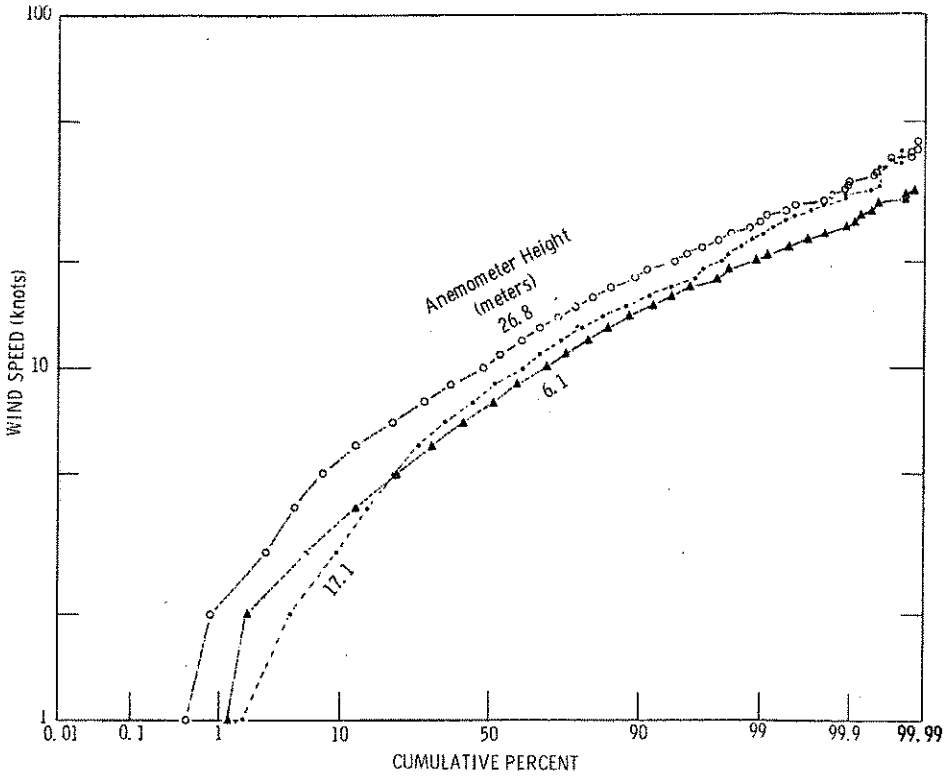

Figure 10. Wind Speed Distributions at Cleveland, OH

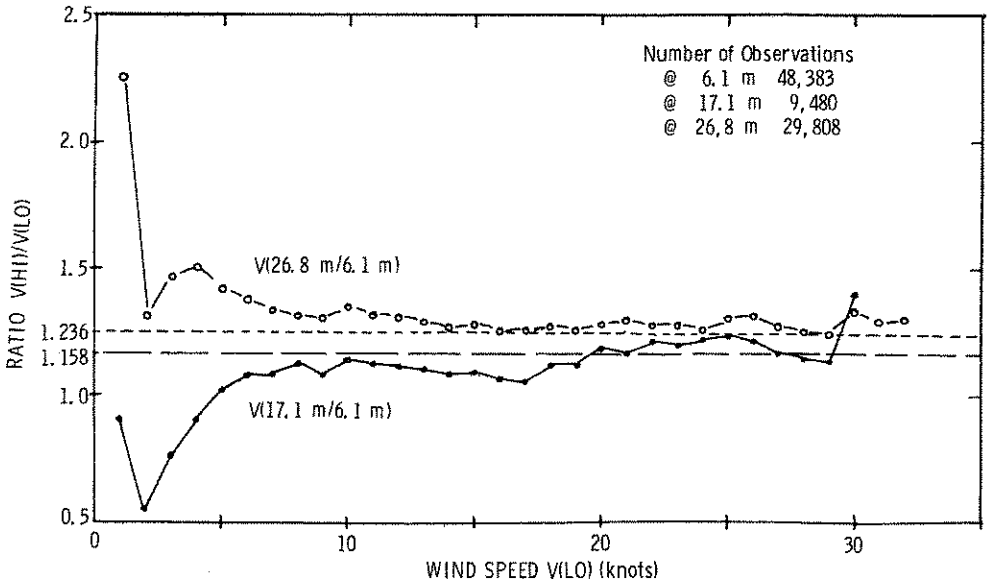

Figure 11. Wind Speed - Height Ratios at Cleveland

Fargo, ND

This station was selected to represent conditions in the northern Great Plains.[3] Wind speed distributions for 6.1 and 26.2 m are shown in Figure 12, and the ratio curve is shown in Figure 13. At this location there does not appear to be the expected convergence toward one-seventh power law dependence. Instead there is simply a gradual decrease of speed ratio with increasing speed. A cause for this response is not apparent, so it must be simply accepted at this time as a site characteristic. Adjustment of 26.2 m speeds to the 6.1 m height will be accomplished with a linear approximation between two points shown in Table II. This speed range encompasses 86 percent of all observations, and speeds above 30 kt at 6.1 m were only reported 0.17 percent of the time.

Cheyenne, WY

This station was selected for its long available record near the very high-wind-power region in southern Wyoming.[3] Wind speed distributions for 10.1 and 22.3 m anemometer heights are shown in Figure 14, with the speed ratio curve shown in Figure 15. Here again it appears that the airport terminal building did influence and reduce lower speed winds, so that only when the speed exceeded about 15 kt was the speed greater at the higher level. One-seventh power law dependence was reached and maintained above 25 kt. Adjustment of this record is made at lower speeds with a linear approximation between points listed in Table II.

Great Falls, MT

This station was selected to represent inhabited regions of the northern Rocky Mountain States. Wind speed distributions are shown in Figure 16 for the 7.0 and 22.9 m observations. The ratio curve in Figure 17 shows fairly good agreement with a one-seventh power law factor, although there are some significant broad oscillations. Until they are explained, however, they will be ignored, and this station record will be adjusted in accordance with the simple power law.

San Nicholas Island, CA

This station was selected to represent the coastline and off-shore wind power potential conditions along the California coast.[3] This station record turned out to be a mixed bag of reports taken during the 10 yrs from 1960 through 1969. Daytime hourly observations were made except during 1965, and three hourlies were reported part of the time outside normal working hours. Wind speed distributions at 4.0 and 21.9 m are shown in Figure 18, with speed ratios in Figure 19. Results show some influence of the early location on the control tower which was atop a new operations building. Wind speeds increase with height but not as much as expected from the one-seventh power law. This condition may also be attributable to particular flow patterns over this rocky island, or it may result from the prevalence of daytime observations during relatively unstable vertical thermal gradient conditions. Speed adjustment is assumed to follow the local pattern, with linear relationship established by the two points listed in Table II.

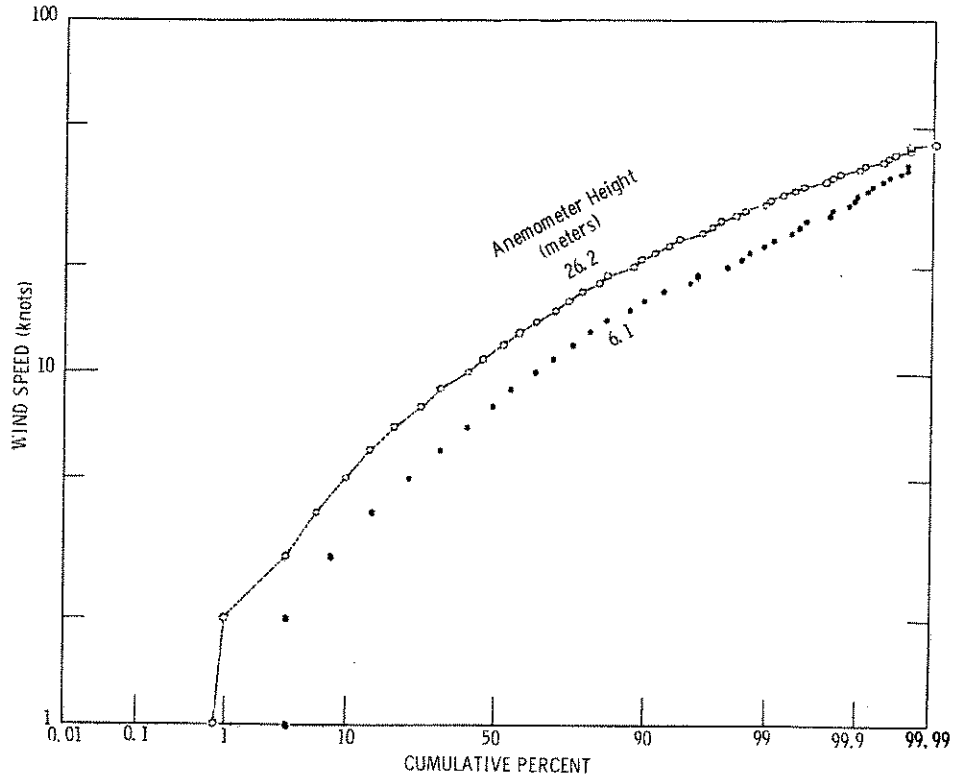

Figure 12. Wind Speed Distributions at Fargo, ND

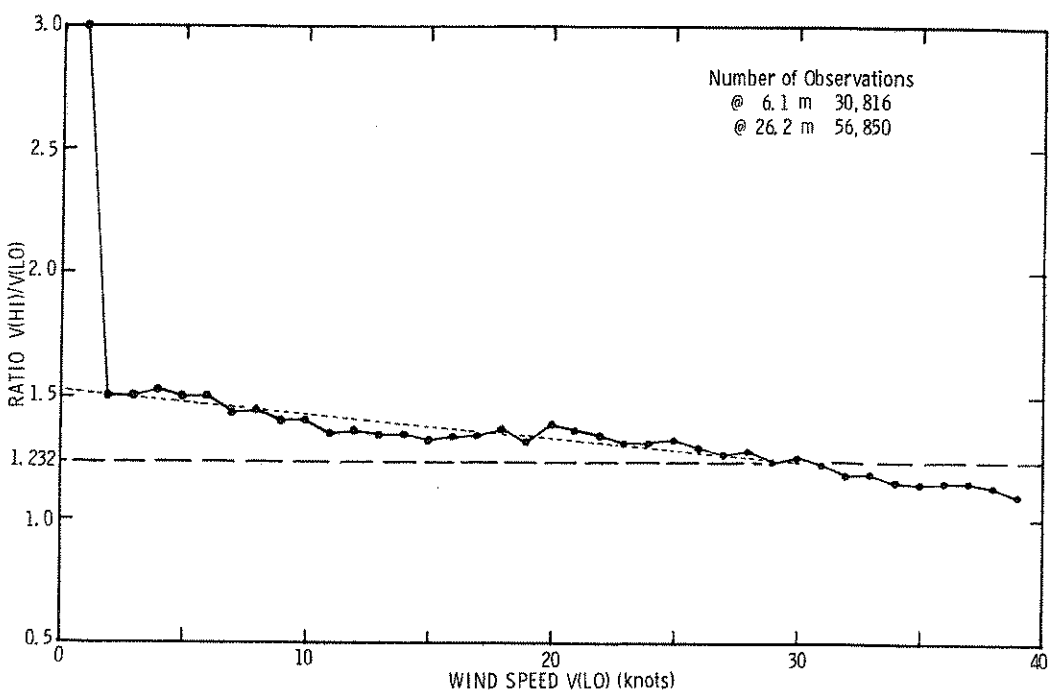

Figure 13. Wind Speed - Height Ratios at Fargo

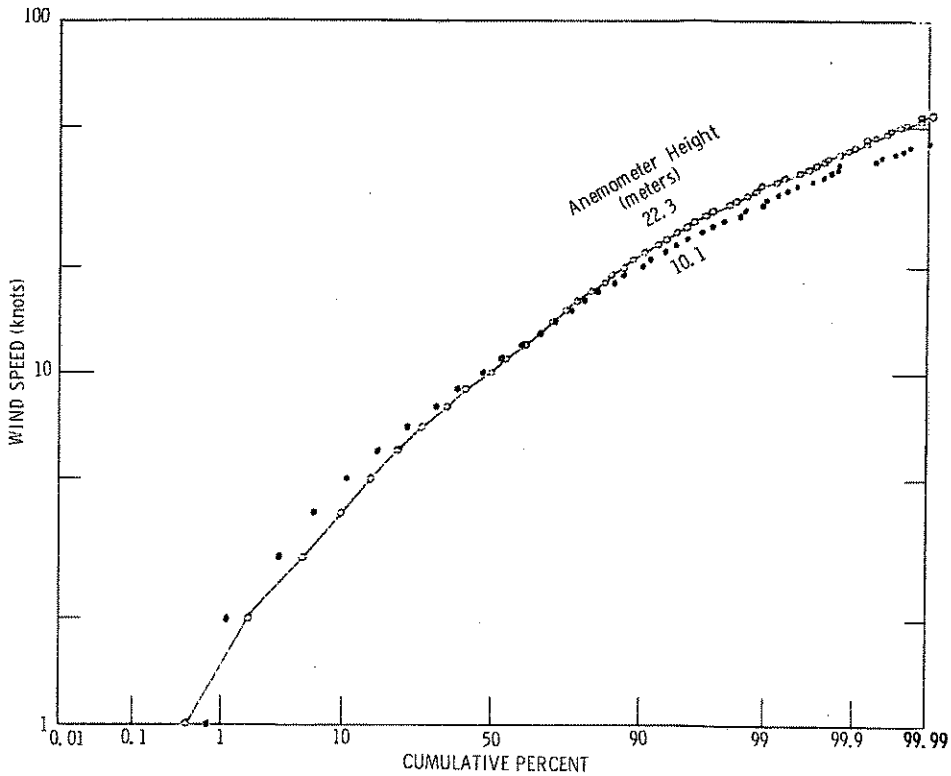

Figure 14. Wind Speed Distributions at Cheyenne, WY

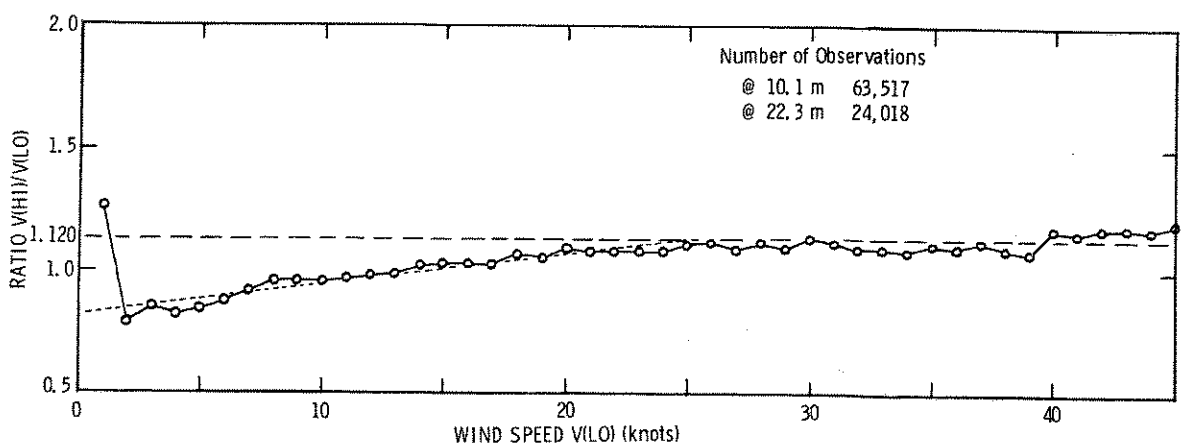

Figure 15. Wind Speed - Height Ratios at Cheyenne

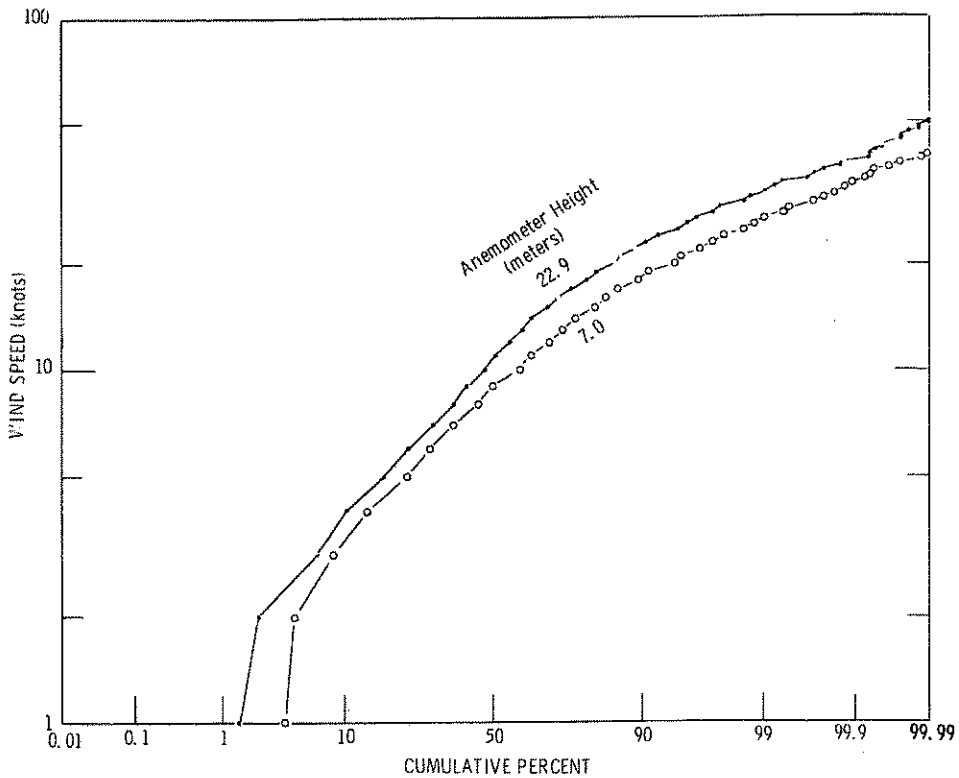

Figure 16. Wind Speed Distributions at Great Falls, MT

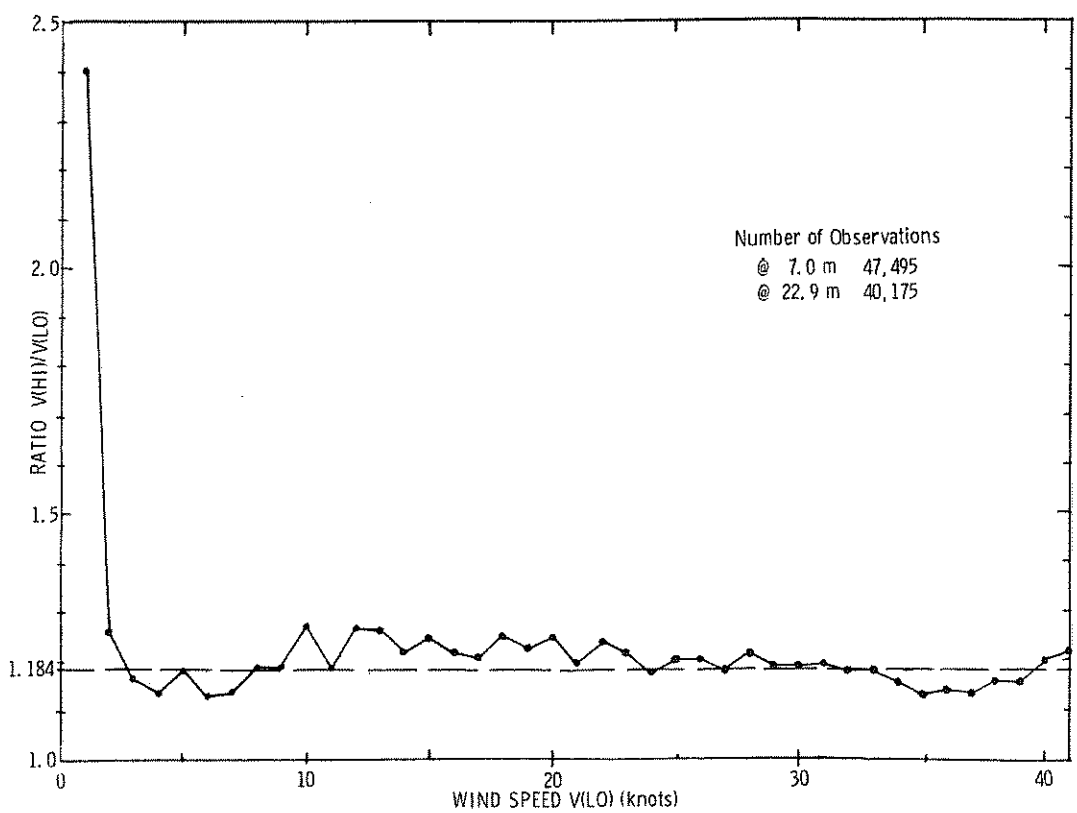

Figure 17. Wind Speed - Height Ratios at Great Falls

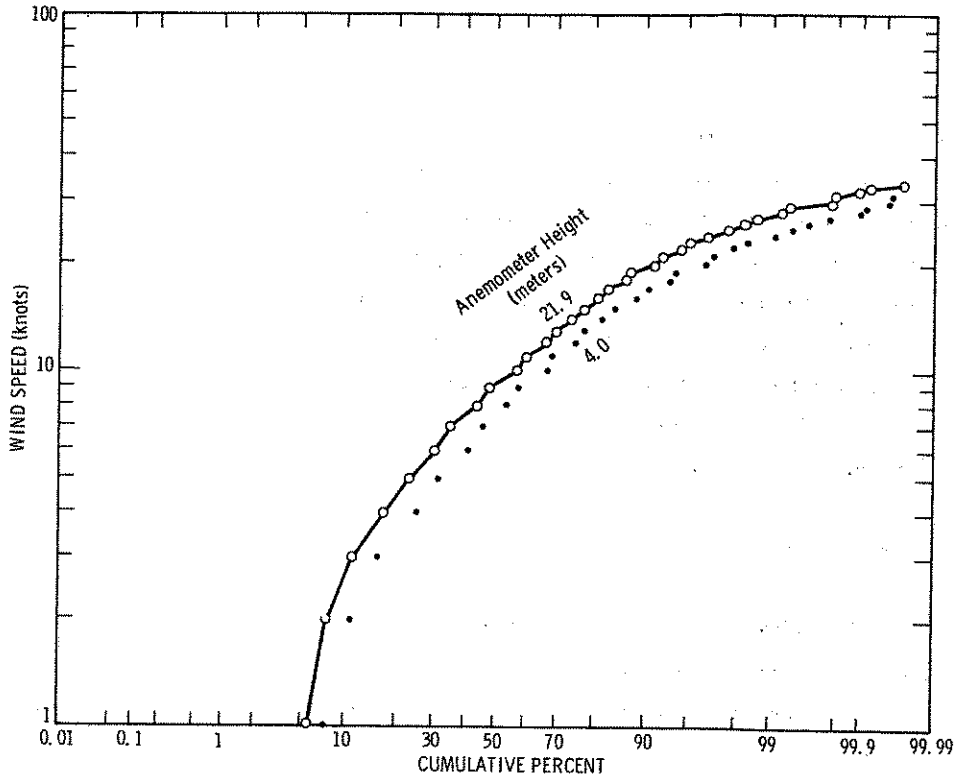

Figure 18. Wind Speed Distributions at San Nicolas Island, CA

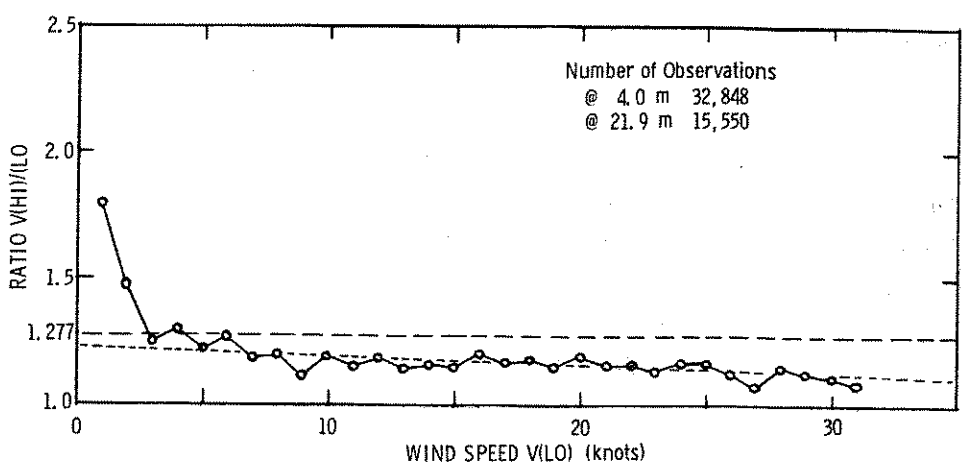

Figure 19. Wind Speed - Height Ratios at San Nicolas Island

Constant Height Records

The six station records in which no anemometer height change was reported may be conveniently separated into continental and maritime regimes. Lubbock, TX and Oklahoma City, OK, the continental stations in the relatively windy southern plains,[3] had speed distributions as shown in Figure 20. Lower speeds at Oklahoma City may be attributed to the lower anemometer height. Power law extrapolation from 4.0 to 20.7 m (the Lubbock height) would give 1.265 times the low-level speed and very nearly approach the Lubbock curve in the 10 and 25 kt range. This result agrees with the national map analysis of annual average wind power available,[3] that shows both locations near the 200 Wm^{-2} contour. The low-speed irregularity at Lubbock probably results from an anemometer cut-in speed near 3 kt.

Four maritime locations provided speed distributions shown in Figure 21. An interesting feature of comparison is that Tatoosh Island and Nantucket Shoals speed distributions differ by a factor of 1.234 at speeds over 20 kt, as predicted by the one-seventh power law for the anemometer height difference. Thus it appears that estimates of New England off-shore wind power may have been overestimated in the national map analysis,[3] for equivalent heights.

Unfortunately, an anemometer height is not available for the Eniwetok record taken in the relatively persistent tropical trade wind belt. Yet, this distribution does show the steady trade winds characteristic: 62 percent of reports were speeds of 10 to 20 kt. The relatively high frequency of gale winds at Cape Hatteras was caused by Hurricanes Helena in 1958 and Donna in 1960.

Wind Speed Distribution Functions

Considerable computational advantages may be gained if wind speeds can be described by some general and common distribution function such as the normal, log-normal, or Weilbull distributions, even over limited ranges of speed. This would allow analytic solutions of integrals for wind power rather than tedious numerical integrations by computer, although this advantage becomes less apparent with the current proliferation of programmable pocket calculators. From most of the preceding figures, it is clear that a log-normal distribution function does not accurately depict distributions over the entire wind speed range. If the interesting range for wind turbines is defined as above an 8 kt cut-in speed with a cut-off near 35 kt, several station records can be reasonably approximated by a log-normal distribution. Lubbock, Cape Hatteras, Memphis, Dodge City, and Cheyenne provide good examples. Yet, a more generally applicable distribution function is required for wide-spread usage in wind-power assessment.

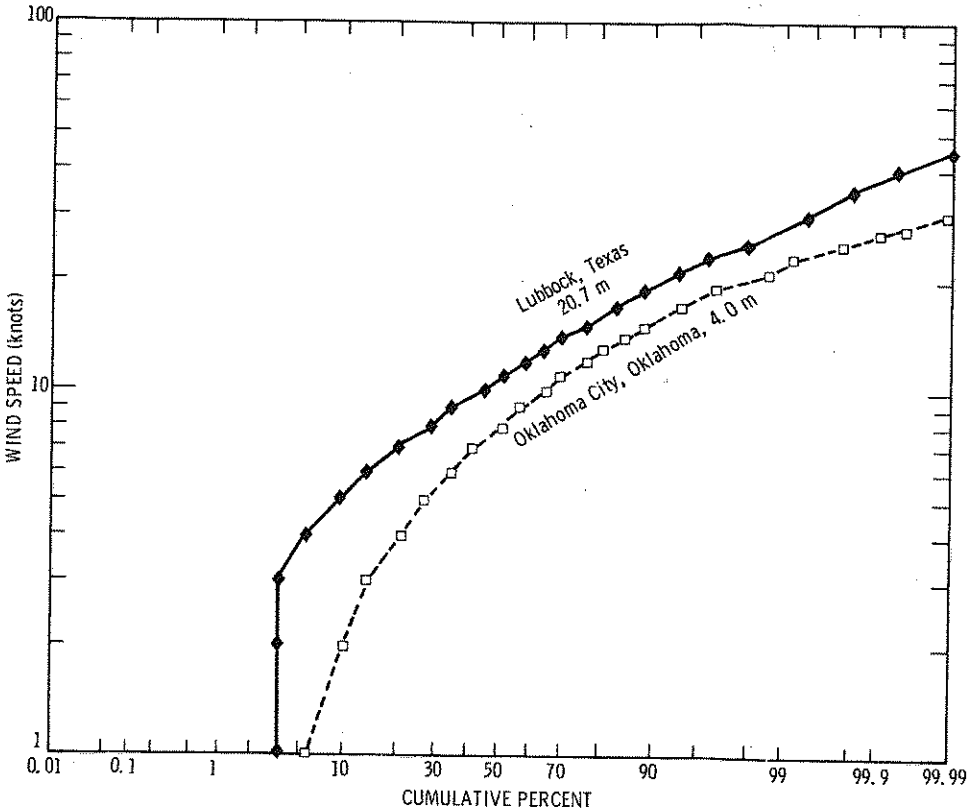

Figure 20. Wind Speed Distributions at Continental Sites

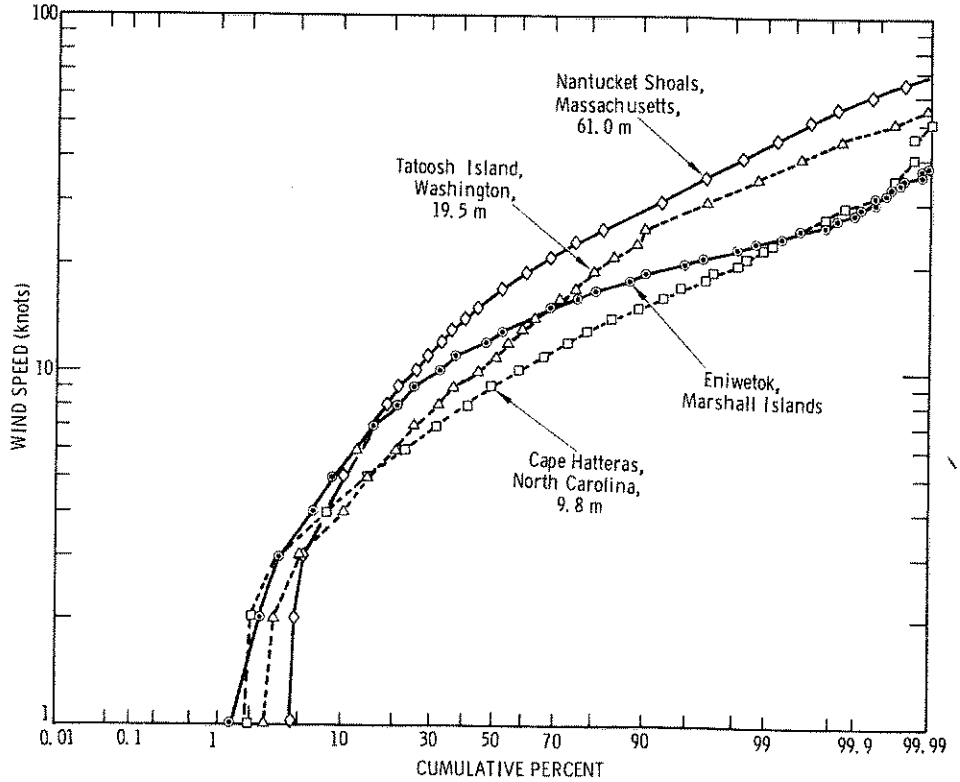

Figure 21. Wind Speed Distributions at Maritime Sites

For comparison purposes, speed distributions for Nantucket Shoals have been graphed in log-normal, Weibull, and normal coordinates in Figures 22, 23, 24, respectively. When a distribution follows one of these common models, the data of the distribution fall along a straight line when plotted in the appropriate coordinates. For these curves, the actual distribution was severely smoothed to counter observer bias in favor of certain digits.[5] (This smoothing caused about 1 kt speed increases at most probability levels that are not yet explained.) The curvature evident in log-normal coordinates can indeed be flattened (linearized) in useful speed ranges by use of Weibull coordinates. On the other hand, the simple normal distribution coordinate curve shows an excellent straight-line fit up to 30 kt, even to 35 kt. Since this range contains over 90 percent of all occurrences, this elementary distribution function certainly should not be discarded without further consideration. Even more appropriately, speeds probably should conform to a bivariate circular normal distribution of wind vectors, as suggested by Buell,[6] but this does not appear to allow a simple description for wind-power applications. Further study of vector wind distributions is planned in hopes of developing direction variation statistics needed for evaluation of horizontal axis turbines.

The other three maritime station records have been shown in normal distribution coordinates in Figure 25 and in Weibull coordinates in Figure 26. At Eniwetok, a normal distribution approximation appears valid from 1 to 25 kt, covering over 98 percent of the data. At Tatoosh Island, 30 percent of occurrences with speeds over 15 kt appear normally distributed, but a somewhat different normal distribution is needed to describe the interesting 40 percent of speeds between 8 and 15 kt. Cape Hatteras speeds show a gradual curve, but it could be approximated by a line between 8 and 20 kt, covering nearly 60 percent of occurrences. From these curves it appears that a normal distribution can be quite useful for describing speeds that are most interesting to wind-power evaluations.

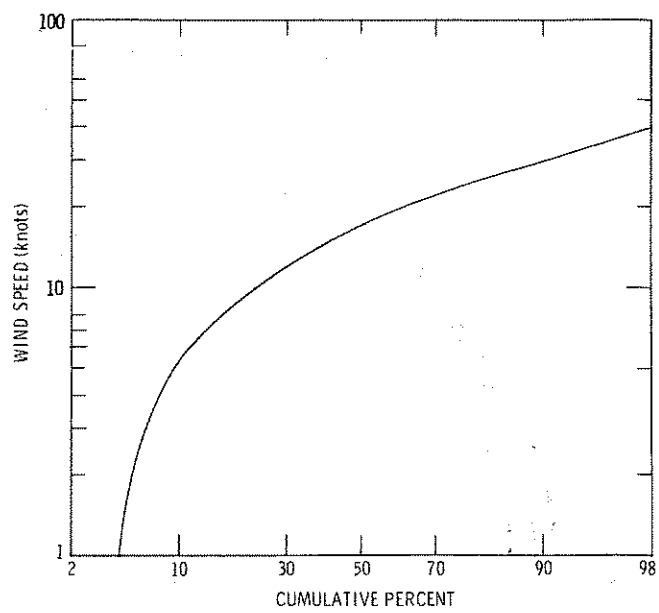

Figure 22. Wind Speed Distribution at Nantucket Shoals, MA, in Log-Normal Coordinates

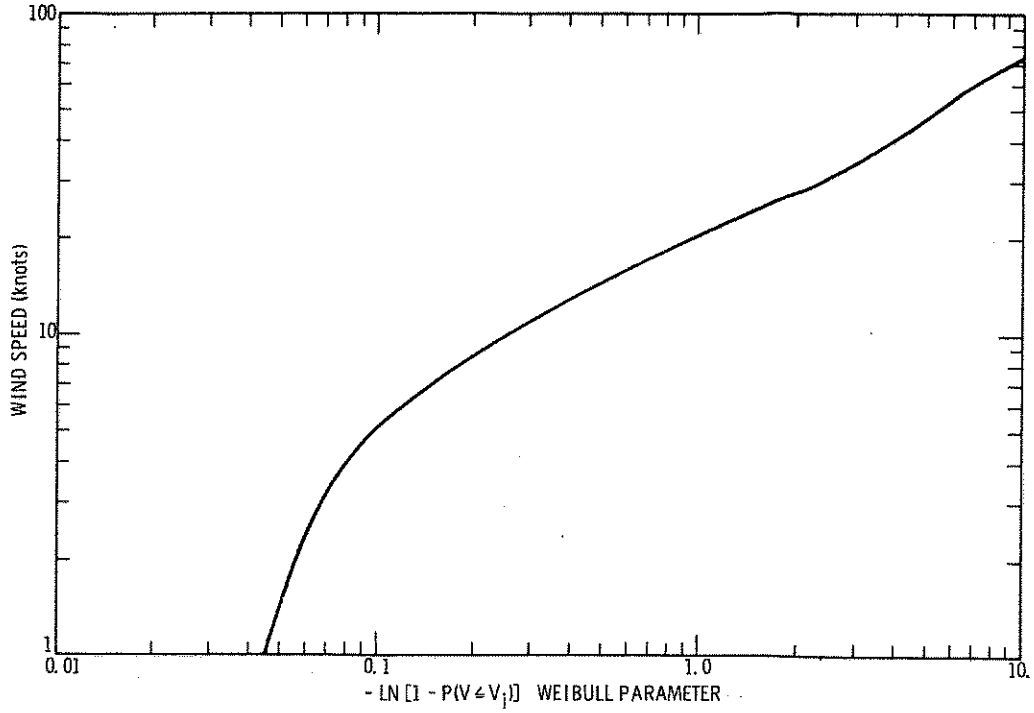

Figure 23. Wind Speed Distribution at Nantucket Shoals, MA, in Weibull Coordinates

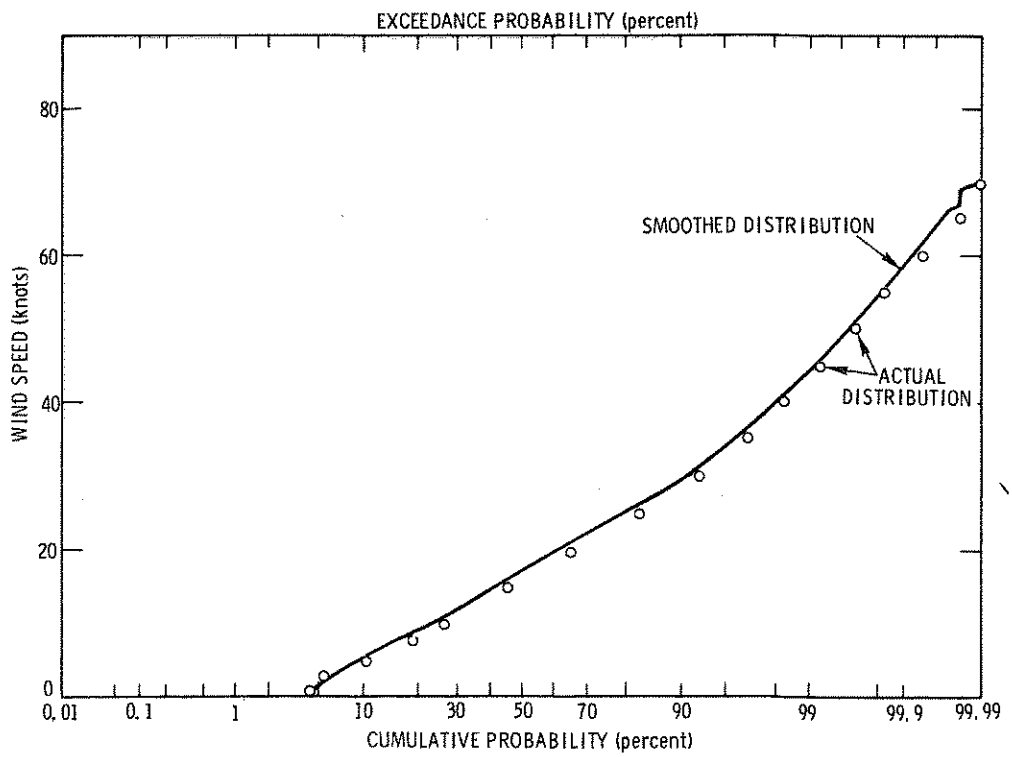

Figure 24. Wind Speed Distribution at Nantucket Shoals, MA, in Normal Coordinates

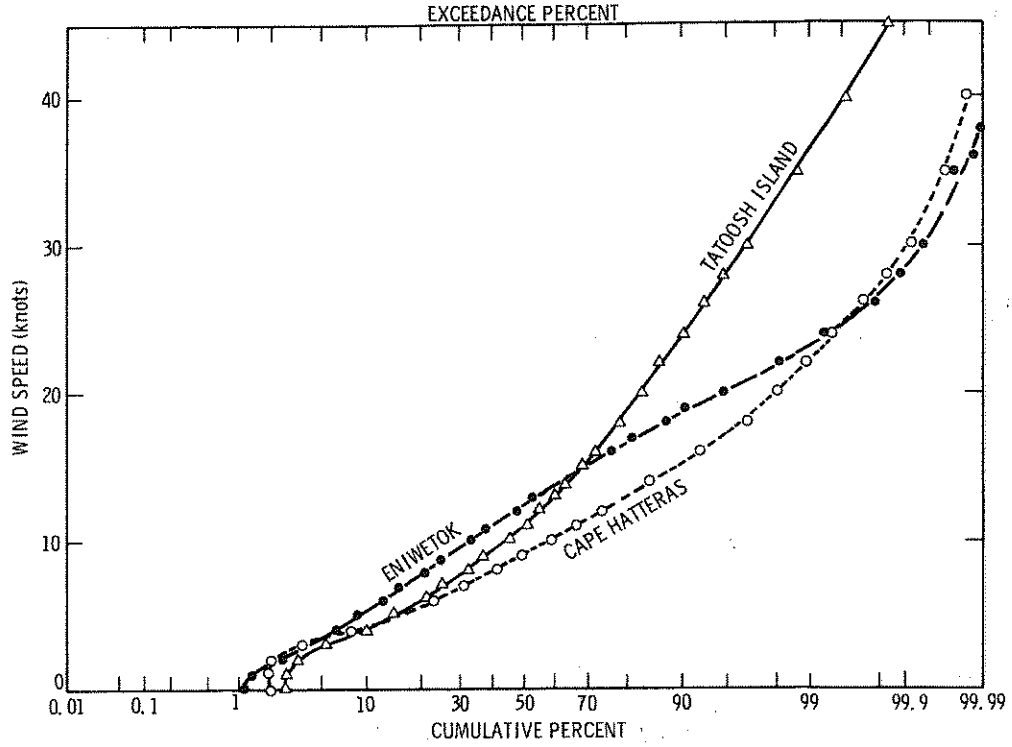

Figure 25. Wind Speed Distributions, Maritime Stations, in Normal Coordinates

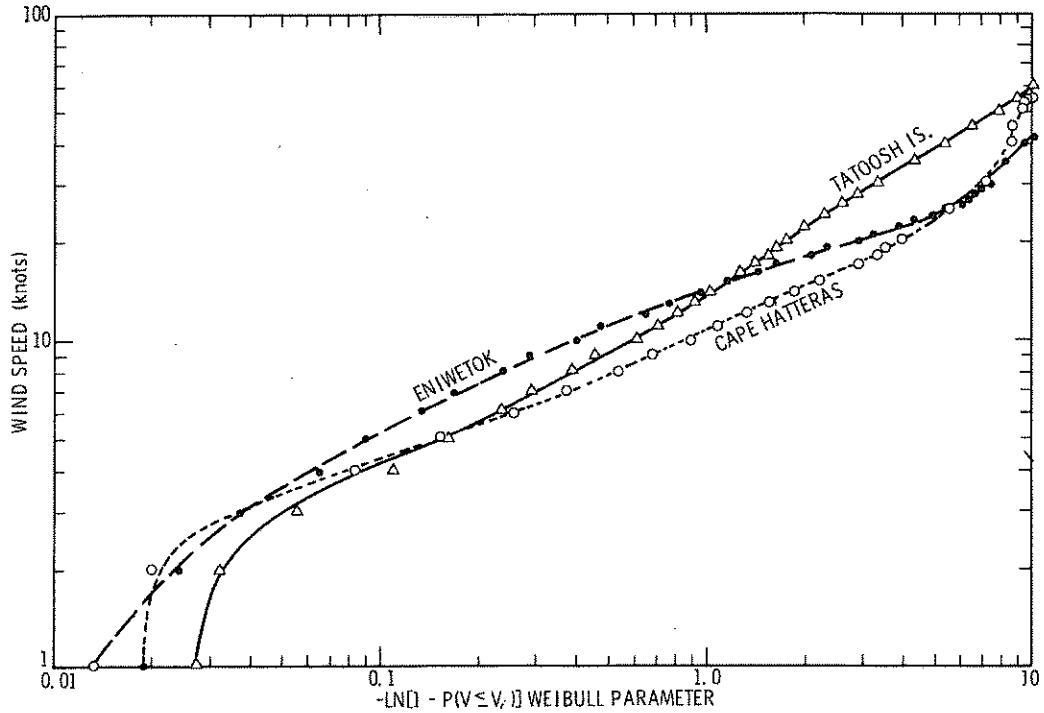

Figure 26. Wind Speed Distributions, Maritime Stations, in Weibull Coordinates

Weibull coordinate distributions in Figure 26 also show extensive linear ranges. At Eniwetok, however, the useful linear segment only extends down from 25 kt to about 8 kt, and this is somewhat more restricted than the comparable normal coordinate curve. Both Cape Hatteras and Tatoosh Island data may also be well estimated by a straight line over useful ranges.

A similar pattern holds valid at continental sites, as shown in Figures 27 and 28, in normal and Weibull coordinates, respectively. A normal distribution adequately describes Oklahoma City data from 5 to 30 kt, but Lubbock data are not so well approximated at higher speeds. Both station data sets can be fit by Weibull distributions over the range of wind power interests.

There was no attempt to make "goodness-of-fit" calculations for comparing these various distribution approximations. Preceding discussions have shown considerable subjectivity in the selection of ranges where various functions fit the data, but the stated conclusions are evident by inspection of appropriate figures. Whether or not common distribution functions are indeed adequate for wind-power calculations will depend on numerical tests and not on arbitrarily selected probabilities derived from goodness-of-fit tests.

In summary, any of three common distribution functions may be useful in simplifying wind-power calculations if the range of applicability is restricted to about 8 to 30 kt. This corresponds to the range of interesting operations of most wind turbines currently envisioned. On the other hand, for more detailed and generalized evaluations being undertaken at Sandia Laboratories, there do not appear to be any particular advantages gained by these simplified approximations. In analyses by large-capacity computers, actual data sequences can be easily handled, so we will continue to operate in this mode.

Estimated Speed Distribution Tables

Homogeneous wind-speed distribution tables have been generated from all 15 station records, and adjusted to the final anemometer exposure where a change occurred. Considerable smoothing was necessary to remove the effects of observer bias which showed significant reporting preference for integer speeds that were divisible by two and five.

In addition, each distribution was used to synthesize a 10-yr series of hourly wind speeds for selected heights of 10, 20, and 50 m above flat ground, by using the one-seventh power law approximation. These extrapolations may err where the series was not obtained with or adjusted to an airfield exposure, as at Nantucket Shoals, Lubbock, Tatoosh Island, Eniwetok, and Cape Hatteras. Lacking other information, however, this appeared to be the best available procedure. Results for each integer knot of wind speed at each height are listed in the Appendix, Tables A-I through A-XV.

Listings show both the raw number of occurrences and the smoothed numbers for the period of record. Smoothed occurrences were used to generate the listings for percent of occurrences and cumulative percent of occurrences. Comparable listings of wind-power statistics, along with turbine speed limit effects, etc., will be included in subsequent reports from this project.

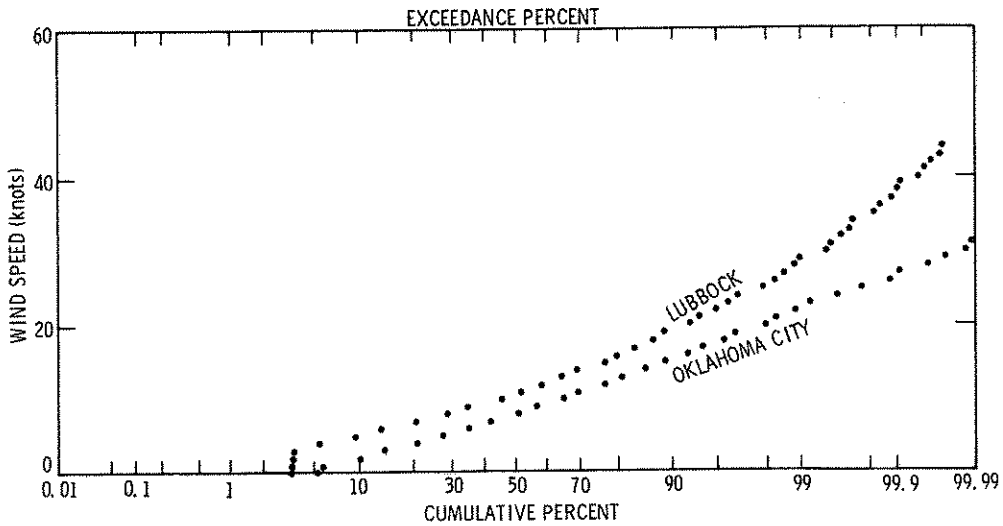

Figure 27. Wind Speed Distributions, Continental Stations, in Normal Coordinates

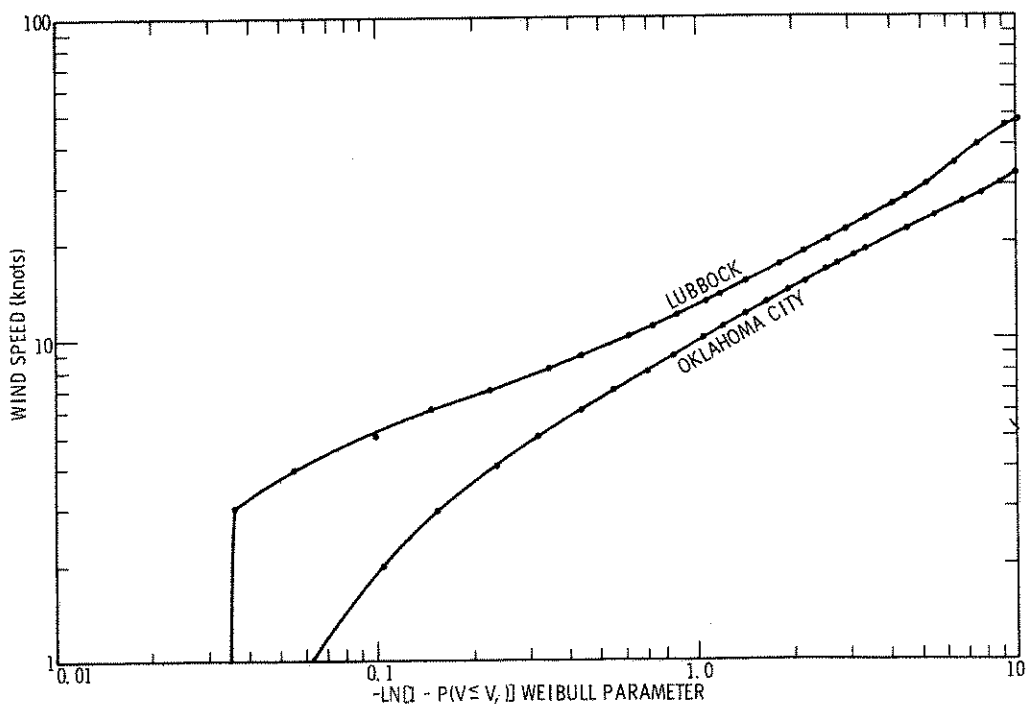

Figure 28. Wind Speed Distributions, Continental Stations, in Weibull Coordinates

Summary

Raw wind-speed records from climatic archives have shown certain faults that required correction for detailed use in wind-power potential studies. In particular, many weather station anemometers were moved at least once during a selected 10-yr period of record. This introduced a nonhomogeneous element into the time series of data that needed correction. Comparisons of speed distributions for eras before and after anemometer moves showed that a uniform and simple adjustment procedure, such as using a height power law, was not adequate for all cases. Each station record with a change had to be individually analyzed to obtain appropriate adjustment functions. This has been done, and homogeneous time series have been synthesized where necessary, along with extrapolated series for three selected heights above level ground in open country.

Inspection of wind-speed distributions has shown that common statistical distribution functions adequately represent some restricted ranges of speeds. Neither the normal, log-normal, or Weibull function appeared universally appropriate, however, so numerical distribution tabulations will be used for subsequent calculations by this project.

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1. American National Standard Building Code Requirements for Minimum Design Loads in Buildings and other Structures A58-1, American National Standards Institute, New York, NY. 1972.

2. R. B. Corotis, Stochastic Modeling of Site Wind Characteristics, RLO/2342-77/2, Northwestern University, Evanston, IL, Sept. 1977.

3. J. W. Reed, "Wind Power Climatology," Weatherwise, 27, 6, Dec. 1974.

4. J. W. Reed, Wind Power Climatology of the United States, SAND74-0348, Sandia Laboratories, June 1975.

5. J. W. Reed, Wind Time Series Analyses for WECS Applications, SAND77-1701, Sandia Laboratories, in preparation.

6. C. E. Buell, private communication, February 1977.

APPENDIX A

ANEMOMETER HEIGHT 22. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMUL TIVE PERCE
0	2048	2048	2.339	2.[illegible]
1	585	1202	1.373	3.[illegible]
2	3055	2932	3.349	7.[illegible]
3	2623	3050	3.483	10.[illegible]
4	6334	5322	6.078	16.[illegible]
5	5295	4647	5.307	21.[illegible]
6	4694	4763	5.439	27.[illegible]
7	1956	5098	5.822	33.[illegible]
8	7824	5860	6.693	39.[illegible]
9	4788	6702	7.654	47.[illegible]
10	11442	7236	8.264	55.[illegible]
11	6284	7024	8.021	63.[illegible]
12	6377	6306	7.202	71.[illegible]
13	5097	5384	6.149	77.[illegible]
14	4292	4485	5.122	82.[illegible]
15	4199	3753	4.286	86.[illegible]
16	2402	3030	3.460	90.[illegible]
17	2791	2382	2.721	92.[illegible]
18	1378	1818	2.076	94.[illegible]
19	1245	1380	1.576	96.[illegible]
20	906	1040	1.187	97.[illegible]
21	1061	760	.867	98.[illegible]
22	279	524	.599	99.[illegible]
23	224	327	.373	99.[illegible]
24	154	186	.213	99.[illegible]
25	54	105	.120	99.[illegible]
26	83	67	.077	99.[illegible]
27	14	42	.048	99.[illegible]
28	28	28	.032	99.[illegible]
29	11	20	.022	99.[illegible]
30	17	15	.017	99.[illegible]
31	18	12	.013	99.[illegible]
32	1	8	.009	99.[illegible]
33	6	5	.006	99.[illegible]
34	1	2	.003	99.[illegible]
35	0	1	.001	100.[illegible]
TOTAL	87566	87566		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	2048	2048	2.339	2.339
1	585	439	.501	2.840
2	0	1391	1.589	4.428
3	3055	1971	2.251	6.679
4	2623	3566	4.072	10.751
5	6334	3369	3.848	14.599
6	0	3546	4.050	18.648
7	5295	3447	3.937	22.585
8	4694	3274	3.739	26.324
9	1956	3306	3.776	30.100
10	0	3920	4.477	34.576
11	7824	4824	5.509	40.085
12	4788	5554	6.343	46.428
13	11442	5887	6.723	53.151
14	0	5627	6.426	59.577
15	6284	5166	5.900	65.477
16	6377	4621	5.277	70.754
17	5097	4100	4.682	75.436
18	0	3640	4.157	79.593
19	4292	3151	3.598	83.191
20	4199	2773	3.167	86.358
21	2402	2419	2.761	89.119
22	0	2010	2.295	91.414
23	2791	1616	1.845	93.259
24	1378	1323	1.511	94.770
25	1245	1105	1.262	96.032
26	0	881	1.006	97.038
27	906	695	.794	97.832
28	1061	573	.655	98.487
29	279	438	.501	98.988
30	0	297	.339	99.326
31	224	174	.199	99.525
32	154	112	.127	99.652
33	54	85	.097	99.749
34	0	60	.069	99.818
35	83	40	.046	99.864
36	14	29	.033	99.897
37	28	23	.026	99.923
38	0	16	.019	99.941
39	11	13	.014	99.956
40	17	12	.013	99.969
41	18	10	.011	99.980
42	0	7	.008	99.988
43	1	5	.005	99.993
44	6	3	.003	99.997
45	1	2	.002	99.998
46	0	1	.001	100.000
TOTAL	87566	87566		

M (Station Number 23050)

EIGHT 66. FEET

IND PEED NOTS	OCCUR- RENCES	SMOOTH OCCUR- RENCES	PERCENT OCCUR- RENCES	CUMULA- TIVE PERCENT
0	4652	4652	5.311	5.311
1	6	802	.916	6.226
2	3191	4892	5.585	11.811
3	10685	4491	5.127	16.938
4	0	8182	9.341	26.279
5	11365	7904	9.023	35.302
6	10693	8504	9.709	45.010
7	8542	8468	9.666	54.677
8	7174	7584	8.657	63.334
9	8207	6010	6.861	70.195
10	3924	4443	5.072	75.266
11	0	3209	3.662	78.929
12	3198	2507	2.862	81.790
13	2387	2238	2.554	84.345
14	2432	2182	2.491	86.836
15	1770	1974	2.254	89.090
16	1995	1613	1.841	90.931
17	1423	1283	1.465	92.396
18	0	1039	1.186	93.582
19	1095	933	1.065	94.647
20	1255	896	1.023	95.670
21	823	851	.971	96.641
22	815	723	.825	97.467
23	516	529	.604	98.071
24	303	364	.416	98.486
25	0	259	.295	98.781
26	288	212	.242	99.023
27	206	196	.224	99.247
28	264	180	.206	99.453
29	104	143	.163	99.615
30	101	96	.110	99.725
31	23	60	.069	99.794
32	0	39	.044	99.839
33	74	31	.035	99.874
34	2	26	.030	99.903
35	36	22	.026	99.929
36	8	17	.019	99.948
37	14	12	.014	99.962
38	9	9	.010	99.972
39	0	6	.007	99.978
40	7	4	.005	99.983
41	3	3	.004	99.987
42	2	3	.003	99.990
43	1	2	.002	99.993
44	4	2	.002	99.995
45	0	1	.001	99.996
46	0	1	.001	99.997
47	2	1	.001	99.998
48	0	1	.001	99.999
49	1	0	.001	99.999
50	0	0	.000	100.000
TAL	87600	87600		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR- RENCES	SMOOTH OCCUR- RENCES	PERCENT OCCUR- RENCES	CUMULA- TIVE PERCENT
0	4652	4652	5.311	5.311
1	6	4	.005	5.316
2	0	2252	2.570	7.886
3	3191	4153	4.753	12.639
4	10685	7631	8.711	21.350
5	11365	7159	8.172	29.522
6	0	7431	8.482	38.005
7	10693	7215	8.237	46.241
8	8542	6673	7.618	53.859
9	7174	6099	6.962	60.822
10	0	5341	6.098	66.919
11	8207	4522	5.162	72.081
12	3924	3755	4.287	76.368
13	3198	3043	3.473	79.841
14	0	2374	2.710	82.551
15	2387	1883	2.155	84.706
16	2432	1690	1.930	86.636
17	1770	1556	1.776	88.412
18	0	1411	1.611	90.023
19	1995	1255	1.432	91.456
20	1423	1126	1.285	92.741
21	1095	1011	1.154	93.894
22	0	887	1.013	94.907
23	1255	805	.919	95.826
24	823	747	.853	96.679
25	815	652	.745	97.424
26	516	504	.575	97.999
27	0	351	.401	98.400
28	303	260	.297	98.697
29	288	211	.240	98.937
30	206	187	.213	99.150
31	0	164	.187	99.337
32	264	138	.158	99.495
33	104	112	.127	99.622
34	101	86	.098	99.720
35	0	59	.068	99.788
36	23	38	.044	99.831
37	74	29	.034	99.865
38	2	24	.027	99.892
39	0	20	.022	99.914
40	36	16	.018	99.932
41	8	13	.015	99.947
42	14	11	.013	99.960
43	0	8	.009	99.969
44	9	6	.007	99.976
45	7	5	.006	99.982
46	3	4	.004	99.986
47	0	3	.003	99.989
48	2	2	.002	99.991
49	1	2	.002	99.993
50	4	2	.002	99.995
51	0	1	.001	99.996
52	0	1	.001	99.997
53	2	1	.001	99.998
54	0	1	.001	99.999
55	0	0	.001	99.999
56	1	0	.000	100.000
57	0	0	.000	100.000
TOTAL	87600	87600		

ANEMOMETER HEIGHT 22. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CU TI PE
0	4295	4295	4.903	
1	592	1779	2.031	
2	5341	4909	5.604	1
3	5273	4706	5.372	1
4	7596	8489	9.691	2
5	8807	7924	9.046	3
6	7904	8352	9.535	4
7	9889	8285	9.457	5
8	9005	7672	8.758	6
9	4480	6688	7.635	7
10	7496	5623	6.419	7
11	3253	4565	5.212	8
12	3796	3718	4.244	8
13	3027	2980	3.402	9
14	2064	2312	2.639	9
15	1886	1765	2.015	9
16	1140	1254	1.431	9
17	476	848	.968	9
18	714	550	.628	9
19	81	341	.389	9
20	256	215	.245	9
21	63	131	.150	9
22	81	79	.090	9
23	38	50	.057	9
24	13	28	.032	9
25	16	16	.019	9
26	3	9	.011	9
27	8	6	.007	9
28	1	4	.004	9
29	3	3	.003	9
30	2	2	.002	9
31	0	1	.001	9
32	1	1	.001	9
33	0	0	.000	10
TOTAL	87600	87600		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	4295	4295	4.903	4.903
1	592	444	.507	5.410
2	0	2448	2.795	8.205
3	5341	3120	3.562	11.767
4	5273	5541	6.325	18.092
5	7596	5095	5.817	23.909
6	0	5699	6.506	30.415
7	8807	6254	7.139	37.554
8	7904	6563	7.492	45.045
9	9889	6532	7.457	52.502
10	0	6164	7.036	59.538
11	9005	5687	6.492	66.030
12	4480	5105	5.828	71.858
13	7496	4498	5.134	76.993
14	0	3775	4.310	81.302
15	3253	3106	3.546	84.848
16	3796	2656	3.032	87.880
17	3027	2291	2.615	90.495
18	0	1954	2.230	92.725
19	2064	1588	1.813	94.538
20	1886	1285	1.467	96.005
21	1140	1025	1.170	97.175
22	0	751	.857	98.032
23	476	499	.570	98.602
24	714	353	.403	99.005
25	81	263	.300	99.305
26	0	191	.218	99.522
27	256	127	.145	99.668
28	63	91	.104	99.771
29	81	71	.081	99.852
30	0	46	.052	99.904
31	38	27	.031	99.935
32	13	18	.021	99.955
33	16	12	.014	99.969
34	0	8	.009	99.979
35	3	5	.006	99.984
36	8	4	.004	99.989
37	1	3	.003	99.992
38	0	2	.003	99.994
39	3	2	.002	99.996
40	2	1	.001	99.997
41	0	1	.001	99.999
42	0	1	.001	99.999
43	1	0	.000	100.000
44	0	0	.000	100.000
TOTAL	87600	87600		

HEIGHT 66. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUP-RENCES	CUMULA-TIVE PERCENT
0	406	406	.464	.464
1	153	290	.331	.795
2	702	485	.553	1.348
3	0	1149	1.311	2.660
4	1537	2521	2.878	5.538
5	4685	3303	3.772	9.310
6	4031	4590	5.240	14.550
7	5510	5648	6.448	20.998
8	6100	6186	7.062	28.060
9	12079	6291	7.182	35.242
10	0	5968	6.814	42.056
11	7138	5739	6.552	48.608
12	6027	5590	6.382	54.990
13	5259	5344	6.101	61.091
14	6660	4810	5.491	66.583
15	3950	4001	4.568	71.151
16	0	3415	3.898	75.050
17	4209	3200	3.654	78.703
18	4601	3168	3.617	82.320
19	2112	3004	3.429	85.750
20	3704	2556	2.919	88.668
21	1755	1955	2.232	90.900
22	0	1542	1.761	92.661
23	1780	1338	1.527	94.188
24	1591	1201	1.371	95.559
25	1337	1062	1.213	96.772
26	493	814	.930	97.702
27	451	533	.609	98.310
28	365	337	.384	98.695
29	0	230	.262	98.957
30	197	187	.213	99.170
31	226	164	.187	99.357
32	176	143	.163	99.520
33	100	112	.128	99.648
34	49	75	.086	99.734
35	0	50	.057	99.791
36	82	38	.043	99.834
37	13	32	.036	99.870
38	29	27	.031	99.901
39	17	21	.024	99.926
40	28	16	.018	99.944
41	0	11	.013	99.957
42	7	8	.009	99.966
43	3	6	.007	99.973
44	10	6	.006	99.979
45	4	5	.006	99.985
46	5	4	.005	99.990
47	4	3	.004	99.994
48	0	2	.002	99.996
49	1	1	.001	99.998
50	1	1	.001	99.999
51	1	1	.001	99.999
52	0	0	.000	100.000
TOTAL	87588	87588		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	406	406	.464	.464
1	153	115	.131	.595
2	0	426	.486	1.081
3	702	1039	1.187	2.267
4	1537	2043	2.333	4.600
5	4685	2313	2.640	7.241
6	0	2980	3.402	10.643
7	4031	3568	4.073	14.717
8	5510	4187	4.780	19.497
9	6100	4984	5.690	25.187
10	0	5536	6.321	31.508
11	12079	5750	6.565	38.073
12	7138	5528	6.311	44.384
13	0	5187	5.923	50.306
14	6027	4830	5.515	55.821
15	5259	4420	5.046	60.867
16	6660	4183	4.776	65.643
17	0	3837	4.380	70.024
18	3950	3451	3.936	74.010
19	4209	3199	3.653	77.662
20	4601	2939	3.356	81.018
21	0	2625	2.997	84.015
22	2112	2270	2.591	86.606
23	3704	1997	2.281	88.887
24	1755	1763	2.013	90.900
25	0	1542	1.761	92.661
26	1780	1317	1.504	94.165
27	1591	1141	1.302	95.467
28	1337	969	1.106	96.573
29	0	726	.829	97.402
30	493	496	.567	97.968
31	451	355	.406	98.374
32	365	281	.321	98.695
33	0	230	.262	98.957
34	197	183	.209	99.165
35	226	154	.175	99.341
36	176	130	.149	99.489
37	0	100	.114	99.604
38	100	70	.080	99.684
39	49	51	.058	99.742
40	0	43	.049	99.791
41	82	37	.042	99.833
42	13	29	.033	99.866
43	29	24	.027	99.893
44	0	18	.021	99.914
45	17	15	.017	99.932
46	28	13	.015	99.947
47	7	10	.012	99.959
48	0	8	.009	99.968
49	3	5	.006	99.974
50	10	4	.005	99.979
51	4	4	.005	99.984
52	0	4	.004	99.988
53	5	3	.004	99.992
54	4	2	.003	99.994
55	1	2	.002	99.997
56	0	1	.001	99.998
57	1	1	.001	99.999
58	1	1	.001	99.999
59	0	0	.000	100.000
TOTAL	87588	87588		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	2002	2002	4.454	4.454
1	2	26	.057	4.511
2	97	279	.620	5.131
3	424	464	1.031	6.163
4	871	902	2.007	8.170
5	1173	978	2.177	10.347
6	1130	1136	2.528	12.875
7	1189	1263	2.810	15.684
8	1504	1381	3.072	18.756
9	1133	1490	3.315	22.072
10	2216	1588	3.532	25.604
11	1297	1636	3.640	29.244
12	1778	1682	3.742	32.986
13	1623	1731	3.850	36.836
14	1748	1865	4.149	40.986
15	2078	2059	4.581	45.567
16	1828	2212	4.921	50.488
17	3656	2267	5.044	55.532
18	1459	2153	4.789	60.321
19	2206	1970	4.382	64.702
20	1441	1774	3.947	68.650
21	1712	1648	3.667	72.317
22	1603	1574	3.503	75.820
23	1585	1472	3.274	79.093
24	1477	1344	2.990	82.084
25	1125	1178	2.621	84.704
26	935	1014	2.255	86.959
27	922	867	1.929	88.889
28	576	741	1.648	90.537
29	818	634	1.411	91.948
30	421	531	1.182	93.130
31	434	447	.995	94.125
32	327	382	.851	94.976
33	334	331	.737	95.713
34	359	289	.643	96.357
35	218	241	.536	96.892
36	144	197	.437	97.330
37	178	162	.359	97.689
38	96	137	.304	97.994
39	174	120	.267	98.261
40	74	103	.229	98.490
41	76	89	.197	98.687
42	54	79	.176	98.863
43	56	72	.161	99.024
44	95	67	.149	99.173
45	54	58	.130	99.303
46	40	49	.108	99.411
47	44	39	.087	99.498
48	19	31	.070	99.568
49	38	26	.058	99.626
50	12	23	.051	99.678
51	16	21	.048	99.725
52	28	20	.045	99.771
53	26	18	.041	99.811
54	8	15	.034	99.845
55	11	12	.027	99.872
56	8	10	.021	99.893
57	9	8	.018	99.911
58	11	7	.015	99.927
59	0	5	.012	99.939
60	6	4	.009	99.948
61	1	4	.008	99.956
62	4	3	.007	99.963
63	6	3	.007	99.970
64	1	2	.005	99.975
65	0	2	.004	99.978
66	1	1	.003	99.982
67	1	2	.003	99.985
68	5	2	.004	99.989
69	0	1	.003	99.992
70	0	1	.002	99.994
71	1	1	.001	99.996
72	1	0	.001	99.997
73	0	0	.001	99.997
74	0	0	.000	99.998
75	0	0	.000	99.998
76	0	0	.000	99.998
77	0	0	.000	99.999
78	1	0	.001	99.999
79	0	0	.000	100.000
TOTAL	44950	44950		

HT 66. FEET

D S	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
	770	770	.879	.879
	124	261	.298	1.177
	672	625	.714	1.891
	0	1447	1.651	3.542
	2952	3151	3.597	7.139
	4354	4115	4.698	11.837
	5697	5492	6.269	18.106
	6920	6304	7.197	25.303
	7971	6382	7.285	32.588
	8477	6109	6.974	39.562
	0	5776	6.594	46.156
	6911	5769	6.585	52.741
	8704	5872	6.703	59.445
	4750	5636	6.434	65.879
	5812	4906	5.600	71.479
	4485	3896	4.447	75.926
	0	3173	3.623	79.549
	3668	2870	3.277	82.825
	3566	2738	3.126	85.951
	2510	2571	2.935	88.886
	2255	2177	2.485	91.371
	2179	1552	1.806	93.257
	0	1234	1.409	94.666
	907	985	1.124	95.790
	1477	835	.953	96.743
	485	717	.818	97.561
	556	575	.657	98.218
	376	399	.456	98.674
	277	271	.310	98.984
	0	193	.221	99.204
	234	145	.166	99.370
	110	118	.135	99.505
	69	98	.112	99.617
	115	79	.090	99.707
	40	59	.068	99.775
	0	47	.054	99.829
	93	39	.044	99.873
	12	30	.034	99.908
	23	22	.025	99.932
	8	13	.015	99.947
	1	8	.009	99.956
	0	6	.007	99.963
	18	6	.006	99.969
	1	5	.006	99.975
	1	4	.005	99.980
	7	3	.004	99.984
	0	2	.003	99.987
	4	2	.002	99.989
	0	2	.002	99.991
	0	1	.002	99.992
	4	1	.001	99.994
	0	1	.001	99.995
	0	1	.001	99.997
	3	1	.001	99.998
	0	1	.001	99.998
	0	0	.001	99.999
	0	0	.000	99.999
	1	0	.000	100.000
	0	0	.000	100.000
	87599	87599		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	770	770	.879	.879
1	124	93	.106	.985
2	0	569	.650	1.635
3	672	1265	1.444	3.079
4	2952	2472	2.822	5.901
5	4354	2789	3.183	9.084
6	0	3693	4.219	13.294
7	5697	4530	5.171	18.464
8	6920	5112	5.836	24.300
9	7971	5494	6.272	30.572
10	0	5393	6.156	36.729
11	8477	5206	5.943	42.672
12	6911	5112	5.835	48.508
13	0	5149	5.878	54.385
14	8704	5109	5.832	60.218
15	4750	4586	5.350	65.567
16	5812	4244	4.845	70.412
17	0	3709	4.234	74.646
18	4485	3256	3.716	78.363
19	3668	2941	3.357	81.720
20	3566	2624	2.995	84.715
21	0	2284	2.607	87.323
22	2510	1969	2.247	89.569
23	2255	1727	1.971	91.541
24	2179	1503	1.716	93.257
25	0	1234	1.409	94.666
26	907	961	1.098	95.763
27	1477	773	.883	96.646
28	485	627	.716	97.362
29	0	498	.568	97.931
30	556	374	.427	98.358
31	376	298	.340	98.697
32	277	251	.286	98.984
33	0	193	.221	99.204
34	234	140	.160	99.365
35	110	107	.122	99.487
36	69	85	.098	99.584
37	0	67	.076	99.661
38	115	54	.062	99.722
39	40	49	.056	99.778
40	0	45	.051	99.829
41	93	39	.044	99.873
42	12	29	.033	99.906
43	23	21	.024	99.930
44	0	13	.015	99.945
45	8	8	.009	99.954
46	1	7	.008	99.961
47	18	6	.007	99.968
48	0	5	.006	99.974
49	1	4	.004	99.978
50	1	3	.003	99.981
51	7	2	.003	99.983
52	0	2	.002	99.986
53	0	2	.002	99.988
54	4	1	.002	99.989
55	0	1	.002	99.991
56	0	1	.002	99.992
57	4	1	.001	99.994
58	0	1	.001	99.995
59	0	1	.001	99.996
60	0	1	.001	99.997
61	3	1	.001	99.998
62	0	1	.001	99.998
63	0	0	.001	99.999
64	0	0	.000	99.999
65	1	0	.000	100.000
66	0	0	.000	100.000
TOTAL	87599	87599		

ANEMOMETER HEIGHT 20. FEET HT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PER OCCUR RENCES	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	1568	1568	0	1568	1568	1.790	1.790
1	104	455	1	104	78	.089	1.879
2	1510	2729	2	0	1053	1.202	3.081
3	4813	3455	3	1510	1797	2.052	5.133
4	4328	6438	4	4813	3459	3.949	9.081
5	9435	6478	5	4328	3690	4.212	13.294
6	5687	7155	6	0	4567	5.214	18.507
7	7784	7469	7	9435	5258	6.003	24.510
8	9485	7222	8	5687	5585	6.376	30.886
9	5248	6747	9	7784	5714	6.524	37.410
10	5925	6138	10	0	5358	6.117	43.526
11	6993	5475	11	9485	4921	5.618	49.145
12	3363	4462	12	5248	4644	5.302	54.447
13	4221	4281	13	0	4529	5.169	59.616
14	5120	3613	14	5925	4410	5.034	64.650
15	2059	2427	15	6993	4078	4.655	69.305
16	1933	2324	16	3363	3779	4.314	73.620
17	1709	1830	17	0	3427	3.912	77.532
18	1482	1511	18	4221	3091	3.529	81.061
19	1362	1272	19	5120	2809	3.207	84.267
20	1201	1007	20	2059	2422	2.765	87.032
21	553	742	21	0	1923	2.195	89.228
22	229	521	22	1933	1495	1.707	90.935
23	546	367	23	1709	1281	1.463	92.397
24	140	268	24	1482	1189	1.357	93.754
25	239	208	25	0	1060	1.210	94.964
26	118	156	26	1362	916	1.046	96.010
27	84	116	27	1201	771	.880	96.890
28	141	91	28	553	610	.696	97.586
29	30	68	29	0	444	.507	98.093
30	44	51	30	229	309	.351	98.444
31	45	37	31	546	246	.281	98.725
32	11	27	32	140	212	.242	98.968
33	33	20	33	0	175	.200	99.167
34	5	14	34	239	135	.154	99.322
35	6	10	35	118	109	.124	99.446
36	8	8	36	84	94	.108	99.553
37	11	7	37	0	75	.086	99.639
38	2	6	38	141	59	.067	99.706
39	7	5	39	30	48	.055	99.761
40	5	4	40	0	39	.045	99.805
41	3	3	41	44	31	.036	99.841
42	0	2	42	45	25	.029	99.870
43	1	1	43	11	22	.025	99.895
44	2	1	44	0	17	.020	99.915
45	0	1	45	33	13	.015	99.930
46	0	0	46	5	10	.012	99.942
47	1	0	47	6	8	.009	99.951
48	0	0	48	0	6	.007	99.959
			49	8	5	.006	99.965
TOTAL	87594	87594	50	11	5	.006	99.971
			51	2	5	.006	99.977
			52	0	4	.005	99.981
			53	7	4	.004	99.986
			54	5	3	.004	99.990
			55	3	3	.003	99.993
			56	0	2	.002	99.995
			57	0	1	.001	99.996
			58	1	1	.001	99.997
			59	2	1	.001	99.998
			60	0	1	.001	99.998
			61	0	0	.000	99.999
			62	0	0	.000	99.999
			63	1	0	.000	100.000
			64	0	0	.000	100.000
			TOTAL	87594	87594		

GHT 66. FEET

D ED TS	OCCUR- RENCES	SMOOTH OCCUR- RENCES	PERCENT OCCUR- RENCES	CUMULA- TIVE PERCENT
0	3002	3002	3.427	3.427
1	1	3	.003	3.430
2	8	213	.244	3.674
3	82	940	1.073	4.747
4	1643	2152	2.457	7.204
5	3570	3065	3.499	10.703
6	3742	4266	4.871	15.574
7	5810	5385	6.148	21.722
8	7527	6231	7.114	28.836
9	5450	6660	7.604	36.440
10	9336	6720	7.672	44.111
11	5284	6357	7.257	51.368
12	5804	5894	6.728	58.097
13	5783	5399	6.163	64.260
14	3927	4894	5.588	69.848
15	6047	4442	5.071	74.919
16	2887	3840	4.384	79.303
17	3393	3276	3.740	83.044
18	2926	2763	3.154	86.198
19	1306	2315	2.644	88.842
20	3222	1972	2.252	91.093
21	885	1599	1.826	92.919
22	1275	1303	1.488	94.407
23	1052	1062	1.213	95.620
24	587	869	.992	96.611
25	1214	724	.827	97.438
26	355	544	.621	98.059
27	218	391	.446	98.505
28	296	279	.318	98.823
29	66	211	.241	99.064
30	388	181	.207	99.271
31	50	141	.161	99.432
32	90	105	.120	99.552
33	58	77	.088	99.640
34	29	62	.070	99.710
35	117	56	.064	99.775
36	26	46	.053	99.827
37	31	35	.040	99.867
38	20	25	.028	99.896
39	5	18	.021	99.917
40	33	15	.018	99.934
41	4	12	.014	99.948
42	9	10	.011	99.959
43	7	8	.009	99.968
44	2	7	.008	99.976
45	16	7	.007	99.984
46	1	5	.006	99.990
47	5	4	.004	99.994
48	1	2	.003	99.997
49	0	1	.001	99.998
50	2	1	.001	99.999
51	0	0	.001	100.000
	87592	87592		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR- RENCES	SMOOTH OCCUR- RENCES	PERCENT OCCUR- RENCES	CUMULA- TIVE PERCENT
0	3002	3002	3.427	3.427
1	1	3	.003	3.430
2	8	31	.035	3.466
3	82	372	.425	3.891
4	0	1038	1.185	5.076
5	1643	1875	2.141	7.216
6	3570	3058	3.491	10.707
7	3742	4263	4.867	15.574
8	5810	5385	6.148	21.722
9	7527	6231	7.114	28.836
10	5450	6418	7.327	36.164
11	9336	5995	6.844	43.008
12	5284	5227	5.968	48.976
13	0	4591	5.241	54.216
14	5804	4448	5.078	59.295
15	5783	4568	5.217	64.511
16	3927	4674	5.336	69.848
17	6047	4442	5.071	74.919
18	2887	3786	4.322	79.241
19	3393	3033	3.463	82.704
20	2926	2349	2.681	85.386
21	0	1866	2.130	87.516
22	1306	1669	1.905	89.421
23	3222	1587	1.812	91.232
24	885	1477	1.687	92.919
25	1275	1303	1.488	94.407
26	1052	1062	1.213	95.620
27	587	859	.981	96.601
28	1214	693	.792	97.393
29	355	498	.569	97.962
30	0	335	.383	98.345
31	218	236	.269	98.614
32	296	199	.227	98.840
33	66	196	.224	99.064
34	388	181	.207	99.271
35	50	140	.160	99.431
36	90	97	.111	99.542
37	58	64	.073	99.615
38	0	47	.054	99.669
39	29	47	.054	99.723
40	117	48	.055	99.777
41	26	44	.050	99.827
42	31	35	.040	99.867
43	20	25	.028	99.896
44	5	18	.020	99.916
45	33	14	.016	99.932
46	4	11	.012	99.945
47	0	8	.009	99.954
48	9	6	.007	99.961
49	7	6	.007	99.968
50	2	7	.008	99.976
51	16	7	.007	99.984
52	1	5	.006	99.990
53	5	4	.004	99.994
54	1	2	.002	99.996
55	0	1	.001	99.998
56	0	1	.001	99.999
57	2	1	.001	99.999
58	0	0	.000	100.000
TOTAL	87592	87592		

ANEMOMETER HEIGHT 13. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CU TI PE
0	4650	4650	5.308	
1	469	1289	1.472	
2	3750	3480	3.973	1
3	3455	3426	3.911	1
4	6307	6171	7.045	2
5	5532	5773	6.590	2
6	7043	6176	7.051	3
7	5620	6366	7.268	4
8	7625	6370	7.272	4
9	4961	6199	7.077	5
10	7945	5890	6.724	6
11	3734	5410	6.176	6
12	6067	4885	5.577	7
13	3512	4310	4.921	8
14	4332	3718	4.244	8
15	2825	3118	3.559	8
16	2758	2496	2.850	9
17	1340	1957	2.234	9
18	1810	1516	1.731	9
19	602	1177	1.344	9
20	1471	916	1.046	9
21	311	688	.786	9
22	531	502	.573	9
23	235	361	.413	9
24	319	258	.295	9
25	162	190	.216	9
26	125	126	.144	9
27	26	77	.088	9
28	45	43	.049	9
29	12	24	.027	9
30	13	13	.015	9
31	2	8	.009	9
32	4	4	.005	9
33	2	3	.003	9
34	2	2	.002	9
35	1	1	.001	9
36	0	1	.001	10
TOTAL	87598	87598		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	4650	4650	5.308	5.308
1	469	352	.402	5.710
2	0	1699	1.940	7.649
3	3750	1742	1.989	9.638
4	3455	3242	3.701	13.339
5	0	3194	3.646	16.986
6	6307	3611	4.122	21.108
7	5532	3955	4.515	25.623
8	0	4428	5.055	30.678
9	7043	4839	5.524	36.203
10	5620	4898	5.591	41.794
11	7625	4909	5.604	47.398
12	0	4611	5.264	52.662
13	4961	4238	4.838	57.500
14	7945	4057	4.631	62.131
15	0	3812	4.351	66.483
16	3734	3544	4.045	70.528
17	6067	3245	3.705	74.233
18	0	3004	3.429	77.662
19	3512	2812	3.210	80.872
20	4332	2535	2.894	83.767
21	0	2331	2.661	86.427
22	2825	2136	2.439	88.866
23	2758	1813	2.070	90.936
24	1340	1514	1.728	92.664
25	0	1194	1.363	94.027
26	1810	922	1.052	95.079
27	602	780	.891	95.970
28	0	697	.796	96.766
29	1471	605	.691	97.457
30	311	485	.554	98.011
31	0	402	.459	98.470
32	531	322	.367	98.837
33	235	256	.292	99.129
34	319	221	.252	99.380
35	0	167	.191	99.571
36	162	117	.134	99.705
37	125	83	.095	99.801
38	0	57	.065	99.866
39	26	39	.044	99.910
40	45	24	.027	99.938
41	0	17	.019	99.957
42	12	12	.014	99.971
43	13	8	.009	99.980
44	0	5	.006	99.986
45	2	4	.004	99.990
46	4	3	.003	99.993
47	2	2	.002	99.995
48	0	2	.002	99.997
49	2	1	.001	99.998
50	1	1	.001	99.999
51	0	0	.001	100.000
TOTAL	87598	87598		

Station Number 24018)

HEIGHT 66. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	510	510	.582	.582
1	59	199	.228	.810
2	621	1031	1.177	1.987
3	1386	1059	1.208	3.195
4	2718	2065	2.358	5.553
5	0	2430	2.775	8.328
6	3841	3422	3.907	12.234
7	4930	4523	5.165	17.399
8	5961	5533	6.317	23.716
9	7006	6210	7.090	30.806
10	6234	6498	7.419	38.225
11	7113	6525	7.450	45.675
12	6055	6262	7.150	52.825
13	6979	5619	6.414	59.240
14	4569	4665	5.326	64.566
15	4089	3706	4.232	68.798
16	0	3002	3.427	72.226
17	3933	2766	3.158	75.383
18	2784	2771	3.164	78.547
19	2898	2781	3.175	81.722
20	3329	2624	2.996	84.718
21	1565	2297	2.623	87.341
22	2294	1993	2.275	89.616
23	1524	1678	1.916	91.532
24	1579	1365	1.559	93.091
25	997	1054	1.204	94.295
26	747	778	.888	95.183
27	0	598	.683	95.865
28	826	524	.598	96.463
29	461	499	.570	97.033
30	531	480	.548	97.581
31	474	429	.489	98.070
32	264	352	.402	98.472
33	378	285	.325	98.797
34	123	218	.249	99.045
35	174	163	.187	99.232
36	155	122	.140	99.372
37	0	96	.109	99.481
38	91	84	.095	99.576
39	119	76	.086	99.663
40	63	68	.078	99.740
41	36	58	.066	99.806
42	67	45	.051	99.857
43	7	34	.038	99.895
44	47	26	.029	99.925
45	3	18	.021	99.945
46	13	12	.014	99.959
47	9	8	.009	99.968
48	0	5	.006	99.974
49	3	5	.005	99.980
50	8	4	.005	99.985
51	5	4	.005	99.989
52	1	4	.004	99.993
53	4	3	.003	99.996
54	2	2	.002	99.998
55	0	1	.001	99.999
TOTAL	87585	87585		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	510	510	.582	.582
1	59	44	.051	.633
2	0	368	.422	1.054
3	621	902	1.030	2.084
4	1386	1787	2.040	4.124
5	2718	2051	2.342	6.466
6	3841	2598	2.967	9.424
7	0	3262	3.724	13.148
8	4930	4203	4.799	17.947
9	5961	4916	5.613	23.560
10	7006	5205	5.943	29.503
11	6234	5116	5.834	35.337
12	0	4952	5.654	40.992
13	7113	5174	5.907	46.898
14	6055	5280	6.029	52.927
15	6979	5019	5.729	58.656
16	4569	4324	4.937	63.594
17	0	3536	4.037	67.631
18	4089	3172	3.622	71.253
19	3933	2969	3.328	74.641
20	2784	2769	3.161	77.803
21	2898	2448	2.795	80.598
22	0	2100	2.398	82.996
23	3329	1987	2.268	85.264
24	1565	1874	2.140	87.404
25	2294	1699	1.940	89.343
26	1524	1432	1.635	90.979
27	0	1154	1.318	92.296
28	1579	1016	1.160	93.457
29	997	901	1.028	94.485
30	747	783	.894	95.379
31	826	632	.722	96.101
32	0	489	.559	96.660
33	461	431	.492	97.151
34	531	395	.451	97.602
35	474	357	.408	98.010
36	264	303	.346	98.356
37	0	238	.271	98.627
38	378	201	.230	98.857
39	123	176	.201	99.058
40	174	152	.174	99.232
41	155	122	.140	99.372
42	0	96	.109	99.481
43	91	82	.094	99.575
44	119	70	.080	99.654
45	63	59	.068	99.722
46	0	48	.055	99.777
47	36	39	.044	99.821
48	67	34	.039	99.860
49	7	30	.034	99.894
50	47	24	.027	99.922
51	0	16	.018	99.940
52	3	11	.012	99.953
53	13	8	.009	99.962
54	9	6	.007	99.969
55	3	6	.006	99.975
56	0	5	.005	99.981
57	8	4	.005	99.985
58	5	4	.004	99.990
59	1	3	.004	99.993
60	4	2	.003	99.996
61	0	2	.002	99.998
62	2	1	.001	99.999
63	0	1	.001	100.000
TOTAL	87585	87585		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
0	2265	2265	2.586	2.586
1	47	35	.040	2.626
2	0	789	.900	3.526
3	611	1815	2.072	5.598
4	5207	3469	3.960	9.558
5	5380	3591	4.100	13.657
6	0	4179	4.770	18.428
7	6707	4532	5.174	23.601
8	5921	4677	5.339	28.941
9	5859	4763	5.437	34.378
10	0	4761	5.435	39.813
11	8516	4702	5.368	45.181
12	3882	4436	5.064	50.245
13	6281	4038	4.609	54.854
14	0	3529	4.029	58.883
15	3333	3129	3.572	62.454
16	4258	2974	3.395	65.850
17	3692	2946	3.363	69.213
18	0	2943	3.360	72.573
19	4430	2823	3.223	75.795
20	3975	2600	2.968	78.764
21	1989	2326	2.655	81.419
22	0	2065	2.357	83.776
23	2764	1966	2.244	86.020
24	2431	1972	2.251	88.271
25	2148	1871	2.136	90.407
26	2064	1580	1.804	92.211
27	0	1212	1.383	93.594
28	1261	948	1.082	94.676
29	977	763	.871	95.547
30	654	661	.754	96.301
31	0	593	.677	96.978
32	807	525	.599	97.577
33	846	458	.523	98.101
34	195	368	.420	98.521
35	0	266	.304	98.825
36	259	182	.208	99.033
37	232	147	.168	99.201
38	78	135	.154	99.355
39	0	120	.137	99.492
40	264	104	.119	99.611
41	45	87	.099	99.710
42	77	67	.076	99.786
43	0	44	.050	99.837
44	28	29	.033	99.870
45	38	24	.027	99.897
46	23	18	.021	99.918
47	0	14	.016	99.934
48	9	9	.011	99.945
49	2	7	.009	99.953
50	19	7	.004	99.961
51	0	7	.008	99.969
52	4	6	.007	99.976
53	9	5	.005	99.981
54	3	4	.004	99.985
55	0	3	.004	99.989
56	5	3	.003	99.992
57	2	2	.002	99.994
58	1	1	.002	99.996
59	0	1	.001	99.997
60	0	1	.001	99.997
61	2	1	.001	99.998
62	0	0	.000	99.998
63	0	0	.000	99.999
64	0	0	.000	99.999
65	0	0	0.000	99.999
66	0	0	0.000	99.999
67	0	0	0.000	99.999
68	0	0	0.000	99.999
69	0	0	0.000	99.999
70	0	0	0.000	99.999
71	0	0	0.000	99.999
72	0	0	0.000	99.999
73	0	0	0.000	99.999
74	0	0	0.000	99.999
75	0	0	0.000	99.999
76	0	0	0.000	99.999
77	0	0	0.000	99.999
78	0	0	.000	99.999
79	0	0	.000	99.999
80	0	0	.000	99.999
81	1	0	.000	100.000
82	0	0	.000	100.000
TOTAL	87599	87599		

HEIGHT 164. FEET

CUMULATIVE PERCENT	WIND SPEED KNOTS	OCCURRENCES	SMOOTH OCCURRENCES	PERCENT OCCURRENCES	CUMULATIVE PERCENT
2.585	0	2264	2264	2.585	2.585
2.765	1	72	157	.180	2.765
4.250	2	414	815	.930	3.695
6.535	3	1897	1156	1.320	5.015
10.890	4	0	2420	2.763	7.778
15.446	5	4371	2980	3.403	11.181
20.595	6	3816	3815	4.355	15.536
26.110	7	5371	4430	5.058	20.595
31.958	8	4001	4831	5.516	26.110
38.005	9	6046	4927	5.626	31.736
44.066	10	3766	4732	5.402	37.138
49.790	11	7738	4401	5.025	42.164
54.996	12	0	4001	4.568	46.731
59.679	13	4668	3803	4.342	51.073
63.949	14	4235	3758	4.291	55.364
67.962	15	3934	3780	4.315	59.679
71.646	16	3305	3739	4.269	63.949
74.942	17	4117	3413	3.897	67.846
77.828	18	3050	2952	3.371	71.217
80.348	19	3136	2447	2.794	74.011
82.525	20	0	2021	2.307	76.319
84.722	21	2445	1841	2.102	78.421
86.675	22	1682	1819	2.077	80.498
88.465	23	2286	1864	2.128	82.625
90.040	24	1797	1836	2.097	84.722
91.409	25	1375	1651	1.886	86.608
92.570	26	2157	1418	1.619	88.227
93.589	27	1025	1161	1.326	89.552
94.533	28	0	967	1.104	90.657
95.406	29	1414	877	1.001	91.658
96.208	30	769	842	.961	92.619
96.890	31	864	850	.970	93.589
97.449	32	886	826	.944	94.533
97.897	33	513	749	.855	95.387
98.261	34	1159	651	.743	96.130
98.578	35	434	519	.593	96.723
98.844	36	0	403	.460	97.183
99.069	37	403	335	.383	97.566
99.253	38	424	308	.352	97.917
99.400	39	225	301	.344	98.261
99.518	40	376	277	.316	98.578
99.609	41	145	230	.262	98.840
99.683	42	235	183	.209	99.049
99.745	43	163	141	.161	99.210
99.795	44	0	107	.123	99.333
99.835	45	96	89	.102	99.435
99.866	46	127	79	.091	99.525
99.892	47	54	73	.084	99.609
99.915	48	49	65	.074	99.683
99.936	49	82	53	.061	99.744
99.953	50	23	41	.047	99.791
99.965	51	45	31	.036	99.827
99.973	52	0	22	.026	99.853
99.979	53	18	18	.021	99.873
99.983	54	16	18	.020	99.894
99.987	55	23	19	.021	99.915
99.990	56	20	18	.021	99.936
99.993	57	24	15	.017	99.953
99.994	58	4	10	.012	99.965
99.995	59	3	6	.007	99.972
99.996	60	0	4	.004	99.976
99.997	61	5	3	.004	99.979
99.998	62	2	3	.004	99.983
99.998	63	6	3	.004	99.987
99.999	64	3	3	.003	99.990
100.000	65	1	2	.002	99.993
100.000	66	2	1	.002	99.994
	67	0	1	.001	99.995
	68	0	1	.001	99.996
	69	1	1	.001	99.996
	70	0	1	.001	99.997
	71	1	1	.001	99.998
	72	1	1	.001	99.998
	73	0	1	.001	99.999
	74	1	0	.000	100.000
	75	0	0	.000	100.000
	TOTAL	87585	87585		

ANEMOMETER HEIGHT 33. FEET HT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT OCCUR-RENCES	CUMULA-TIVE PERCENT
				329	329	1.161	1.161
0	329	329	1.161	37	28	.098	1.259
1	37	105	.372	0	147	.520	1.779
2	308	335	1.183	308	256	.905	2.684
3	355	389	1.374	355	475	1.678	4.362
4	749	734	2.592	749	483	1.706	6.069
5	663	781	2.756	663	551	1.944	8.013
6	1095	945	3.337	0	649	2.289	10.302
7	836	1124	3.968	1095	813	2.868	13.170
8	1666	1317	4.649	836	939	3.314	16.485
9	1017	1526	5.386	1666	1039	3.665	20.149
10	2372	1738	6.131	1017	1102	3.888	24.037
11	1286	1910	6.742	0	1229	4.339	28.377
12	2868	2041	7.203	2372	1480	5.224	33.601
13	1536	2091	7.384	1286	1548	5.815	39.416
14	2605	2072	7.315	2868	1710	6.036	45.452
15	1729	1985	7.006	1536	1639	5.784	51.236
16	2194	1840	6.497	0	1582	5.585	56.821
17	1291	1654	5.838	2605	1651	5.828	62.649
18	1930	1430	5.049	1729	1657	5.850	68.499
19	764	1177	4.156	2194	1584	5.590	74.089
20	1250	920	3.249	1291	1379	4.862	78.951
21	400	670	2.362	0	1165	4.112	83.063
22	502	458	1.613	1930	1067	3.768	86.831
23	171	298	1.014	764	957	3.379	90.209
24	181	183	.645	1250	817	2.884	93.094
25	70	113	.406	400	606	2.140	95.234
26	63	66	.277	0	405	1.429	96.663
27	16	38	.138	502	289	1.019	97.682
28	17	21	.099	171	210	.743	98.425
29	5	11	.060	181	161	.568	98.993
30	9	7	.041	70	106	.374	99.367
31	0	5	.032	0	60	.212	99.579
32	5	3	.023	63	38	.133	99.712
33	1	3	.014	16	24	.085	99.798
34	3	2	.015	17	17	.060	99.857
35	1	2	.016	5	11	.037	99.895
36	3	2	.017	0	6	.021	99.915
37	0	1	.018	9	4	.015	99.930
38	1	1	.019	0	3	.011	99.942
39	1	1	.020	5	3	.010	99.951
40	0	0	.021	1	2	.007	99.959
41	0	0	.022	0	2	.006	99.965
42	1	0	.023	3	2	.006	99.971
43	0	0	.024	1	2	.005	99.976
44	1	0	.025	3	1	.005	99.981
45	0	0	.026	0	1	.004	99.985
			47	0	1	.003	99.987
TOTAL	28331	28331	48	1	1	.002	99.989
			49	1	0	.002	99.991
			50	0	0	.001	99.992
			51	0	0	.001	99.993
			52	0	0	.001	99.994
			53	1	0	.001	99.996
			54	0	0	.001	99.997
			55	1	0	.001	99.999
			56	0	0	.001	99.999
			TAL	28331	28331		

:A (Station Number 93116)

EIGHT 66. FEET

IND PEED NOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT CCCUR-RENCES	CUMULA-TIVE PERCENT
0	3139	3139	6.492	6.492
1	130	97	.202	6.693
2	0	888	1.836	8.529
3	1596	1540	3.185	11.714
4	3038	2797	5.784	17.499
5	3803	2618	5.414	22.913
6	3224	2654	5.489	28.402
7	0	2589	5.354	33.756
8	3913	2688	5.560	39.316
9	2894	2757	5.702	45.018
10	3316	2740	5.667	50.685
11	3147	2545	5.264	55.949
12	0	2278	4.712	60.661
13	3926	2166	4.481	65.142
14	1249	1986	4.108	69.249
15	2728	1783	3.687	72.936
16	1253	1519	3.141	76.077
17	0	1336	2.764	78.841
18	2126	1358	2.808	81.648
19	1242	1360	2.813	84.462
20	2019	1296	2.681	87.143
21	1072	1089	2.252	89.395
22	0	861	1.780	91.175
23	1053	737	1.524	92.698
24	595	649	1.342	94.040
25	948	580	1.200	95.240
26	308	474	.980	96.220
27	0	368	.762	96.982
28	565	307	.636	97.618
29	250	262	.541	98.159
30	288	225	.466	98.625
31	0	176	.365	98.990
32	209	137	.283	99.273
33	112	111	.231	99.503
34	98	87	.180	99.683
35	60	60	.125	99.808
36	0	35	.072	99.880
37	11	20	.041	99.921
38	21	13	.026	99.947
39	6	10	.020	99.968
40	12	7	.015	99.983
41	0	4	.009	99.992
42	0	2	.004	99.996
43	2	1	.002	99.998
44	0	0	.001	99.999
)TAL	48353	48353		

HEIGHT 164. FEET

WIND SPEED KNOTS	OCCUR-RENCES	SMOOTH OCCUR-RENCES	PERCENT CCCUR-RENCES	CUMULA-TIVE PERCENT
0	3139	3139	6.492	6.492
1	130	97	.202	6.693
2	0	888	1.836	8.529
3	1596	1089	2.252	10.781
4	3038	2053	4.246	15.027
5	0	2028	4.194	19.220
6	3803	2232	4.615	23.836
7	3224	2335	4.828	28.664
8	0	2462	5.092	33.756
9	3913	2557	5.288	39.045
10	2894	2495	5.160	44.205
11	3316	2478	5.125	49.329
12	0	2362	4.885	54.214
13	3147	2192	4.533	58.747
14	3926	2045	4.229	62.977
15	0	1812	3.748	66.725
16	1249	1555	3.215	69.940
17	2728	1351	2.794	72.734
18	0	1251	2.588	75.322
19	1253	1201	2.484	77.806
20	2126	1146	2.369	80.175
21	0	1155	2.389	82.564
22	1242	1183	2.447	85.011
23	2019	1119	2.315	87.326
24	1072	1000	2.069	89.395
25	0	821	1.698	91.093
26	1053	645	1.334	92.427
27	595	544	1.125	93.552
28	0	492	1.017	94.569
29	948	443	.916	95.485
30	308	380	.787	96.271
31	0	344	.711	96.982
32	565	307	.636	97.618
33	250	262	.541	98.159
34	288	225	.466	98.625
35	0	172	.356	98.982
36	209	126	.261	99.242
37	112	98	.203	99.446
38	0	77	.160	99.606
39	98	60	.124	99.730
40	60	42	.088	99.818
41	0	30	.061	99.879
42	11	19	.039	99.918
43	21	11	.023	99.942
44	0	8	.018	99.959
45	6	7	.015	99.974
46	12	5	.011	99.985
47	0	3	.007	99.992
48	0	2	.004	99.996
49	2	1	.002	99.998
50	0	0	.001	99.999
TOTAL	48353	48353		

ANEMOMETER HT 164. FEET

WIND SPEED KNOTS	OCCURRENCES	SMOOTH OCCURRENCES	PERCENT OCCURRENCES	CUMULATIVE PERCENT
	1398	1398	1.875	1.875
0	0	0	0.000	1.875
1	0	161	.216	2.092
2	75	855	1.147	3.239
3	1227	1810	2.427	5.666
4	3263	2309	3.097	8.763
5	4640	3048	4.089	12.852
6	0	3857	5.174	18.026
7	6278	4836	6.487	24.513
8	6414	5461	7.325	31.838
9	7725	5609	7.524	39.362
10	5973	5314	7.128	46.490
11	0	4905	6.580	53.069
12	7500	4860	6.519	59.588
13	5058	4731	6.346	65.934
14	5597	4373	5.865	71.799
15	3911	3733	5.007	76.806
16	0	3095	4.152	80.958
17	4016	2819	3.781	84.739
18	3417	2570	3.447	88.186
19	2553	2216	2.972	91.158
20	1475	1684	2.258	93.417
21	0	1144	1.534	94.951
22	1356	831	1.114	96.065
23	457	642	.861	96.926
24	845	515	.691	97.617
25	0	381	.511	98.128
26	191	275	.369	98.497
27	363	221	.296	98.793
28	151	184	.246	99.040
29	190	157	.210	99.250
30	0	121	.163	99.412
31	164	98	.132	99.544
32	95	81	.109	99.653
33	37	63	.085	99.738
34	62	46	.062	99.799
35	0	31	.042	99.841
36	19	25	.033	99.874
37	40	21	.028	99.902
38	14	17	.022	99.924
39	10	12	.016	99.940
40	0	8	.010	99.951
41	7	5	.007	99.958
42	5	4	.006	99.963
43	3	3	.005	99.968
44	3	3	.004	99.971
45	0	2	.003	99.974
46	2	2	.002	99.976
47	2	1	.002	99.978
48	1	1	.002	99.979
49	0	1	.001	99.981
50	2	1	.001	99.982
51	0	0	.001	99.982
52	0	0	.000	99.982
53	0	0	.000	99.983
54	0	0	.000	99.983
55	0	0	.000	99.983
56	0	0	.000	99.983
57	1	1	.001	99.984
58	1	1	.001	99.985
59	0	1	.001	99.986
60	2	1	.001	99.987
61	0	1	.001	99.988
3	2	1	.001	99.990
TOTA 4	0	1	.001	99.990
5	0	1	.001	99.991
6	1	1	.001	99.992
7	0	1	.001	99.993
8	1	1	.001	99.994
9	2	1	.001	99.995
0	0	1	.001	99.996
1	1	1	.001	99.997
2	0	0	.000	99.997
3	0	0	.000	99.997
4	0	0	.000	99.998
5	0	0	.001	99.998
6	2	1	.001	99.999
7	0	0	.001	100.000
AL	74552	74552		

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