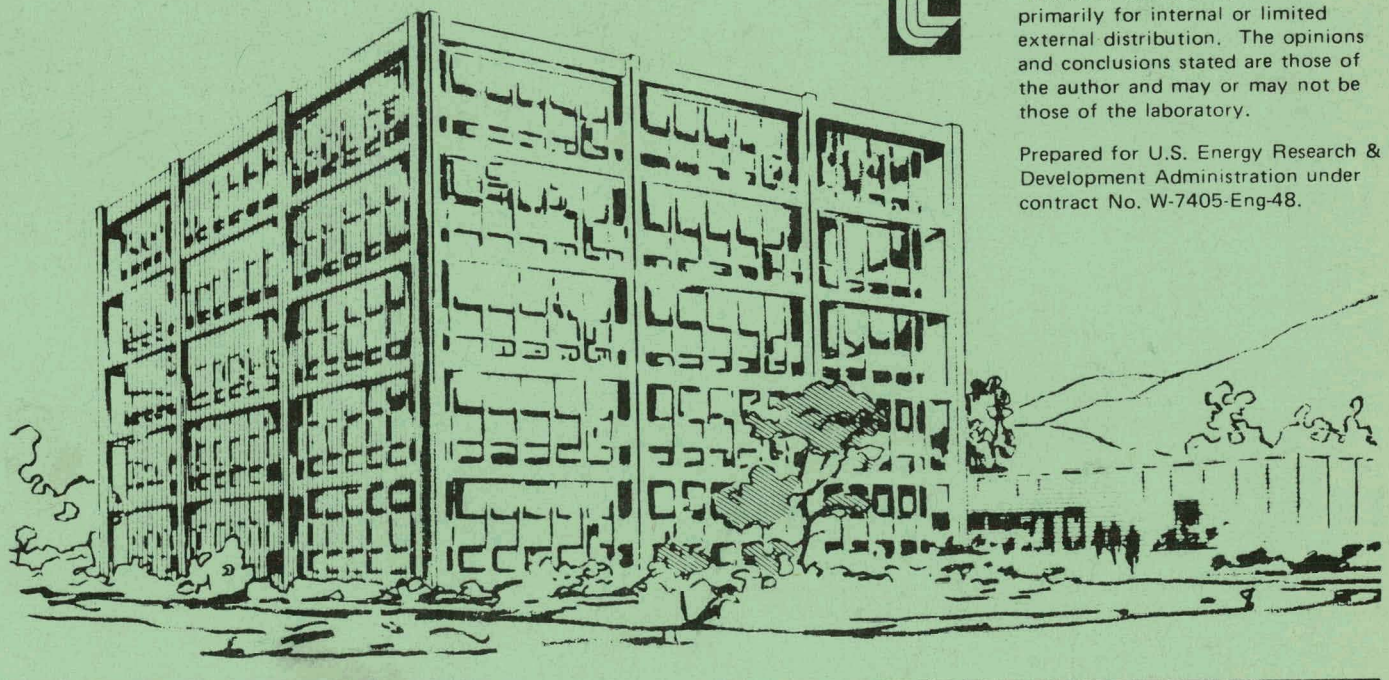
UCID- 17403

Lawrence Livermore Laboratory

KAHUKU, OAHU WIND SUMMARY (AUGUST THROUGH NOVEMBER 1976)

Donald M. Hardy, Robert L. Zalkan
John J. Walton and Kenneth L. Hill

February 1977



Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

DISCLAIMER

UCID-17403

KAHUKU, OAHU WIND SUMMARY

(August through November 1976)

Donald M. Hardy, Robert L. Zalkan,
John J. Walton and Kenneth L. Hill

Lawrence Livermore Laboratory, University of California,
Livermore, CA 94550

February 1977

ABSTRACT

Wind-energy measurements conducted by the Lawrence Livermore Laboratory on the island of Oahu, Hawaii are discussed briefly. Measurement locations in northern Oahu are identified. The measurement site at Kahuku, Oahu is described. Data obtained at the Kahuku location are summarized as daily and monthly mean velocities for August through November, 1976. Velocity duration curves for each month are also given.

1. INTRODUCTION

The objective of the Lawrence Livermore Laboratory wind power study is to develop methods of regional wind-energy assessment suitable for application throughout the nation. Hilly or mountainous regions with the potential for multi-megawatt power collection are of primary interest. The methods being developed to document wind energy[1-5] involve a coordinated program of meteorological field experiments and numerical simulation of regional wind velocities.

The island of Oahu, Hawaii, shown in Fig. 1, is the initial study area. Subregions of expected wind enhancement were predicted in numerical calculations which made use of a limited amount of historical wind measurements.[2] Additional numerical calculations[4] were employed in planning our field measurements. The purposes of these field measurements are: (1) to supplement existing wind measurements in order to form a more complete set of synoptic data for use in our diagnostic numerical model, and (2) to provide current information at two locations near expected velocity maxima on Oahu.

To satisfy our field measurement objectives, the four locations in northern Oahu shown in Fig. 1 were selected for installation of wind velocity measurement stations. Offshore winds near Oahu are from the east or northeast under normal tradewind conditions. The trades first flow over and around the steep Koolau mountain range and then cross the central valley before encountering the Waianae mountains. Measurements at Laie on the northeastern coast of Oahu provide information about the onshore trades. The measurement station at Kahuku is in the Koolau hills near one

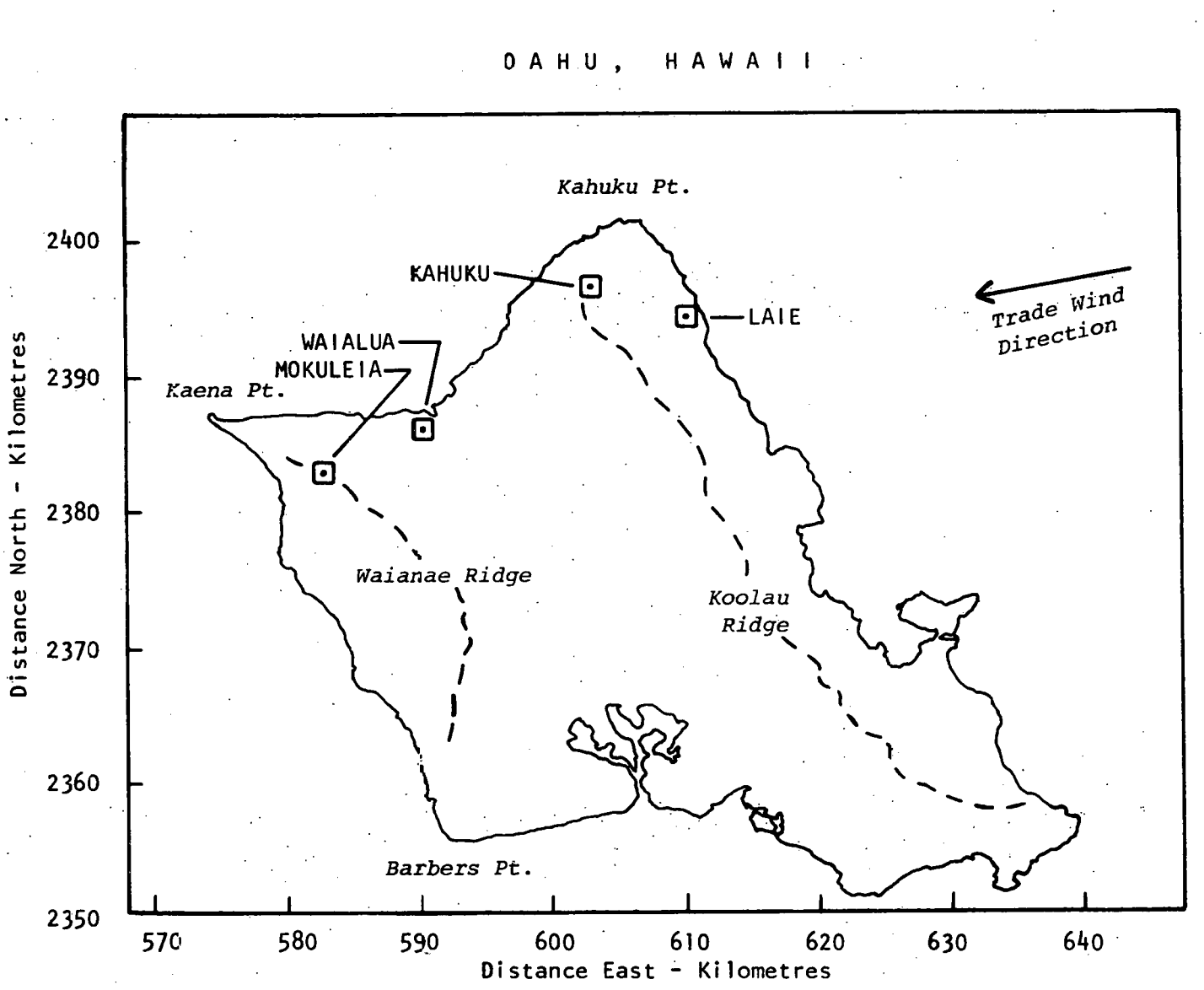


FIGURE 1. Locations of the four wind velocity measurement stations installed in the northern part of the island of Oahu, Hawaii. The Waianae and Koolau ridge lines are indicated by the dashed lines.

of the predicted velocity maxima. The measurement station at Waialua provides data for winds in the northern part of the inland valley and, under trade conditions, is downwind of the Kahuku location. The Mokuleia measurement station is located on the Waianae ridge line near several expected velocity maxima.

Data collection was initiated at these four locations in the summer of 1976 after LLL instrumented the sites. At each location, an automated station digitally records wind speed and direction. The speed and direction sensors are filtered with a two-minute time constant and sampled every five minutes. These data are then calibrated and combined into hourly means for use in numerical analyses. The Kahuku station data, which were processed first, are summarized in this report.

2. KAHUKU DATA SUMMARY

The Kahuku measurements were taken at an elevation of 257 m in a hilly area at the northern end of the Koolau mountain range. The elevation drops to sea level within approximately 8 km east of the site. The sensors are mounted on a 10 m tower erected on the top of a knoll with an exposure unimpeded by trees or other vegetation. The terrain in the area is hilly and uneven but does not include the abrupt, sheer cliffs found in some parts of Oahu. Vegetation in the surrounding area is mixed and includes both grasslands and forest. Trees within a few kilometres of the site show varying degrees of distortion due to the prevailing winds. The

knoll on which the tower is located is steep but rounded. Simple tests with streamers showed that the wind flow over the top of the knoll is essentially horizontal and gave no indication of a significant vertical component. Based upon our data analysis to date, wind speeds throughout a broad area surrounding the Kahuku measurement site appear to be significantly greater than those at Laie, the nearby coastal site.

Summaries of our Kahuku measurements are given in Table 1 and in Figs. 2 and 3 for the months of August through November 1976. The mean daily wind speed, the standard deviation about the mean, and the mean daily wind direction are given for each day of the month in Table 1. Monthly mean wind speeds and directions are also given. Mean wind speeds are computed as simple arithmetic means. Mean wind directions are defined as an average of unit vectors.

The highest daily wind speeds at Kahuku correlate strongly with wind directions in the range of 70° to 90°, which are characteristic of trade-wind periods. Wind directions not in this range were more common in November than in August. The westerly winds at the end of November are typical of the winter "Kona storms" of the area. The correlation of high wind speeds with trade conditions is also shown as a decrease of the mean monthly speed from August to November.

Velocity duration curves are given in Figs. 2 and 3. These curves are based on data taken at 5 minute intervals during each month. The percentage of wind observations equal to or greater than a given wind speed is plotted in each case. It is of interest to consider winds equal to or greater than 8 m/s, a speed at which modern wind turbine generators may be assumed to reach their full rated capacity. The results shown in

TABLE 1. August through November 1976 mean daily wind speed, standard derivation about the mean and mean daily wind direction at Kahuku, Oahu. The mean monthly wind speed and direction are also given. All speeds are in metres per second. Mean wind directions are defined as an average of unit vectors. Asterisks denote data that are not available.

Day	August	September	October	November
1	*	7.9 ± 1.0 (82°)	1.8 ± 1.0 (36°)	3.6 ± 0.9 (73°)
2	*	8.5 ± 1.5 (82°)	3.3 ± 0.7 (164°)	4.7 ± 2.0 (294°)
3	11.3 ± 1.6 (87°)	11.0 ± 1.1 (77°)	4.2 ± 1.4 (106°)	10.9 ± 2.5 (68°)
4	*	10.0 ± 1.2 (71°)	4.0 ± 1.3 (110°)	13.9 ± 0.9 (77°)
5	12.6 ± 1.3 (83°)	9.6 ± 0.6 (72°)	3.9 ± 1.2 (188°)	10.8 ± 0.9 (66°)
6	10.8 ± 1.3 (84°)	8.6 ± 0.6 (76°)	5.1 ± 0.9 (240°)	12.5 ± 1.1 (69°)
7	10.7 ± 2.2 (87°)	9.0 ± 1.2 (88°)	7.3 ± 1.8 (49°)	12.8 ± 0.5 (79°)
8	8.5 ± 1.0 (82°)	12.8 ± 0.9 (83°)	10.1 ± 1.3 (72°)	10.8 ± 1.3 (80°)
9	8.5 ± 1.2 (84°)	12.5 ± 0.8 (72°)	12.1 ± 1.1 (74°)	8.4 ± 0.7 (90°)
10	9.6 ± 1.2 (81°)	9.8 ± 1.2 (67°)	10.3 ± 0.9 (77°)	8.1 ± 1.0 (97°)
11	11.5 ± 1.1 (78°)	9.7 ± 0.8 (68°)	9.5 ± 1.2 (75°)	6.8 ± 1.5 (95°)
12	12.3 ± 0.6 (80°)	8.1 ± 1.0 (76°)	8.9 ± 1.4 (84°)	9.6 ± 1.2 (85°)
13	13.8 ± 1.0 (83°)	8.4 ± 0.6 (72°)	9.1 ± 1.3 (77°)	8.8 ± 1.1 (86°)
14	12.5 ± 1.1 (78°)	9.8 ± 1.8 (75°)	11.5 ± 1.3 (73°)	7.3 ± 1.2 (97°)
15	8.0 ± 0.9 (76°)	11.7 ± 1.5 (73°)	9.5 ± 1.7 (79°)	4.7 ± 1.7 (34°)
16	3.9 ± 1.9 (65°)	11.9 ± 0.8 (67°)	*	8.6 ± 1.1 (24°)
17	4.3 ± 1.3 (159°)	8.3 ± 1.1 (74°)	8.1 ± 0.7 (76°)	11.6 ± 0.9 (62°)
18	8.7 ± 2.4 (93°)	2.9 ± 1.5 (99°)	8.8 ± 1.2 (86°)	8.6 ± 2.8 (61°)
19	11.8 ± 2.2 (84°)	3.0 ± 1.2 (72°)	8.9 ± 0.6 (89°)	*
20	12.1 ± 1.0 (79°)	5.2 ± 0.9 (70°)	7.9 ± 1.3 (95°)	11.6 ± 1.4 (75°)
21	9.5 ± 1.0 (81°)	7.1 ± 1.5 (74°)	9.2 ± 0.8 (99°)	9.0 ± 1.4 (80°)
22	9.3 ± 1.4 (88°)	8.2 ± 1.9 (81°)	9.4 ± 2.4 (100°)	6.0 ± 0.8 (95°)
23	9.8 ± 0.8 (84°)	4.4 ± 0.4 (52°)	11.8 ± 1.4 (85°)	3.7 ± 1.2 (119°)
24	9.6 ± 1.2 (76°)	7.1 ± 1.6 (86°)	11.7 ± 1.6 (81°)	7.1 ± 1.3 (156°)
25	10.6 ± 1.1 (75°)	6.0 ± 0.7 (65°)	12.0 ± 1.2 (82°)	6.2 ± 2.3 (214°)
26	10.1 ± 0.8 (83°)	7.8 ± 1.3 (55°)	8.8 ± 0.9 (82°)	2.0 ± 0.7 (289°)
27	10.9 ± 1.0 (83°)	8.3 ± 1.4 (72°)	8.7 ± 0.9 (81°)	4.6 ± 1.3 (290°)
28	11.1 ± 0.7 (78°)	7.5 ± 1.3 (68°)	10.0 ± 1.2 (88°)	5.2 ± 1.6 (289°)
29	9.5 ± 1.4 (87°)	4.9 ± 1.4 (58°)	10.4 ± 1.0 (82°)	4.6 ± 0.9 (289°)
30	9.4 ± 0.8 (79°)	1.8 ± 0.8 (350°)	9.3 ± 0.8 (84°)	2.7 ± 0.8 (290°)
31	7.4 ± 1.3 (80°)	---	7.5 ± 1.1 (83°)	---
Monthly mean wind speed and wind direction:				
	10.0 (83°)	8.0 (72°)	8.4 (87°)	7.7 (73°)

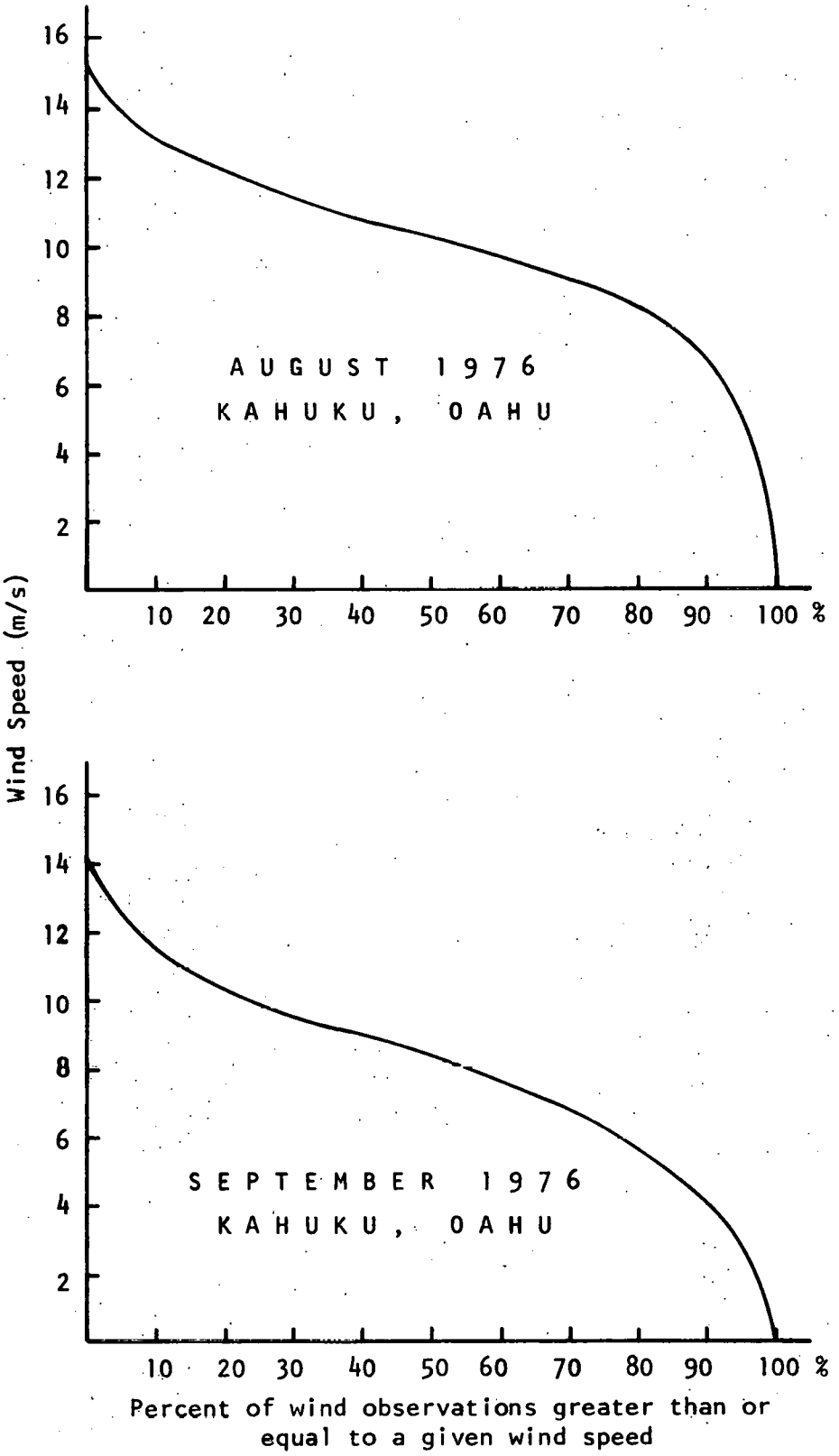


FIGURE 2. Velocity duration curves for August and September 1976 based on data taken at 5-min intervals during each month. Wind speeds in m/s are given along the ordinate and the percentage of wind observations equal to or greater than a given speed are indicated along the abscissa.

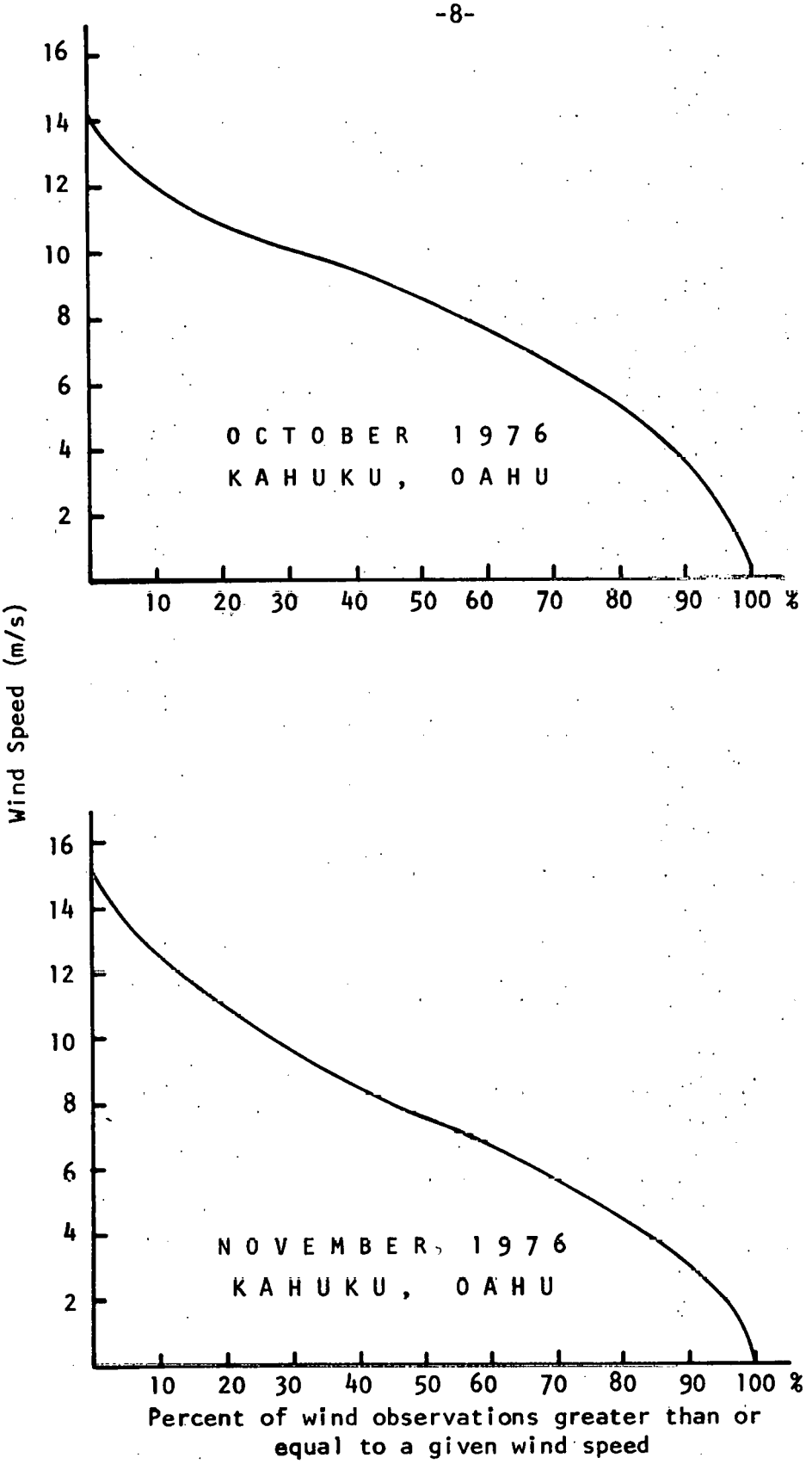


FIGURE 3. Velocity duration curves for October and November 1976 based on data taken at 5-min intervals during each month. Wind speeds in m/s are given along the ordinate and the percentage of wind observations equal to or greater than a given speed are indicated along the abscissa.

Figs. 2 and 3 indicate that speeds equal to or greater than 8 m/s occurred 45% of the time in November, 58% of the time in October, 55% of the time in September, and 83% of the time in August.

REFERENCES

1. Hardy, D. M., "Wind Power Studies: Initial Data and Numerical Calculations," Lawrence Livermore Laboratory Report UCRL-50034-76-1, 1976.

2. Hardy, D. M., "Wind Power Studies: Initial Regional Applications," Lawrence Livermore Laboratory Report UCRL-50034-76-2, 1976.

3. Hardy, D. M., "Wind Power Studies: Field Measurement Priorities for Numerical Analysis of Wind Energy," Lawrence Livermore Laboratory Report UCRL-50034-76-3, 1976.

4. Knox, J. B., D. M. Hardy, C. A. Sherman, and T. J. Sullivan, "Status Report: Lawrence Livermore Laboratory Wind Energy Studies," Lawrence Livermore Laboratory Report UCID-17157-1, 1976.

5. Hardy, D. M., "Wind Power Studies: Regional Wind Energy Measurements," Lawrence Livermore Laboratory Report UCRL-50034-76-4, 1976.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy $; Microfiche $3.00

Page Range	Domestic Price	Page Range	Domestic Price
001–025	$ 3.50	326–350	10.00
026–050	4.00	351–375	10.50
051–075	4.50	376–400	10.75
076–100	5.00	401–425	11.00
101–125	5.50	426–450	11.75
126–150	6.00	451–475	12.00
151–175	6.75	476–500	12.50
176–200	7.50	501–525	12.75
201–225	7.75	526–550	13.00
226–250	8.00	551–575	13.50
251–275	9.00	576–600	13.75
276–300	9.25	601–up	*
301–325	9.75		

*Add $2.50 for each additional 100 page increment from 601 to 1,000 pages; add $4.50 for each additional 100 page increment over 1,000 pages.

Technical Information Department
LAWRENCE LIVERMORE LABORATORY
University of California | Livermore, California | 94550