

Wind-electric power generation in Montana
by John Lee Obermeier

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Mechanical Engineering
Montana State University
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Abstract:
This investigation considered the suitability of wind energy in Montana for generation of electric power delivered to residential electric loads. The major emphasis is directed toward small diversified systems, primarily in rural areas, however large wind system evaluation is included. The four-step approach included wind resource evaluation, estimation of energy production by wind energy conversion systems, energy supply to residential electric loads and economic evaluation.

The evaluation of the wind resource, based on airport Weather Bureau records, provided the necessary wind characteristic information and identified high wind areas in Montana. The characteristic performance of wind machines, coupled with wind speed data, provided estimations of maximum attainable energy production from the wind.

The results indicate that with the appropriate selection of wind energy conversion equipment and area of the state, it is possible to meet most residential electric requirements. Wind energy costs are generally higher than present utility electric rates, however lower costs are possible in some cases and indications are that in the future the comparative position of wind power may improve.

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Date February 6, 1976

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by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

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ABSTRACT

This investigation considered the suitability of wind energy in Montana for generation of electric power delivered to residential electric loads. The major emphasis is directed toward small diversified systems, primarily in rural areas, however large wind system evaluation is included. The four-step approach included wind resource evaluation, estimation of energy production by wind energy conversion systems, energy supply to residential electric loads and economic evaluation.

The evaluation of the wind resource, based on airport Weather Bureau records, provided the necessary wind characteristic information and identified high wind areas in Montana. The characteristic performance of wind machines, coupled with wind speed data, provided estimations of maximum attainable energy production from the wind.

The results indicate that with the appropriate selection of wind energy conversion equipment and area of the state, it is possible to meet most residential electric requirements. Wind energy costs are generally higher than present utility electric rates, however lower costs are possible in some cases and indications are that in the future the comparative position of wind power may improve.

SECTION I

INTRODUCTION

Today's Western industrialized society uses fossil fuel energy resources at such a rate they are not renewable within any reasonable time span of human history. An increasing rate of use of this "energy bank account" is rapidly bringing the Western world into a crisis situation. In Energy for Survival, an Alternative to Extinction, Wilson Clark (1) states that "The current struggle to develope safe, clean and dependable sources of energy constitutes the most crucial battle for survival man has yet fought. Without solutions to today's energy shortages . . . . there will be little chance of preserving the legacy of this civilization for future generations." (1)

An appreciation of the impending energy crisis requires the recognition of two aspects of a finite earth: first, fossil fuel reserves are finite and will be exhausted in the forseeable future, given present growth rates; second, the natural ecological systems of the earth can only sustain limited levels of environmental degradation due to industrialized civilization. The tremendous increase in the scale of use of fossil fuels in the last generation has made the effects of strip mined land, which is taken out of agricultural production, and the resulting air and thermal pollution at plant sites, more visable and more objectionable. Serious questions should be asked regarding the wisdom of using nuclear fission for energy production since the

resulting lethal waste products, foreign to the earth's natural environment, will remain for thousands of years and present a problem with which future generations must deal. Consideration of these facts has convinced many investigators that solar energy in its various forms represents the most (perhaps only) reasonable alternative for future energy use in Western society.

Wind energy is a form of solar energy in that the sun's radiant heating of the earth's surface is thought to be the primary cause of convective heat exchange in the atmosphere.(2) The usable power in the wind on a global scale, as estimated by Putnam (3,4) and revised by Hewson (2), is ten million MW, about twenty times the potential for water power.

Wind energy is fundamentally different than fossil fuel and nuclear fission in several respects. Wind Energy Conversion Systems (WECS) release no significant energy in the form of heat into the environment which is not already there and are notably free of other pollutants. Solar and wind energy are renewable within the time span of human history, thereby presenting the possibility for society to exist within the no-growth economics required by the finite earth (5).

The wind has been used by man as a power source for several thousand years. In the United States, small wind machines for pumping water and generating electricity were common until the mid-twentieth century. These wind machines were characterized by high first costs

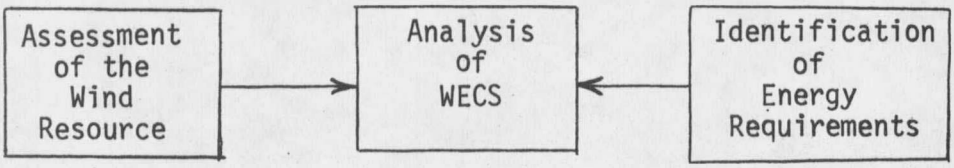
and discontinuous energy supply due to the variable wind. When the Rural Electrification Administration (REA) built an inexpensive and widely distributed electric power network, small wind systems became a second choice. As a direct result of the REA, the market for wind electric generators was virtually eliminated in the United States by the mid 1950's.

The position of small wind electric power generation has improved in the quarter century since 1950 due to technical, economic and social developments. Technical developments in electronics have virtually eliminated the need for massive and expensive storage systems by allowing individual wind generators to share existing electric power networks. Electric utility rates have begun to increase rapidly due to fossil fuel shortages and stricter environmental constraints. Thus, although wind system first costs remain high, the economic comparison with utility costs has improved. Finally, an increasing social awareness of the impact of high energy society on Montana (6) has convinced many people that environmentally clean energy options may be desirable even at a cost disadvantage.

Many large scale wind power projects were undertaken in Denmark, France, Russia, England, Germany and the United States between the turn of the centry and World War II (7, 4, 8, 9). Most of these projects were considered technically successful but were phased out because they were not cost effective compared to readily available

fossil fuels. Large scale WECS are again being considered in the mid 1970's due to recognition of impending fossil fuel shortages.

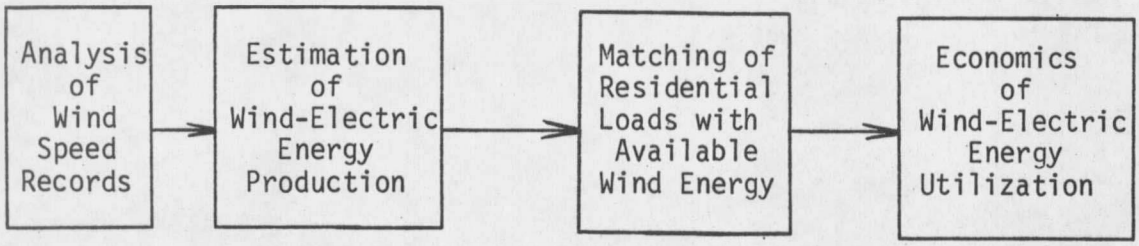
The problem of utilizing wind as an energy resource can be outlined as follows:



The method of approaching the problem is indicated above, where identification of the energy resource and requirements leads to development of conversion methods or systems.

A primary consideration in renewable energy utilization should be the energy requirements of society, the right hand block of the diagram above. Several generations with cheap, readily available energy on demand have conditioned this society to gluttonous levels of energy consumption and material waste. The effect of reducing energy requirements through strong conservation measures can be achieved on a short term basis with less energy expenditure than exploitation of any energy resource. The immediate importance of materials and energy conservation are pointed out by Clark (1) --presently available material and fossil fuel resources are necessary to develop renewable energy conversion systems capable of sustaining society in the future.

The scope of renewable energy utilization in this thesis is limited to wind energy as a resource in Montana, used to deliver residential electric requirements with diversified small wind powered electric generating systems. The procedure consisted of four major steps, as follows:



Detailed meteorological wind speed records from ten Montana airport weather stations were analyzed to determine wind speed characteristics. Then, the maximum electric energy production of various wind-electric machines, up to 1.25 MW in size, was estimated. Wind system performance was analyzed in terms of electric energy delivered to residential requirements, for systems both with and without a utility power network. Finally, wind energy costs were estimated for various options of residential energy use, storage methods and equipment life.

SECTION II

MONTANA'S WIND ENERGY RESOURCE

Energy in the Wind

The amount of energy in the wind can be determined by considering that the kinetic energy of a mass of air is related to the square of the scaler wind speed by

$$K.E. = \tfrac{1}{2} m v^2 \qquad (1)$$

where K.E. is kinetic energy, m is the mass of air and v is the scaler speed.

The power in the wind is the time rate that kinetic energy is passed through a given cross sectional area,

$$P = \tfrac{1}{2} \dot{m} v^2 = \tfrac{1}{2} (\rho A v) v^2 = \tfrac{1}{2} \rho A v^3 \qquad (2)$$

where P is the power in watts, A is the area in square metres, $\dot{m}$ is the mass flow rate of air in kilograms per second, ρ is the air density in kilograms per cubic metre and v is the scaler speed in metres per second.

The power density, defined as the power per unit area in the wind, is written

$$p = P/A = \tfrac{1}{2} \rho v^3 \qquad (3)$$

Since the power density depends on the cube of the wind speed and only the first power of air density, the scaler wind speed is the primary factor in virtually all power calculations.

Wind Speed Measurement

A primary consideration in any form of power generation is to assess the available energy resource and the net energy production from a given power plant. In the case of fossil fuels and nuclear or hydro power production, it is possible to predict power plant performance and net energy yield fairly accurately because the energy source can be controlled. The situation is more difficult in the case of wind power generation because the wind speed, and therefore the power input to the machine, is continually fluctuating. Despite this difficulty, reliable methods of wind speed measurement and estimations of net energy production have been developed (10, 11, 12, 13). Additionally, annual energy production is greatly influenced by the precise location of the wind plant in a given area.

Measurements of wind behavior can be classified according to the purposes for which they are intended. Golding (12) outlines three purposes for wind power studies:

1. To enable special studies to be made regarding the design and performance of wind power plants;
2. To furnish information on wind characteristics at the site;
3. To provide data from which the estimated energy production of a wind plant of known characteristics, located at the measuring site, can be predicted.

These three classes correspond to various time scales of wind speed measurement as 1) short-period measurements, 2) medium-period measurements and 3) long-period measurements.

Short period wind speed measurements of several minutes to fractions of a second are necessary to determine the effect of gusts on performance of wind power plants and to analyze stresses in the blades and structure of the machine. Medium period measurements of several minutes to an hour are necessary to determine changes in wind direction and the variation of speed with height above ground.

Long period measurements in the form of hourly mean speeds provide the most useful information for the purpose of estimating the total energy production of a wind plant at a selected location (12, 10, 11). For this calculation, it is essential that the frequency of occurrence of each speed be known. Additionally, the usefulness of these data can be listed as follows:

1. As a basis for indicating areas of highest wind speeds;
2. As an indication of the prevailing wind directions;
3. As a measure of the annual (year to year) variation in mean wind speed;
4. As an indication of the seasonal (month to month) variation in mean wind speed;
5. As a measure of the diurnal (hour to hour) variations in mean wind speed;

6. As a guide to the maximum wind gusts and to the duration of calm spells, which may occur at a site.

The usefulness of hourly mean speeds in estimating the energy production of a wind power plant results from a trade-off of two factors. Here, the energy pattern factor (EPF) is introduced as the ratio of the actual energy in a fluctuating wind to the energy calculated from the cube of the mean wind speed,

$$EPF = \frac{\int_0^T v^3 \, dt}{T \left(\frac{1}{T} \int_0^T v \, dt\right)^3} \qquad (4)$$

where v is the wind speed and T is the length of time interval. Since energy pattern factors are greater than unity, it would appear that energy estimates based on hourly mean speeds would be low. This may be the case, however the EPF based on one-hour time periods does not vary greatly from unity (12, 7, 4) and this low estimate is countered by the fact that wind machines are restricted in their response to short-term gusts due to inertia of rotating parts. Wind plant energy estimates based on hourly mean speeds have been shown to be quite accurate by Golding (12, 7), Hutter (14), Tagg (10,11) and others.

Meterological Wind Speed Records for Montana

Available wind speed data for Montana were of the long term type, discussed above, measured at airport weather stations for meteorological purposes. Measurements were taken with direct reading "magneto" type anemometers (15). Recorded data consists of one-minute averages taken hourly or once every three hours. This data is suitable for indicating areas of high wind energy potential, identifying annual, seasonal and diurnal wind characteristics and estimating wind plant energy production at the measurement site.

Compared to this meteorological information, a wind power survey would compute hourly wind speed averages based on continuous measurements. The correlation between the available hourly or three-hourly sample readings and continuous measurements averaged hourly is unknown. A wind power survey would seek locations with high wind speeds, whereas criteria for siting airports usually avoid high wind areas. In addition, weather station anemometers have no standard height and are often located on or near buildings. For these reasons, long term average wind speeds indicated in this thesis may be lower than average speeds at many potential wind generator sites.

Wind speed data for the thirteen Montana locations listed in Table 1 were derived from three sources. Original Weather Bureau records (16) for Federal Aviation Agency (FAA) airports at Livingston and Belgrade were used. These records include additional readings

taken during adverse conditions(15). Summarized monthly mean wind speeds were obtained from Environmental Data Service (EDS) publications (17) for Cut Bank, Lewistown and Dillon. Three-hourly data were obtained for the remaining eight locations of Table 1 from additional EDS publications (18). All these data are compiled by the National Oceanic and Atmospheric Administration (NOAA) in Ashland, North Carolina (15).

The geographical locations of the sites studied are shown in Figure 1 with their respective elevations in metres and feet above sea level. The shaded mountain areas include Kalispell, Missoula, Helena, Bozeman and Dillon. Cut Bank, Great Falls and Livingston lie along the eastern slopes of the Rocky Mountains. The eastern plains area includes Havre, Lewistown, Billings, Glasgow and Miles City.

Effect of Air Density on Power Estimates

Since the power density depends directly upon the air density, it was necessary to assess the magnitude of variation in air density. The equation of state of a perfect gas is

$$\rho = P/R\,T \qquad (5)$$

where ρ is the air density, P is the atmospheric pressure, R is a gas constant and T is the absolute air temperature.

The pressure P is relatively constant at a given elevation having only small fluctuations due to local temperature and weather conditions. Atmospheric pressure as a function of elevation was obtained from the

U. S. Standard Atmosphere (19). Table 2 lists annual mean temperature, air density and elevation for each site studied.

At a given location, the air density is inversely related to the absolute temperature (Equation 5). Thus, the seasonal variation in air density, based upon monthly mean temperatures, was found to vary by about 10 percent during the year for each location. This is the same magnitude of variation found by Putnam (4) in Vermont.

A random distribution of air density variation will have no net effect on the annual mean power density. However, if the highest air densities are in-phase with the highest wind speeds, a net change in annual mean power density will result. For example, the highest wind speeds occur during the winter in Livingston. To determine the magnitude of this change, the annual power density was computed by two methods for Livingston. First, the averaged value was determined using the annual average air density. Second, the seasonal value was computed using monthly mean speeds and air densities. The seasonal value was 1.4 percent higher than the averaged value. Since Livingston has the most extreme conditions of high winds during the cold winter season, the 1.4 percent value represents the highest error attributable to seasonal air density variation. This is generally a small error compared with the twenty to thirty percent variations in annual power density observed at many locations. A similar comparison based on daily averages would be expected to show even smaller errors, since

diurnal variations of wind speed and temperature are generally in phase.

Wind Speed and Power Analysis

It has been pointed out that the wind speed data for Montana was suitable for the following topics, which are presented in this section:

1. As a basis for indicating high wind speed areas;
2. As a means of estimating net energy production for wind plants of known characteristics;
3. As a measure of the time variation of available winds on an annual, seasonal and diurnal basis;
4. As a guide to maximum gusts and to the duration of low wind periods, which occur at each site.

The thirteen locations studied are listed in descending order of annual mean wind speed in Table 3 along with the time interval between wind speed measurements. The following generalizations can be made from annual mean speed information:

1. Mountain regions of Montana tend to have relatively low mean wind speeds, in the range of 3 to 3.5 m/s (6 to 8 mph). These sites include Dillon, Helena, Kalispell, Missoula and Bozeman.
2. The eastern plains area of the state has an annual mean speed of approximately 4.8 m/s (10.8 mph) and shows a small variation over a wide geographical area. This area includes

Billings, Glasgow, Miles City, Havre and Lewistown.

3. The eastern slopes of the Rocky Mountains show the most extreme wind conditions with annual mean speeds as high as 6.3 m/s (14.1 mph). This area includes Livingston, Cut Bank and Great Falls.

The eastern slopes of the Rocky Mountains show similarily high annual mean wind speeds along the entire range from Montana to Texas (20).

The cubic dependance of power density on wind speed makes the wind speed and the frequency distribution of the speed prime factors in power plant energy estimates. Table 4 lists the percent of time in speed ranges by location. The percent time in the range 3.4 to 10.5 m/s (5.2 to 17.4 mph) is of particular interest in this analysis since this is the operating speed range of most small wind-electric generators. All the eastern slope and eastern plains areas have wind speeds in this range more than 50 percent of the time. Locations with winds over 10.6 m/s (18 mph) a high percent of the time, such as Livingston and Great Falls, may present structural and overspeed difficulties for wind generators. A tabulation of the percent of time at speed in one-knot (0.51 m/s) speed catagories which was used in a computer program to estimate energy output of wind plants is included in Appendix A for ten locations.

The frequency distribution of wind speeds are essential for estimates of net energy production by wind power plants. Such dis-

tributions are shown in Figure 2 for three locations with varying annual mean wind speeds. These distributions are the percent of time the wind blows at the indicated speed in one-knot (0.51 m/s) speed catagories. The mean wind speed is always greater than the median, or most frequent speed, since the distribution is not normal. The trend is for low mean speed areas, such as Missoula, to have winds a high percentage of the time at low wind speeds and for high mean speed areas, such as Great Falls, to have winds a low percentage of the time at higher wind speeds.

The relationship between the most frequent wind speed and the annual mean wind speed is shown in Figure 3 for ten locations in Montana. The results of siting analyses in Great Britain by Golding (7) and in New England by Putnam (4) are also presented.

The distribution of power with wind speed is shown in Figure 4 for the same three locations. The power density in watts per square metre (W/m^2) is indicated for each one-knot (0.51 m/s) speed catagory. This distribution points out that the wind speed range of greatest power density is higher than the range of most frequent wind speed. For example, at Great Falls the most frequent wind speeds are between 2.6 and 5.1 m/s (5.8 and 11.5 mph), whereas the greatest power density occurs between 7.7 and 12.9 m/s (17.3 and 28.8 mph).

Wind power plant energy estimations using frequency distributions of wind speeds are discussed in Section III.

A tabulation of the annual mean wind speeds, most frequent wind speeds and maximum wind speeds for ten locations is presented in Table 5. The maximum speeds recorded for seven locations are maximum one-minute gusts recorded in a thirty year period. For Bozeman and Livingston, the maximum speed is the highest instantaneous gust recorded in a four year period.

Also presented in Table 5 are the ratios of the maximum wind speed to the average speed. This ratio is of major consequence to the structural integrity of a wind power system since the drag on a structure is proportional to the square of the speed. In the case of Helena, where the maximum speed to average speed ratio is 11.8, a structure must be more than 100 times stronger than required for the average speed. Mathematical methods of estimating maximum gusts are discussed in the literature (7, 13).

Another method of displaying the frequency of occurrence of each wind speed at a location is the speed duration curve, such as Figure 5 for Livingston. The speed duration curve is a plot of the percent of time for which the speed is greater than or equal to a particular value as a function of the range of wind speeds. The annual mean speed duration, along with the speed duration of the average windiest and the average calmest months, are presented for each of ten locations in Montana in Figures 5 through 14.

The advantage of the speed duration method of presentation is that

the annual mean power density in the wind at a given location is proportional to the wind speed cubed (on the absissa). Such a power duration curve is shown in Figure 15 for Livingston. The integral of this duration function over time (i.e. the area under the power duration curve) is a measure of the annual mean power density in W/m^2 for each location. For this analysis, the mean power density, $\bar{p}$, was computed by

$$\bar{p} = \sum_{i=1}^{N} \tfrac{1}{2} \rho v_i^3 \left(\frac{\Delta t}{t}\right)_i \qquad (6)$$

where $\left(\frac{\Delta t}{t}\right)$ is the fraction of time the wind blows at speed v_i, i is the index from 1 to N where v_N is a high enough wind speed to include all the data. Equation 6 represents a stepwise integration of a power distribution curve, such as in Figure 4.

As with the speed duration curves, the annual mean power duration and the average months of highest and lowest power duration are presented for each of ten locations in Montana in Figures 15 through 24. The total annual energy density in kilowatt-hours per square metre (kWh/m^2) is the product of the number of hours per year (22) and the annual mean power density $\bar{p}$. Power and energy density values, computed by Equation 6, are presented in Table 6. These values emphasize the very large difference in the wind energy resource at high wind (eastern slope) areas compared to low wind (mountain) areas.

It is important to establish the reliability of the wind energy

resource in order to predict wind plant performance. Golding (7) and other researchers (4, 12, 8) have found that the variation in annual mean wind speed is less than twenty percent from year to year at a single location.

The annual mean speeds for thirteen Montana locations are compared with Environmental Data Service (18) (EDS) mean wind speeds for the period 1941 to 1970 in Table 7. The percentage variations from year to year were computed by

$$\Delta_1 \% = 100 \times \frac{\bar{v}_i - \bar{v}_1}{\bar{v}_1} \qquad (7)$$

where $\bar{v}_i$ is the annual mean wind speed for the i^{th} year based on the available data and $\bar{v}_1$ is the EDS thirty year mean. For five locations not having EDS means, the percentage variation was based on the study period mean speed, i.e. $\bar{v}_1$ of Equation 7 is replaced with $\bar{v}_{sp}$, the study period mean. All variations are less than twenty percent and more than ninety percent of the cases considered had variations under ten percent. These results correspond to the findings of Golding (7) in Great Britain and Thomas (8) in other parts of the United States.

The right hand column of Table 7 compares the long term EDS mean speeds with the study period means as

$$\Delta_2 \% = 100 \times \frac{\bar{v}_{sp} - \bar{v}_1}{\bar{v}_1} \qquad (8).$$

The percentage deviations suggest the present analysis may be overestimating long term energy potential, in terms of airport data, for Miles City, Havre and Missoula while significantly underestimating it for Great Falls.

Seasonal and daily variations in wind speed and power density are important to the wind power user. The seasonal variation in mean wind speed has been computed on a monthly basis for each average month and is shown in Figure 25 for Livingston. The percentage variation by month from the annual mean power density $\bar{p}$, is also shown in the same Figure. These variations are based on twelve equal length months of 730 ½ hours, so there is no variation due to short or long months. Seasonal variations for the other locations are shown in Figures 25 through 37.

The seasonal variation of wind speed and power density for Livingston and Great Falls (Figures 25 and 27) show that most of the energy in the wind is available during the coldest months of the year, suggesting the possibility of using excess wind generated power for space heating or water heating.

Diurnal variations in the wind show that wind speeds generally peak in the afternoon and drop off significantly during the night. Annual mean diurnal variations of wind speed and power density are presented in Figures 38 to 45. Although annual average diurnal variations display general trends, significant seasonal trends exist,

as shown in the tabulated monthly values for eight locations in Tables 8 through 23.

Wind power systems usually include some form of storage method which has a limited energy storage capacity. Thus wind power users are interested in the probability of occurrence of a given time period with no energy from a wind plant. Such probability functions are available for wind speeds below 3.3 m/s (7 mph) and below 8.7 m/s (20 mph), which correspond to the cut-in speed and rated speed of many small wind-electric generators. These functions are displayed for ten locations in Figures 46 to 55. Probability of occurrence and length of time data have been curve fitted by the method of least squares to an exponential equation of the form.

$$F = a\,T^{b} \qquad (9)$$

where F is the probability of occurrence of the time span T in hours with low energy winds, a is a coefficient and b is an exponent. The constants a and b are tabulated for ten locations in Table 24. These equations may be in error by a factor of three or more for individual points but are included to identify general trends. The range of validity of each equation is also listed in Table 24.

Some of the preceeding information is available for each of thirteen locations in Montana. Table 25 is provided as a quick reference displaying the Figures and Tables available by location.

The concept of the energy pattern factor (EPF), introduced in Equation 4, shows that power estimates based on long term mean wind speeds can be highly inaccurate. Energy pattern factors based on monthly means for several Montana locations are compared in Figure 56 with the limits of Golding's data for Great Britain (7). Monthly EPF's decrease with the monthly mean wind speed and display a wide range of scatter.

Effect of Height Above Ground on Power Density

There is a wealth of literature on the subject of wind speed variation with height. For unobstructed, flat open country, the most common formulation is the general form

$$\frac{v}{v_o} = \left[\frac{h}{h_o}\right]^n \qquad (10)$$

where v is the wind speed at height h, v_o is wind speed at a reference height h_o and n is an exponent.

Golding (7) warns that formulas like Equation 10 apply to average speeds only and are not valid on a short term basis. Furthermore, the exponent n can vary with the height, time of day and season of the year, ground surface type, mean wind speed and temperature gradient. Mark's Handbook (23) lists the exponent n as a function of speed as follows:

n = 1/2 for 0 to 2.2 m/s (0 to 5 mph) winds,

n = 1/5 for 2.2 to 15.6 m/s (5 to 35 mph) winds, and

$n = 1/7$ for winds greater than 15.6 m/s (35 mph).

Since the power density is related to the wind speed cubed by Equation 3, a substitution yields the following power dependence on height:

$$\frac{p}{p_o} = \left[\frac{h}{h_o}\right]^{3n} \qquad (11)$$

where p_o is the power density at the reference height h_o. Based on Equation 11, the percentage increase in power density with height is listed in Table 26 using a reference height of 10 metres (32.8 ft) and $n = 1/5$. Equation 11 is also plotted in Figure 57, which shows the rate of increase of power (i.e. the slope) decreases with increasing tower height. Since tower costs increase with height, Figure 57 indicates the existence of an economically optimum tower size.

It must be emphasized that Equation 11 is based on a restricted set of conditions and in general, should be used only as a guide in estimating variations in power output from a reference height. Actual on-location wind speed measurements will provide the most reliable information.

Site Selection

Long term average wind speeds can vary greatly with location. The dependence of wind speed on height has been discussed above. Putnam (4) and Golding (7) showed that with careful site selection, it

was possible to find locations having annual means more than 50 percent higher than that of the surrounding area. Such increases in mean speed could result in increases in energy production of 50 to 250 percent (7) depending on wind plant characteristics.

Continuous on-site wind speed measurements leading to a frequency distribution function are often expensive and difficult to obtain. For reasons discussed in Section III, the annual mean wind speed can be useful in estimating net energy production of wind machines. Annual mean speeds could be compared with wind records at a nearby airport for the same time period. With suitable correction factors, the summarized airport data in this analysis could be rendered more appropriate to the new location. Putnam (4) discusses the minimum time period required to establish wind speed correlations between two locations within certain error limits.

Historically, wind power for residential use in the United States has been limited to rural areas. The same trend is expected in the future because cities and towns usually have low winds, building code restrictions on tall structures and visual and safety objections.

Basic guidelines to site selection in rural areas are to make wind speed measurements and to install wind machines above nearby obstructions

(trees or buildings) yet near enough to the load center to minimize transmission losses and costs. Optimum site selection is discussed in the literature by Duchon (24) and Vukovich and Clayton (25).

SECTION III

WIND-ELECTRIC GENERATORS

Types of Wind-Electric Generators

A wind-electric generator is a device which converts the kinetic energy of the wind to electrical energy. The myriads of different shapes and forms these devices have taken bears witness to the variety of human ingenuity. Information on wind system design is well documented in the literature (2,4,7,9,14,26,27,28) and will not be considered here in detail.

There are two primary classifications of wind generators, the horizontal axis and the vertical axis types. The largest wind system ever built was the horizontal axis Smith-Putnam Wind Turbine (4) which supplied a.c. power to the lines of the Central Vermont Public Service Corporation between 1941 and 1945. This system stood 33 m (107 ft) at the hub, had two blades with a 3.5 m (11 ft) chord and 53 m (175 ft) diameter, and produced 1.25 MW in a 13.4 m/s (30 mph) wind. Most currently available wind-electric generators for home use are of the horizontal axis design and range in size from 0.1 to 10 kW installed capacity.

Vertical axis wind plants employ a variety of rotors. The primary advantage of this design is its non-directionality, thus eliminating the need to orient into the wind. Some vertical axis generators are called hybrid systems because they employ airfoils similar to those

used on horizontal axis turbines.

A concept unlike those discussed above, is the tracked vehicle airfoil system (29, 26). The system uses vehicles like railroad flatbed cars with vertical airfoils and is driven around an elongated oval track. Power could be taken from linear induction generators under the track or from generators on the turning axels. This design requires a location with strongly directional winds and is better suited for large scale power generation (>1 MW).

Wind Turbine Augmentation

Compared with water and steam, the wind has a relatively low energy density. Putnam (4) and others (24,25) sought geographic locations which would speed up the local wind stream, thereby increasing the energy density. Hewson (2) suggested terrain modification to achieve the same results. Additionally, augmentation of conventional wind turbines has been considered to increase wind energy density.

Oman and Foreman (30) have analyzed a conventional wind turbine at the entrance to a diffuser. This "diffuser-augmented" wind turbine can theoretically produce twice the power of the same sized turbine in a free stream of air. However, such a system can not exceed the performance of a wind turbine whose swept area is equal to the exit area of the diffuser.

Sforza (31) recently introduced a "vortex augmentor" which employs a triangular delta wing airfoil in conjunction with a horizontal axis wind turbine. This augmentor produces a vortex with a vector velocity greater than the horizontal air speed, thereby increasing the power density of a portion of the air flow around the air foil. This augmentor can theoretically produce up to eight times the power of the lone wind turbine. Sforza reports a factor of four to five increase in power output compared to the non-augmented turbine.

Augmented wind turbines offer the advantages of operation in lower and higher wind speeds, more control over wind turbine speed and decreased size of rotational parts. Although they simplify wind plant control, the augmenting devices must themselves be controlled. Augmented wind systems will very likely find specialized applications but the economic trade-off between increased power density and increased material investment has not been determined.

Performance Characteristics and Limitations

For a horizontal axis wind turbine in a constant velocity free stream of air, it can be shown that the maximum fraction of wind energy which can be converted to mechanical energy at the hub is 16/27 or 59.3 percent (32,23,33). This theory applies the principals of conservation of momentum, mass and energy but does not include boundary layer effects. G. Kh. Sabinin (34) obtained a figure of 68.7 percent

as an upper limit on performance by including vortex effects in the flow around the disk area, which effectively increases the area of momentum exchange. The 59.3 percent figure is most commonly used in this country. Some wind plant designs have achieved peak overall efficiencies--the ratio of electric power output to the total kinetic energy in the wind--of 50 percent.

An important parameter in wind plant design is the blade speed to wind speed ratio, which varies along the length of the blade. Many modern wind machines use blades with airfoil cross sections. The blades are twisted to maximize the lift to drag ratio over their entire length. The ratio of the tip speed to wind speed is used as a parameter for comparing efficiencies. In Figure 58 the efficiencies, as given by Mark's Handbook (23) and Park (35), for several major design types are compared over a range of tip speed ratios. Mark's Handbook (23) indicates an optimum tip speed ratio for two-blade horizontal axis designs, however these efficiencies are apparently based on power at the rotor rather than electric power delivered, since the efficiencies are significantly higher than those shown by Park. Park (35) indicates that horizontal axis systems increase their efficiencies linearly with tip speed ratio and that hybrid systems can achieve high efficiencies at lower tip speed ratios.

The solidity ratio is the area of the horizontal projection of the blades divided by the total swept area of the blades. High tip speed

ratios necessitate less massive blades to maintain centrifical forces at a safe level. The trend toward thinner and lighter blades in wind-electric generators is reflected in Hutter's (14) data, Figure 59. Multiblade "American windmills," used for pumping water, require high starting torque and corresponding high solidity ratios.

The most important consideration with regard to wind-electric generator performance is the electric power output as a function of the wind speed--the power characteristic. A power characteristic curve, typical of most horizontal axis wind plants, is presented in Figure 60 on a power per swept area basis (W/m^2) for the Aerowatt 4100 FP7. Electric power generation begins at the cut-in speed of 2.6 m/s (4.3 mph) and becomes constant at a rated speed of 8 m/s (18 mph), at which point the generator has reached its full rated capacity and some type of speed control method prevents overpowering the generator and over-speeding the blades. Total kinetic energy in the wind and overall efficiency are also shown.

Power characteristics can be determined by several methods. Small wind plants can be driven on a truck during calm periods in both directions along a road at various speeds (7,35). Wind tunnel tests produce the same results, however both these methods do not account for the effects of gusts and cannot be applied to very large wind systems. Clausnizer (36) describes test procedures, lasting several

days to a week, for determining power characteristics in real wind situations. The results of such a test are presented in Figure 61 for two 100 kW wind generators. Tagg (10,11) discusses methods to reduce the scatter in these data.

Clausnizer (36) emphasizes that the shape of the power characteristic is sensitive to the averaging time period of wind speed and power output. For the purpose of estimating net energy output, it is necessary that the time period used to determine the power characteristic correspond to the time period over which wind speed data are averaged. Analytical methods for modifying a short time period power characteristic to correspond to long term wind data are available (36).

Wind generators used in this analysis are listed in Table 27 with their respective blade diameters and rated capacities. Corresponding power characteristics are tabulated in Appendix B. In most cases, the method of test or averaging time period used for these power characteristics were not available.

Estimated Wind Energy Production at Selected Montana Locations

The only meaningful way to compare wind plant performance is in terms of net energy produced in a given wind regiem. Estimation of net energy production requires a knowledge of the wind plant power characteristic and the frequency distribution of wind speeds. The annual average power output of thirty wind plants was computed by taking

the numerical sum of the products of the power output at each wind speed and the fraction of time the wind blows at each speed. This is written:

$$\bar{P}_{avg} = \sum_{i=1}^{N} P(v_i) \quad \left(\frac{\Delta t}{t}\right)_i \tag{12}$$

where $\bar{P}_{avg}$ is the annual average power output, $P(v_i)$ is the power generated at the speed v_i, $\left(\frac{\Delta t}{t}\right)_i$ is the fraction of time at the v_i^{th} wind speed on an annual basis and i is the index from 1 to N wind speeds. The annual energy generated is simply the product of the average power $\bar{P}_{avg}$ and the number of hours per year, 8766.

Similar methods of energy estimation, based on hourly averaged wind data, have been found by several investigators, notably Tagg (10, 11), Golding (12,7), and Hutter (14), to give very close comparisons with on-site measurements.

Estimated energy values generally increase with annual mean wind speed and with wind plant rated capacity. Annual average power estimates are presented for thirty wind plants (Table 27) at each of ten locations in Table 29. Estimated mean monthly and annual energy yield, computed by multiplying the mean power by 730½ hours and 8766 hours respectively, are presented for thirty wind plants at ten locations in Tables 30 and 31. Monthly energy values, in Table 30, may be the most useful presentation since most residential consumers

are familiar with their monthly power bills. Percentage seasonal variations in monthly energy output are the same as energy density variations, presented in Figures 25 through 37.

It must be emphasized that these estimated power and energy output figures (Tables 29-31) are ideal values. Such results could be obtained only if the wind plant were never down for repairs and if the power demand always equaled the wind power supplied. Thus, these power output estimates represent the upper limit of wind energy which can be made available to residential users at each location with the appropriate wind plant.

Golding's method of computing the net annual energy output of a wind genrator (7) is based on the power duration curve. The annual power duration curve for Livingston is presented in Figure 62 with the indicated performance characteristics of the Elektro WV 35G. This wind-electric system starts generating power at the cut-in speed of 3.6 m/s (8 mph). The available wind energy below this speed is very small compared to the net available wind energy (i.e., the total area under the power duration curve). This wind generator reaches its full rated output of 4.5 kW at its rated speed of 12.3 m/s (28.6 mph). At the furling speed the system ceases operation to avoid damage, thus no energy is produced above this speed. For the sake of clarity, the furling point in Figure 62 was taken at 20.6 m/s (46 mph), although it is 53.7 m/s (120 mph) for the Elektro WV 35G.

The annual net energy produced by the Elektro WV 35G at Livingston is proportional to the cross hatched area a-b-c-d-e-a. If the wind plant operated at full capacity 100 percent of the time, the energy produced would be proportional to the area o-x-y-z. The area ratio, a-b-c-d-e-a / o-x-y-z, gives the specific output, which is the equivalent fraction of time the plant operates at full capacity. Specific output is expressed in units of kilowatt-hours per year per installed kilowatt (kWh/yr/kW). Specific output is tabulated in Tables 32 and 33 for thirty wind plants at ten locations. The values in Table 32 are listed as the equivalent percent of time at full capacity. Percent specific outputs for wind-electric generators under 10 kW at windy locations range from 15 to 70 percent.

Golding's method of estimating specific output clearly points out that net energy production depends on the wind spectrum and the rated speed, cut-in speed and overall efficiency of the wind plant. Additionally, Golding demonstrated that the relationship between the specific output and annual mean wind speed was roughly linear for mean speeds between 3.6 and 9 m/s (8 and 20 mph) and has decreasing slopes for speeds greater than 9 m/s (20 mph) (7). Stodhard (13) points out that because of the linear relationship between mean speed and specific output, it is possible to estimate wind plant performance based only on annual mean wind speed.

Percent specific output is plotted as a function of annual mean

wind speeds in Montana for several wind plants in Figure 63. Specific output increases with increasing annual mean wind speed for each wind plant and increases with decreasing rated speed for different wind plants. The relationship between percent specific output and the mean wind speeds for Montana indicate that the energy production of wind machines can be estimated at sites where only the annual mean wind speeds are known.

Some investigators prefer to compare system performance on the basis of energy output per unit swept area of the system. In Table 34 the mean monthly energy output per unit area in kilowatt-hours per square metre ($kWh/mo/m^2$) are presented for each wind plant by location. These values generally increase with increasing mean speed but their magnitudes differ greatly between wind plants. The output per swept area is plotted as a function of annual mean wind speed for selected wind generators in Figure 64.

Performance, in terms of net energy produced, depends strongly on the wind plant's rated wind speed. The Aerowatt turbines achieve low rated speeds with large blades, whereas the Elektro design relies on high power output with large generators. A comparison of an Aerowatt and an Elektro plant of similar size (Aerowatt 4100 FP7, 4.1 kW with an Elektro WV 35G, 4.5kW) reveals that the Aerowatt plant produces more energy at all locations in Montana, although the difference decreases with increasing annual mean wind speed, as indicated in Figure 64.

Extrapolating from values in Table 30, shows that equal performance would only be achieved with mean speeds of 7.6 to 9.4 m/s (17 to 21 mph). This indicates that rated wind speed should be the deciding factor in wind plant selection, however cost considerations add to the complexity of selection criteria. Increasing blade size usually increases total cost faster than increasing generator size, thus indicating an economically optimum trade-off between low rated speed and high rated capacity. Wind energy costs are considered in Section V.

The importance of proper site selection is clearly indicated in this performance analysis. When measured by net energy production (Table 30), specific output (Figure 63) or output per swept area (Figure 64), wind generator performance is always an increasing function of annual mean wind speed. For any wind plant there is not as much energy available in the low wind (mountain) areas as there is in windy areas (eastern Montana and the eastern slopes).

SECTION IV

WIND ENERGY STORAGE

Energy Storage Methods

Energy storage methods are not unique to wind systems but are used for any situation where the energy supply can not be controlled to meet energy demand. The function of energy storage in a complete wind power system is shown in the block diagram in Figure 65. Although a shared utility grid does not store energy, this method fulfills the role of energy storage.

The merits of any storage method for power systems depend upon the stored energy density, the ease and flexability of energy reconversion into a useful form overall efficiency and cost per unit stored energy. The storage methods discussed here are: flywheels, pumped hydro, fuel cells, compressed air and lead-acid batteries.

Flywheels store kinetic energy in a spinning disk. In the past, flywheels had the drawbacks of limited energy storage capacity, poor efficiency and danger of catastrophic failure. Recent developments using a fanned circular brush confirugation (37) may have removed the danger of catastrophic failure. Other super-flywheel concepts (38) are in the design and development stages. Compared with lead-acid batteries, super-flywheels offer lower weight per unit energy stored, lower cost and longer life. Such flywheel systems are also capable of producing high power rates which are common to residential uses for starting

motors. Energy losses due to friction can be reduced with magnetic bearings and low pressure gas chambers.

Pumped water storage is a well developed and well understood storage method. The gravitational potential energy of a mass of water is raised by pumping the water to a higher level. Overall efficiencies of this method (energy returned compared to energy invested) can achieve 67 percent (1). Pumped hydro storage is greatly restricted because it requires either a large elevation difference or large volumes of water and the associated land area. The method is presently used in conjunction with nuclear plants to meet peak demands. Indications are that pumped hydro storage could perform the same function for large wind systems in a national grid (8, 9).

Fuel cells are basically a form of battery in which chemical reactions generate electric power. They are not regenerative since they must be supplied fuel from an external source. With wind systems, electrical energy could be used to separate hydrogen and oxygen by electrolysis. The stored hydrogen can be recombined with oxygen in the fuel cell to produce electric power. The promise of the fuel cell lies in its simplicity and its pollution free operation, although its use is presently restricted by high cost.

Excess wind generated electric energy could be used to compress air stored in underground chambers. Existing natural gas technology uses depleated oil and gas fields, acquifiers, and solution mined salt

caverns for storing compressed natural gas (39). Fryer (39) concluded that compressed air storage using a motor-generator with compressor-gas turbine is now (1974) cost competitive with pumped hydro storage. This storage method is only practical for large scale energy systems.

Lead-Acid Battery Storage

Lead-acid batteries have been the standard of comparison for electrical energy storage. They are an old and proven concept, easy to use, have instant startup and have low costs per unit stored energy. Costs range from $54 to $80 per kWh of stored energy (40) and are not expected to decrease significantly with improved technology. Both cost and total weight of batteries increase linearly with storage capacity. Some disadvantages of lead-acid batteris are their low peak power capability, low efficiency, low energy density and associated heavy use of materials, and the necessary d.c. to a.c. conversion. Since lead-acid batteries are heavy users of copper, lead and zinc, all increasingly scarce materials, they cannot be considered a viable energy storage method of the future. For example, consider the mass of storage batteries required to store 20 kWh of energy, which is a reasonable storage size for residential home use. With an energy density of 4.5 Wh/kg (10 Wh/lb), a total mass of 909 kg (2000 lb) is required.

There are several factors which influence the cost and lifetime of

lead-acid batteries other than initial storage capacity. The number, rate and depth of charge-discharge cycles influence the lifetime and effect the efficiency of battery operation. Most lead-acid batteries can withstand approximately 1,500 full charge-discharge cycles.

Battery efficiency ranges from 50 to 87 percent (41, 7) depending on the type of use as well as the duration and depth of charge-discharge cycles.

Shared Utility Network

By sharing a utility power grid, a wind power source becomes a part of a larger power distribution network. The shared grid system is accomplished by using an inverter (42) capable of changing any electrical signal to line frequency and voltage at an efficiency of more than 90 percent over the entire power range. When wind generated power is greater than the load, the excess power is diverted into the utility network, thus decreasing demand on other power sources. When the residential load is greater than the wind power supplied, the difference in power required is drawn from the power company in the conventional manner. Although not an energy storage method, the role of the shared grid system, as seen in Figure 65, is the same as the role of energy storage in the wind power system.

Large wind-electric generators on a power network are a proven concept (7,4,9). Such systems work best in conjunction with another

power source, such as hydroelectric, which can change its power level quickly and act as a storage medium. Wide spread use of large wind powered systems on a national grid may contribute to network instabilities due to variable winds. Significant contributions to network instability from small, diversified wind power systems seems unlikely since such wind systems are largely restricted to windy, rural areas where population densities are extremely low.

The shared grid concept offers many advantages over conventional energy storage methods. Although very expensive ($1275) (42), the inverters are highly efficient, easy to install, proven technology. These costs may decrease significantly with increasing competition and improving technology. Consumers can have uninterrupted power on demand which can meet high peak loads. This option does not represent the heavy use of scarce materials required by battery storage. Additionally, the shared grid option represents the possibility of full utilization of all energy a wind plant is capable of producing.

SECTION V

ECONOMICS OF RESIDENTIAL WIND ENERGY GENERATION

Analysis Performed

The economics of wind energy systems is a paramont concern since the viability of wind generated energy depends strongly upon the final cost to the consumer. Unit energy costs in cents per kilowatt-hour (¢/kWh) depend upon the prorated system costs and useful energy delivered to the residence.

The following economic analysis models wind system performance in terms of energy delivered to residential loads. The costs of generating this energy are then considered. The analysis considers twenty-four sets of conditions, consisting of:

four variations of electric energy storage;

three different equipment life estimations; and

two residential use loads.

The four energy storage variations consist of three different sizes of lead-acid battery storage and the shared grid option to energy storage. Storage battery capacities are based on the recommendations of a wind systems distributor for the Windcharger, Dunlite and Elektro systems (40). Ratios of storage size to installed capacity and storage size to maximum monthly output for these systems were used as the basis for sizing the remaining storage capacities, which are tabulated in Appendix C. The "STOR 2" and "STOR 3" designations refer to options

having twice and three times the first storage capacity ("STOR 1"). The "STOR 0" designation refers to the shared network option where no storage is used.

Equipment lives of 10,15 and 20 years were assumed for the wind turbine, generator, gearing, blades and tower. The inverter for the shared network option was given a 20 year life (42). All remaining system components were given 10 year lives.

Residential Use Loads

The wind-electric energy delivered to a residential load depends upon the amount of overlap between two time varying functions, the wind energy supply and the residential consumption. The time variation in the wind energy supply is known from the three-hourly wind speed data. The time variation in residential electric use can be estimated by an average residential load function. Since data on Montana residential electric use was not readily available, the seasonal variation of the load function was based on the author's electric energy consumption during the period from July 1974 to June 1975. Daily variation in the load function was based on records of utility loads (43). Seasonal and daily variations in the residential load function are presented in Figures 66 and 67, respectively.

A low and a high residential use function (designated "LOAD 1" and "LOAD 2) were established, based on an average monthly use of

271 kWh and 650 kWh, respectively. Both functions follow the time variation of Figures 66 and 67 and are presented in Tables 35 and 36, respectively showing the daily and seasonal variation. Tabulated values are the kilowatt-hours of energy used in the indicated three hour period. Since average Montana residential electric use (44,45) is somewhere between 450 to 650 kWh monthly, the analysis based on these two functions is indicative of wind system performance for most residential electric users.

Wind System Performance with Residential Electric Loads

An upper limit of wind electric energy production, in terms of kWh/average month, is listed for various wind generators in Table 30. Wind system performance is evaluated in terms of the portion of the available energy from Table 30 which is used (Use Factor, UF) and in terms of the fraction of the residential electric load which is delivered (Load Factor, LF).

The Use Factor (UF) is the fraction of energy delivered to a residential load compared to the upper limit of energy the system could produce at a given location. For example, the upper limit on performance of the Aerowatt 4100 FP7 at Livingston is 1,597 kWh per average month (Table 30). If this system were able to deliver an

average of 650 kWh monthly to a residential load, its UF would be 0.41.

The magnitude of UF depends on the amount of overlap between the wind energy supply and the residential electric load. The residential load functions presented in Tables 35 and 36 were used in two computer programs with three-hourly wind speed data to model wind system performance at several locations. The two programs correspond to the independent systems and shared grid options. A block diagram displaying the logic of these programs is presented in Appendix D. The computer models used twenty-two wind systems at each location with the various storage options. A battery efficiency of 86.5 percent based on Golding's (7) findings was used and attenuation of d.c. power through inverters was accounted for. A loss of ten percent was used for the inverter in the shared network option (42).

In order to minimize the extensive computer time required to analyze all wind systems at ten locations, an estimation procedure was developed for determining Use Factors. The computer programs were executed for Missoula, Helena, Havre, Billings and Great Falls. Use Factors for twenty-two wind systems with all the different storage options and two load schedules were computed for these locations. These Use Factors were curve fitted as functions of system rated capacity using the least squares technique. The resulting functions are pre-

sented in Figures 68 and 69. Use Factors for Livingston, Glasgow, Kalispell and Bozeman were extrapolated or interpolated for the various parameters of storage size and residential load.

The parameters in Figures 68 and 69 are three annual mean wind speeds, four storage options and two load conditions. The lowest set of curves in both Figures represent the shared network option which has no storage capacity. The minimum near a 5 kW system size in the UF curves and the positive slopes at higher rated capacities is believed due to curve fitting procedures and scatter in the data, rather than the indication of a significant trend.

Several general trends can be identified in Figures 68 and 69. Use Factors increase with increasing load and storage capacity and decrease with increasing annual mean wind speed. For both load schedules, a significant increase is seen between the no storage condition and the first storage capacity. However, by doubling and tripling this storage capacity, only small increases in the UF are realized. Thus, increasing storage capacity is expected to increase energy costs since battery costs are directly related to storage capacity.

Performance can also be compared on the basis of the Load Factor (LF), which is the fraction of the residential load delivered by the wind system. This LF is not to be confused with the load factor of

electric utility companies. Values of LF for twenty-two wind systems were computed by the two computer programs previously mentioned for Missoula, Helena, Havre, Billings and Great Falls. LF for fourteen wind systems at these five locations are tabulated in Tables 37 through 40 for the independent systems and shared network options with two residential load schedules.

To clarify trends, LF values have been plotted in Figures 70 through 73 for selected wind systems. For all cases considered, LF increases with increasing annual mean wind speed, although there are large differences in magnitude between various wind systems. A comparison of the storage options with the shared network option (Figure 70 with 72 and Figure 71 with 73) shows that some energy storage capacity greatly increases the load delivered by the wind. However, by tripling the energy storage size (Figures 70 and 71) only small gains are realized in terms of useful energy delivered. LF also decreases with increasing use loads.

It was found that both LF and UF are insensitive to changes in the shape of the daily load function. Thus an exact determination of the shape of this function is not critical to this analysis.

The LF provides a measure of the residential load delivered by the wind energy system. Thus the fraction of the load not delivered (1-LF), is a measure of the inconvenience encountered with the indepen-

ent systems option. For example, by using the Windworks Twelve Footer for the "LOAD 1" load and the "STOR 1" battery storage capacity at Havre (Table 37), the LF is 0.574. This means that 43 percent of the "LOAD 1" load schedule is not met by this wind energy system so that the user would necessarily have to adjust to a portion of the time with no power and to a lower net energy use. The fraction of the load not delivered (1-LF) and the amount of time without power could be significantly reduced by a user who made some adjustments in his energy use schedule to coincide with windy periods.

The amount of inconvenience encountered with the independent systems option has the additional effect of decreasing battery life. In the computer model, each failure of the wind energy system to supply the residential load represents a deep cycle drain of the battery storage. In actual practice, it is likely that a user would prolong battery life by monitoring battery level and avoiding deep cycle draining. Thus the following estimates of battery deep cycling are intended primarily to display major trends in battery life.

The annual average number of deep cycles in a battery storage system are listed in Tables 41 and 42 for three locations with three different storage sizes. Lead-acid batteries can sustain approximately 1,500 deep cycles in the battery's lifetime (41), thus a ten year life would require less than 150 annual deep cycles, whereas a five year

life would allow up to 300 deep cycles annually. These values show that even for the low residential load schedule (Table 41) there are only a few combinations of location, storage size and wind system which allow a ten year lead-acid battery life. Trends reflected in Tables 41 and 42 show the number of deep cycles decreasing significantly with increasing annual mean wind speed and with increasing storage size. Thus, for a given wind system, a windier location will tend to increase battery life. Although increased storage size has little effect on improving load factors (Figures 70 and 71), larger storage sizes may be required to prolong battery life and reduce the inconvenience of a sporatic energy supply.

Even though a wind system with battery storage is monitored by the user, the fact remains that continuous electric power which most consumers are accustomed to is not always available for independent wind systems. The portion of time without power can be reduced by installing larger wind systems, increasing energy storage size or selecting locations with higher mean wind speeds. It is also possible to introduce another power source, such as a gasoline powered electric generator, into the system of Figure 65. This would increase first costs but would insure a continuous electric power supply. If the wind system were selected to minimize time without power, the backup generator would operate only a small portion of the time and would have low maintenance and operating costs. Such backup generators are discussed

in the literature (46,47).

Under the shared network option, the user's load is always supplied by a combination of two sources so that the inconvenience of the indpendent system option is avoided. The two electric energy sources are the utility company and the wind generator. The LF is simply the fraction of the total electric load supplied by the wind generator.

Once an investment has been made in a wind system, lowest energy costs are realized by using as much of the available wind generated energy as possible. For windy locations with wind systems larger than 2 kW installed capacity, there are significant portions of time during which the wind energy supplied exceeds the residential electric load. Improved utilization of this "lost" energy can be realized by altering the home use schedule to coincide with diurnal variations of the wind. Infrequent energy intensive activities could be performed during windy periods.

Another method of improving Use Factors would be to divert the "lost" energy into heat for domestic hot water and heating. Wind systems in conjunction with hot water heated homes would do well in locations such as Livingston and Great Falls where most of the wind energy is available during the winter months. This method could complement a solar home heating system, as discussed by Heronemus (48).

The total amount of energy which various wind generators are

capable of producing is tabulated on a monthly basis in Table 30. There are many small wind generators (less than 6 kW) which are capable of producing more than enough electric energy to supply the average Montana resident, although this analysis has shown that it is difficult to effectively utilize all the available energy. It must be emphasized that energy output depends very strongly on the annual mean wind speed. For example, in the low wind speed areas of Kalispell, Missoula and Bozeman, there are no wind systems under 6 kW which are capable of producing over 271 kWh monthly. By contrast, at Great Falls there are six wind generators with outputs over 650 kWh monthly and thirteen over 271 kWh monthly.

The Load Factors tabulated in Tables 37 and 38 for fourteen wind systems under 6 kW shows that for windy areas it is possible to supply over 200 kWh monthly to the low load schedule and well over 300 kWh monthly to the high load schedule. A flexible use schedule could significantly increase total wind energy utilization within the upper limits shown in Table 30.

This analysis clearly indicates that it is possible to meet residential electric requirements using wind-electric generating systems. The methods of energy use considered were systems independent of existing power networks and systems working as part of a power network. In both types of use it is possible to deliver more than one half of the residential load with wind generated energy at windy locations.

The amount of energy generated depends strongly on the annual mean wind speed at the site considered and points out the importance of on-location wind speed measurements. The areas displaying the required level of wind energy intensity to meet residential requirements are the eastern slopes of the Rocky Mountains and the eastern plains of Montana.

Wind Energy Costs

This economic analysis identifies major trends in the cost of wind-electric energy delivered to residential loads and is intended to be representative of costs encountered by residential users. Wind energy costs are computed by

$$COST = \left(\frac{AC}{SO \times UF} \right. \tag{13}$$

where COST is the cost of wind-electric energy delivered to the residence in cents per kilowatt-hour (¢/kWh), AC is the annual cost of the wind-electric system in cents per installed kW, SO is the annual specific output in kWh/kW and UF is the Use Factor.

Annual costs (AC) consist of three parts:

first costs of the complete wind-electric system prorated over the expected life of the equipment;

interest charges; and

maintenance costs.

Wind generator costs were available for the fourteen wind plants indicated by an asterisk in Table 27. Equipment costs are based on prices quoted between June 1974 and January 1975 and generally do not include shipping charges from the distributor.

Since first costs of wind systems are roughly equivalent to first costs of new automobiles, the same interest rates were used for this analysis. Interest rates of 7 percent "add-on", equivalent to approximately 13 percent per year on the unpaid balance, is common practice. Maintenance costs were taken as a fixed percent per year of the first cost and depend on type of use as well as durability of system components. These maintenance costs were taken as 1 percent for factory produced wind generators, 3 percent for partly owner assembled systems and 5 percent for home built systems.

An itemized listing of the equipment type, costs and size is presented for fourteen systems in Appendix E. Separate tables are presented for the independent system and shared network options. The Helion and Windworks system are home built from plans and the Sencenbaugh is user assembled. In these three cases the time for building and assembling is not considered in the system costs. The Jacobs Wind Electric has not been produced since 1957 but was included in the analysis because of its proven durability and the available

information on its performance, cost and maintenance. Estimated 1974 production costs (49) of this system are tabulated. All other systems listed are factory produced and are presently available to consumers. There are other wind generators presently on the market, but this analysis only includes those for which performance and cost information were readily available.

There are so many ways of assembling and financing a complete wind power system that it is impossible to account for all the variations in this analysis. For example, a wind power user may find it difficult to build or assemble a wind generator and blades but would prefer to reduce costs by assembling his own tower. A great deal of inexpensive used equipment, such as batteries and inverters, are also available. Auto loan financing is probably the most expensive way to finance such a project. Many users could reduce interest costs if they had adequate savings or could finance through government insured or home improvement loans. Cost figures are tabulated in Appendix E so that a wind power user can estimate costs for a particular situation.

Economic Trends in Residential Wind Energy Generation

Cost of wind-electric energy delivered to residential loads was determined for the twenty-four different combinations of parameters

which were previously described and are outlined in Table 43. For each set of parameters there is one corresponding table (Tables 44 to 67) listing the cost in ¢/kWh for each of fourteen wind systems at ten locations in Montana. Energy costs for Great Falls, Billings,Havre, Helena and Missoula were computed using the assumptions of this analysis. Energy costs for the remaining locations are estimates based on interpolated and extrapolated Use Factors.

To display trends in wind energy cost for various combinations of equipment life, load schedules and storage type, the values tabulated in Tables 44 through 67 have been plotted for the Windworks Twelve Footer. Wind energy costs for this home built system are shown as a function of annual mean wind speed for two load schedules in Figures 74 and 75. For all cases considered, wind energy costs decrease with increasing annual mean wind speed.

A comparison of Figures 74 and 75 shows that an increase in the load schedule decreases wind energy costs for all types of use. This is expected since the high load schedule (Load 2) tends to increase the UF. However, energy cost improvement due to increasing load schedule is small for all conditions except the shared grid option and the "STOR 3" option at high annual mean wind speeds.

For all cases, the 20 year equipment life resulted in lower energy costs than the 10 year life estimate. Cost improvement from

increased equipment life is large only for the shared grid option and in general such cost reductions are small compared to cost reductions resulting from changes in energy storage size.

By far the most important variables affecting wind energy costs are the annual mean wind speed and the type of storage method used. There are very large energy cost reductions between the shared grid (no storage) option and the "STOR 1" battery storage option, whereas the larger battery storage sizes increase energy costs.

It must be emphasized that energy cost values for the shared grid option and for the battery storage option are based on the cost of energy delivered to the residential load. Under the independent systems option the wind energy user may be subjected to the inconvenience of a sporatic electric power supply unless a backup generator is used. With this option, there is a substantial amount of available wind energy which is not used. On the other hand, full utilization of available wind energy may be possible under the shared network option. In this case, the fraction of energy not used in the residential load (1-UF) is used somewhere else in the power network. In a reasonable arrangement with a utility company, the wind power user would be paid for power delivered to the network. Thus, the cost of electric energy to the consumer under the shared network option depends on the cost of wind generated energy, the cost of utility energy and the rate paid by the utility for the excess generated wind energy.

For example, a sample calculation was carried out for a wind energy user under the shared network option at Great Falls. The Helion (#10), Windworks Twelve Footer (#12) and the Elektro WVG50G (#20) were considered for the low (LOAD 1) and high (LOAD 2) load schedules. The breakdown of monthly average energy distribution in kWh is shown in Table 68 for wind energy delivered to the load, utility energy to the load and wind energy to the network.

To arrive at energy cost figures, it was assumed that utility rates were the proposed 1976 electric rates of Figure 76 and that the consumer was paid a base rate of 2 ¢/kWh for energy delivered to the network. The utility rate schedule includes a monthly service charge. The elektro WVG50G was rated at a 20 year life and the Helion and Windworks Twelve Footer were given 10 year lives.

Electric energy costs for the three catagories of wind energy to the load, utility company energy to the load and wind energy to the network are presented in Table 69 in dollars per average month ($/mo). Column 4 lists the average monthly net payment to (or from) the utility. Costs of the same amount of energy from the utility with no wind system are compared in column 6. In all cases, there is a sizable cost savings in terms of payment to the utility company. This type of savings may be the primary concern of many wind energy users, however the wind user must make an investment (column 5) to realize this savings.

The ratio of wind system investment to utility cost savings is listed in column 7. A one-to-one ratio represents an economic break-even condition and higher ratios represent greater investment costs than savings.

An obvious conclusion based on Table 69 is that for the conditions described, wind energy costs more than utility company energy. It is important to recognize that these costs represent only the particular set of conditions described. For wind systems delivering a greater dollar value of energy to the network than is taken from the utility, wind energy costs will improve as utility rates increase.

In remote areas where utility power lines are not available or are too expensive to install, the cost of wind electric power must be compared with other methods of remote electric energy generation. Some of these methods include solar cells, thermoelectric devices and gasoline or diesel generators. For a residential scale of energy use in remote windy areas, wind-electric generation compares favorably with other methods. This was recognized by thousands of independent wind system users in the United States in the early part of the twentieth century (29). Cost comparisons for energy generation in remote areas are well documented in the literature, notably by Hutter (14) and Dodge (50,51).

Minimum attainable wind energy costs are of interest as a basis for comparison with costs obtained using the various parameters stated

above. Minimum costs were obtained by assuming full utilization of the energy which a wind generator was capable of producing in a given wind spectrum, i.e. UF = 1. These costs are tabulated for fourteen wind systems at ten locations in Tables 70 and 71. The values in Table 70 represent minimum attainable costs for systems independent of a power grid with the "STOR 1" battery storage size, whereas those of Table 71 are for the shared network option. In both cases a twenty year equipment life was assumed.

The minimum attainable wind energy costs presented in Figures 77 and 78 decrease sharply with increasing annual mean wind speeds, although there is a great deal of variation between wind systems. The independent system option has significantly lower minimum energy costs than the shared network option. With the independent system option, home built generators (Windworks and Helion) produce the cheapest energy. However, under the shared network option, the Elektro WVG50G produces comparable energy costs. This is because the shared network inverter (42) is very expensive compared to home-built system costs but represents a smaller fraction of the total investment in the 6 kW Elektro WVG50G.

It must be recognized that wind energy costs can also be reduced by decreasing the total monetary investment for the same net energy yield. A comparison of wind system component costs in Appendix E shows that for home-built wind systems, more than one half the first cost is for batteries or the shared grid inverter. This indicates that cost

reduction methods could be most effectively applied in the area of energy storage and distribution methods.

In light of the foregoing wind-electric energy costs it is instructive to compare utility company rates. Residential electric utility rates in ¢/kWh are plotted as a function of monthly electric energy use in Figure 76. The wide cross hatched cruve represents the United States average electric rate structure for the thirty year period from 1940 to 1970 (49). The next higher curve represents the same national average rate schedule for the year 1973 (49). This curve nearly coincides with the rate schedule of a large Montana utility company for 1975 (52). The remaining two curves are the requested rate schedules for two major Montana utilities to be in effect during 1976 (53). The highest curve in Figure 76 represents the proposed rate schedule of an eastern Montana utility (53). These costs clearly indicate a trend toward rapidly increasing residential electric rates from utility companies.

This cost analysis has shown that wind electric energy costs decrease rapidly with increasing annual mean wind speeds and vary between different wind generators and system configuration. Minimum attainable wind energy costs are identified for two major system configurations in Figures 77 and 78 for selected wind generators. A comparison of Figure 77 with Figure 76 shows that it is possible to generate wind-electric energy at lower cost than proposed utility

residential rates, although wind energy costs are generally higher than existing utility electric costs. It should be recognized that an investment in a reliable wind system will yield essentially fixed electric energy costs over the lifetime of the equipment. There is no guarantee that residential electric utility rates will stabilize during the same time period.

Figure 76 indicates a trend toward rising residential electric utility rates. Since the world's reserve of fossil fuels is finite, it is reasonable to expect that fossil fuel generated electric energy will continue to increase in cost relative to an inflating economy. On the other hand, the costs of wind generated electric energy are well established and are not expected to increase in cost relative to other products. For this reason, wind energy costs are expected to improve compared to fossil fuel energy costs.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

Wind is characterized by wide fluctuations in energy density, both temporarily and spacially. Wind records were available in Montana with a short enough time interval to analyze the annual, seasonal and daily variations in available energy. This time variation in the wind requires substantial investment in energy storage or power distribution methods as part of a total wind energy system.

Spatial variation in wind is difficult to predict on the basis of only thirteen measuring stations across the state of Montana. Despite this difficulty, existing wind speed records indicate the following:

1. Western and southwestern Montana regions are generally low wind areas and would not produce substantial amounts of wind-electric energy.
2. Winds blow consistently across the eastern plains of Montana where residential electric requirements can be met with wind energy conversion systems.
3. A high-wind belt exists along the eastern slopes of the Rocky Mountains in Montana where the cost of small scale generation of wind-electric power may be economically competitive with existing electric utility rates.

The economics of wind power generation are characterized by high initial investments which return electric energy over a relatively long

period of time. Wind energy costs decrease rapidly with increasing annual mean wind speed and depend strongly upon the energy storage method used. Increasing residential electric demand and increased equipment life are only small factors in decreasing wind energy costs.

Future work with wind energy in Montana should include a thorough investigation of energy requirements in each region of the state. This would provide information regarding the amount of energy required, source and type of fuel presently used and end use of each fuel. A wind siting analysis to measure available wind energy should be performed in selected areas to establish an accurate and reliable data base for the wind as an energy resource. Such reliable data would be useful in an estimation of the net energy capability of large and small wind energy conversion systems in Montana.

For example, Clark (1) indicates that, on a national average, 75 percent of residential energy has an end use in the form of heat for water or space heating. Perhaps it would be more cost effective to use wind energy for heating requirements than for electrical uses. Such a wind furnace concept is attractive in eastern slope areas where strongest winds are available during the time of highest space heating requirements.

Economic comparisons of energy systems should be performed on the basis of life cycles. For example, electric energy costs from a wind system should be totaled over the lifetime of the system and compared

with utility electric costs over the same period. This comparison was not performed because of the difficulty of predicting future utility prices.

TABLE 1. LOCATION AND SOURCE OF DATA

Identification	Location	Reference
Livingston	Livingston FAA Airport*	16
Cut Bank	Cut Bank FAA Airport	17
Great Falls	Great Falls WB Airport**	18
Billings	Billings WB Airport	18
Glasgow	Glasgow WB Airport	18
Miles City	Miles City FAA Airport	18
Havre	Havre WB Airport	18
Lewistown	Lewistown FAA Airport	17
Dillon	Dillon FAA Airport	17
Helena	Helena WB Airport	18
Kalispell	Kalispell WB Airport	18
Missoula	Missoula WB Airport	18
Bozeman	Belgrade FAA Airport	16

* FAA refers to Federal Aviation Agency

** WB refers to Weather Bureau

TABLE 2. ANNUAL MEAN TEMPERATURE AND AIR DENSITY

	Mean Annual Temperature °F	°C	Elevation Ft	M	Mean Annual Air Density gm/m^3
LIVINGSTON	44.2	6.78	4653	1418	1066
CUT BANK	40.5	4.72	3838	1170	1101
GREAT FALLS	44.9	7.17	3662	1116	1103
BILLINGS	46.3	7.94	3567	1087	1103
GLASGOW	41.5	5.28	2284	696	1166
MILES CITY	45.3	7.39	2629	801	1144
HAVRE	42.2	5.67	2584	788	1153
LEWISTOWN	41.9	5.50	4145	1263	1091
DILLON	42.5	5.83	5218	1590	1048
HELENA	43.2	6.22	3828	1167	1100
KALISPELL	41.8	5.44	2965	904	1138
MISSOULA	43.7	6.50	3190	972	1124
BOZEMAN	41.7	5.39	4451	1357	1079

TABLE 3. ANNUAL MEAN WIND SPEED

Location	Mean Annual Wind Speed mph	knots	m/sec	Time Interval
LIVINGSTON	14.1	12.2	6.3	hourly
CUT BANK	12.6	10.9	5.6	monthly
GREAT FALLS	12.4	10.8	5.5	3-hourly
BILLINGS	11.5	10.0	5.2	3-hourly
GLASGOW	11.0	9.6	4.9	3-hourly
MILES CITY	10.8	9.4	4.8	3-hourly
HAVRE	10.4	9.0	4.7	3-hourly
LEWISTOWN	10.1	8.7	4.4	monthly
DILLON	9.1	7.9	4.0	monthly
HELENA	7.9	6.8	3.5	3-hourly
KALISPELL	6.9	6.0	3.1	3-hourly
MISSOULA	6.5	5.6	2.9	3-hourly
BOZEMAN	6.4	5.5	2.9	hourly

TABLE 4. PERCENT TIME IN WIND SPEED RANGE

Location	Percent Time in Speed Range		
	0-3.3	3.4 - 10.5	> 10.6 m/s
	0-6	7 - 20	> 20 knots
LIVINGSTON	23.4	64.5	12.1
GREAT FALLS	25.6	67.1	7.3
BILLINGS	22.7	75.0	2.3
GLASGOW	30.5	66.4	3.1
MILES CITY	26.8	71.1	2.1
HAVRE	36.9	60.3	2.8
HELENA	56.7	42.1	1.2
KALISPELL	60.6	38.5	0.9
MISSOULA	69.5	30.1	0.4
BOZEMAN	64.6	34.9	0.5

TABLE 5. ANNUAL MEAN WIND SPEEDS, MOST FREQUENT SPEEDS, AND MAXIMUM WIND SPEEDS FOR TEN MONTANA LOCATIONS

	Annual Mean Wind Speed		Most Frequent Wind Speed		Maximum Wind Speed		Ratio Max
Location	mph	m/s	mph	m/s	mph	m/s	Average
LIVINGSTON	14.1	6.3	11.6	5.2	88	39.6*	6.2
GREAT FALLS	12.4	5.6	10.4	4.6	82	36.7	6.3
BILLINGS	11.5	5.1	9.3	4.2	79	35.3	6.9
GLASGOW	11.0	4.9	9.3	4.2	46	20.6	4.1
MILES CITY	10.8	4.8	9.3	4.2	n.a.	n.a.	n.a.
HAVRE	10.4	4.6	7.0	3.1	71	31.7	7.1
HELENA	7.9	3.5	3.5	1.5	73	32.6	9.2
KALISPELL	6.9	3.1	5.2	2.3	52	23.2	7.4
MISSOULA	6.5	2.9	3.5	1.5	72	32.2	11.8
BOZEMAN	6.4	2.8	5.8	2.6	66	30.4*	10.3

* Based on fastest recorded wind speed gust during the 4 year period 1970-1973. All other maximum speeds are based on maximum one minute gusts during the period 1941-1970

n.a. means not available

TABLE 6. ANNUAL MEAN POWER AND ENERGY DENSITY

Location	Annual Mean Power Density W/m^2	Average Monthly Energy Density* kWh/m^2
LIVINGSTON	305.9	223.5
GREAT FALLS	190.4	139.1
BILLINGS	124.9	91.2
GLASGOW	130.8	95.5
MILES CITY	117.5	85.5
HAVRE	121.5	88.8
HELENA	68.2	49.8
KALISPELL	54.5	39.8
MISSOULA	44.7	32.7
BOZEMAN	42.5	31.0

*Average Monthly Energy Density values are the product of the annual mean power density and 730.5 hours per month.

TABLE 7

ANNUAL VARIATION IN MEAN WIND SPEEDS COMPARED WITH ENVIRONMENTAL DATA SERVICE (EDS) THIRTY YEAR PERIOD

	EDS 30 yr mean mph	percent annual variation Δ_1%								study per. mean mph	Δ_2%
		1966	1967	1968	1969	1970	1971	1972	1973		
LIVINGSTON*						0.2	-0.3	4.1	-3.9	14.1	0.0
CUT BANK*		1.5	1.9	0.6	-9.6	-0.1	3.7	2.8	-0.9	12.6	0.0
GREAT FALLS	13.1				-19.8	-8.3	-1.2	1.1	0.7	12.4	-5.5
BILLINGS	11.4				-6.7	1.6	4.4	4.6	2.9	11.5	1.3
GLASGOW	11.1				0.4	0.5	2.2	-2.9	-3.0	11.0	-0.7
MILES CITY	10.0					5.1	10.7	9.1	8.5	10.8	8.4
HAVRE	10.0				2.8	4.5	5.2	5.8	2.1	10.4	4.1
LEWISTOWN*		4.9	10.7	0.8	-7.4	1.2	-1.1	-2.5	-6.5	10.1	0.0
DILLON*		2.5	1.3	-1.7	-13.4	0.5	4.2	6.6		9.1	0.0
HELENA	7.9				-8.2	-4.3	3.5	4.7	3.0	7.9	-0.3
KALISPELL	7.0						1.0	2.3	-7.9	6.9	-1.6
MISSOULA	6.1				-7.4			11.3	14.4	6.5	6.1
BOZEMAN*						-3.1	1.1	5.0	-2.8	6.4	0.0

* annual variation based on study period means

TABLE 8

GREAT FALLS MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	12.8	12.8	13.3	15.0	15.5	13.8	13.6	13.5
2	11.7	12.0	12.2	14.1	14.9	13.0	11.4	11.6
3	11.6	11.6	13.3	16.1	16.0	15.0	11.5	11.8
4	11.3	12.0	13.9	15.5	16.2	15.9	11.7	11.2
5	9.7	9.5	11.9	12.0	13.0	13.3	10.4	9.6
6	9.5	9.6	12.5	12.5	13.7	13.7	11.1	10.0
7	8.4	8.4	10.1	11.0	11.9	12.8	10.2	8.4
8	8.1	8.0	9.8	10.6	11.6	12.6	9.5	8.8
9	10.2	10.2	12.0	13.8	14.6	13.6	10.8	10.1
10	11.0	11.4	12.7	15.4	15.3	13.5	11.8	11.5
11	12.5	11.9	12.3	15.2	16.0	13.0	12.9	12.3
12	13.7	14.4	14.5	16.3	16.7	14.0	13.7	13.4
MEAN	10.9	11.0	12.4	13.9	14.6	13.7	11.6	11.0

TABLE 9

GREAT FALLS MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	257	252	290	387	427	316	324	296
2	182	176	202	324	366	211	146	156
3	158	137	206	360	380	296	148	143
4	117	145	235	338	373	343	125	107
5	66	70	144	155	207	229	97	66
6	71	73	178	189	237	245	110	72
7	49	45	84	123	166	210	79	42
8	38	40	82	120	148	171	64	51
9	87	88	150	227	283	207	100	92
10	119	135	189	307	317	209	132	134
11	191	165	192	364	373	227	213	172
12	285	295	295	399	430	280	270	245
MEAN	135	135	187	274	309	245	151	131

TABLE 10

BILLINGS MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	13.0	13.0	13.4	14.2	14.0	13.4	13.3	13.6
2	11.7	11.9	12.2	12.9	13.0	12.3	12.4	12.0
3	10.8	10.9	11.5	12.3	13.1	12.1	10.4	10.5
4	11.0	11.2	12.1	13.2	14.3	13.5	11.0	10.3
5	10.1	10.8	11.1	11.6	12.1	12.9	10.6	10.0
6	9.4	10.0	10.4	11.0	11.8	13.1	11.3	10.3
7	9.3	10.2	10.0	10.2	10.1	11.5	10.5	9.4
8	9.7	10.4	10.4	9.5	10.4	11.4	9.6	8.7
9	10.3	10.5	10.8	11.2	11.7	11.0	10.0	10.1
10	11.0	11.7	11.9	12.2	12.6	11.5	11.2	10.8
11	11.4	11.6	11.9	12.6	12.4	11.5	11.2	11.2
12	13.3	13.5	12.6	13.6	13.7	12.3	12.2	13.0
MEAN	10.9	11.3	11.5	12.0	12.4	12.2	11.1	10.8

TABLE 11

BILLINGS MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	183	177	190	237	239	194	211	216
2	135	144	145	176	195	160	151	146
3	99	95	117	152	190	135	83	95
4	110	132	144	207	247	227	104	79
5	67	91	99	131	131	166	90	80
6	61	72	90	106	135	169	117	85
7	54	67	67	76	80	114	108	60
8	68	74	72	58	78	120	64	49
9	72	82	87	123	133	107	71	70
10	104	113	123	155	159	118	121	95
11	130	133	137	172	158	136	120	120
12	175	196	170	206	233	142	137	181
MEAN	105	115	120	150	165	149	115	106

TABLE 12

GLASGOW MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	10.7	10.5	9.6	11.0	11.6	10.4	10.7	10.9
2	10.0	9.4	9.9	10.6	10.8	11.3	10.6	10.6
3	10.5	10.6	10.8	12.4	12.5	12.0	10.7	10.3
4	11.2	10.8	13.3	14.6	15.9	15.1	12.3	11.8
5	10.0	10.0	12.4	13.6	13.7	13.4	10.2	10.5
6	9.4	9.4	12.1	13.3	14.5	13.8	9.9	9.8
7	8.9	8.7	10.7	11.5	12.3	12.2	9.3	9.7
8	9.5	8.9	10.3	12.4	13.8	13.2	10.5	10.7
9	9.8	9.1	10.9	12.5	14.0	12.6	10.0	9.6
10	9.9	9.9	10.1	12.3	13.5	11.3	9.5	9.7
11	9.1	9.7	9.9	11.4	12.1	9.9	9.7	9.1
12	9.8	9.7	9.4	10.4	10.8	10.2	10.1	9.8
MEAN	9.9	9.7	10.8	12.2	13.0	12.1	10.3	10.2

TABLE 13

GLASGOW MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	128	142	116	142	168	124	137	140
2	108	110	120	136	133	167	127	112
3	104	113	132	192	198	177	121	100
4	125	123	217	274	328	282	169	149
5	99	93	172	203	233	212	103	109
6	82	72	151	183	248	225	100	95
7	66	66	121	140	175	164	91	89
8	75	57	94	169	219	194	98	88
9	101	74	124	175	232	183	98	86
10	103	96	111	178	200	149	82	85
11	82	95	106	161	200	99	99	82
12	97	103	94	134	139	109	117	91
MEAN	98	95	130	174	206	174	112	102

TABLE 14

MILES CITY MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	10.9	10.6	11.0	11.1	12.3	10.5	10.4	11.0
2	10.3	9.9	10.1	10.4	11.0	10.0	10.3	10.3
3	10.2	10.2	10.3	12.5	13.3	11.4	9.5	9.9
4	10.2	9.8	11.4	14.5	15.7	14.7	11.3	11.5
5	10.2	9.7	11.4	13.7	13.7	13.3	11.6	10.7
6	8.8	9.0	11.7	12.3	12.9	12.4	10.8	9.2
7	9.0	8.3	10.0	11.7	12.6	12.0	10.0	9.1
8	9.5	8.8	9.0	11.0	11.1	11.7	10.6	9.7
9	9.8	9.3	10.8	12.9	13.5	11.7	9.5	10.1
10	10.4	10.7	10.4	12.1	12.7	10.1	10.2	10.7
11	9.4	9.6	10.0	11.9	12.3	10.7	10.0	9.6
12	9.9	9.7	9.7	9.3	10.8	10.1	10.3	10.2
MEAN	9.9	9.6	10.5	12.0	12.7	11.6	10.4	10.2

TABLE 15

MILES CITY MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	140	126	117	135	186	95	103	146
2	93	92	97	108	113	93	103	107
3	96	101	98	183	210	138	90	87
4	98	77	128	226	300	287	157	156
5	90	76	129	202	207	195	149	95
6	72	78	142	155	165	154	118	75
7	110	47	92	121	171	150	98	75
8	72	60	58	114	113	152	96	69
9	81	68	120	178	239	163	77	87
10	96	129	106	180	183	94	102	107
11	82	94	100	172	174	116	89	81
12	84	92	90	83	126	87	94	90
MEAN	93	87	106	155	182	144	106	98

TABLE 16

HAVRE MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	10.4	10.7	10.3	11.7	12.4	11.1	10.7	11.0
2	9.6	9.3	9.6	10.5	11.0	10.4	9.5	9.7
3	9.3	9.1	9.7	13.1	13.5	11.9	9.9	9.1
4	9.2	10.3	11.8	14.2	15.3	14.2	11.1	10.2
5	8.6	8.8	11.6	11.9	13.2	12.7	10.8	9.2
6	9.1	8.9	12.0	13.6	13.7	13.8	10.4	9.3
7	7.4	7.6	10.0	11.2	12.7	12.5	9.5	7.5
8	6.9	6.7	9.5	10.6	11.3	11.8	8.8	8.0
9	8.4	8.6	9.9	12.1	13.2	12.1	8.8	8.4
10	8.5	8.6	9.2	12.2	13.1	10.8	8.9	9.3
11	8.7	9.4	9.4	11.5	12.6	9.2	8.5	9.2
12	9.2	9.8	9.8	11.1	11.5	9.8	9.1	9.3
MEAN	8.8	9.0	10.2	12.0	12.8	11.7	9.7	9.2

TABLE 17

HAVRE MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	140	152	144	187	192	165	154	159
2	115	93	99	165	153	131	106	111
3	86	88	106	199	219	166	99	90
4	88	117	150	296	313	263	134	109
5	68	72	146	156	219	183	124	82
6	68	77	151	222	229	222	103	74
7	43	51	99	136	167	167	87	42
8	57	34	89	118	138	150	87	62
9	63	64	99	160	207	150	64	68
10	65	67	91	174	208	119	70	88
11	81	91	90	161	200	90	79	118
12	101	119	112	149	156	98	97	115
MEAN	81	85	115	177	200	159	100	93

TABLE 18

HELENA MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	7.5	7.4	7.4	7.7	9.5	8.0	7.9	8.1
2	6.2	6.1	5.5	7.2	8.4	8.5	7.2	7.2
3	6.8	6.9	5.8	9.3	11.9	11.8	9.2	7.3
4	7.1	7.1	8.1	11.1	13.9	13.8	9.1	8.0
5	6.2	5.4	6.5	9.1	11.2	11.6	8.2	7.8
6	6.7	5.6	6.6	10.2	12.5	13.2	9.4	7.9
7	5.3	5.3	5.9	8.4	11.2	12.0	8.6	7.0
8	4.8	4.2	4.8	7.0	9.9	11.4	7.4	6.6
9	5.7	5.2	5.0	7.9	11.2	12.2	8.1	7.2
10	5.7	5.5	5.0	7.3	10.1	10.0	7.7	6.7
11	6.0	5.9	5.8	6.9	8.9	8.0	7.7	6.3
12	6.6	6.2	6.1	6.3	8.4	7.3	7.5	7.2
MEAN	6.2	5.9	6.1	8.2	10.6	10.7	8.2	7.3

TABLE 19

HELENA MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	71	70	71	87	120	67	75	85
2	51	50	38	74	102	94	51	61
3	38	46	36	104	160	147	79	49
4	53	52	84	144	242	199	66	65
5	30	27	43	90	143	132	48	41
6	34	32	46	108	175	169	74	49
7	16	20	29	62	133	141	66	37
8	16	11	24	44	97	130	42	37
9	28	26	21	68	137	160	48	40
10	24	26	23	70	119	96	52	36
11	37	47	29	62	95	67	56	40
12	54	43	46	51	103	45	53	56
MEAN	38	38	41	80	136	121	59	50

TABLE 20

KALISPELL MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	7.5	7.9	7.2	7.9	8.3	8.5	8.2	7.5
2	5.6	5.4	5.8	6.6	7.3	6.8	5.9	5.7
3	5.9	6.0	5.9	8.2	10.1	9.9	6.8	6.6
4	5.6	5.8	7.5	10.4	11.8	12.2	8.1	6.5
5	5.3	6.1	8.4	9.6	10.3	10.2	6.9	5.5
6	5.6	5.3	6.7	8.6	10.3	9.7	6.5	5.5
7	5.0	5.3	7.8	8.3	9.5	9.6	6.6	4.7
8	4.4	5.0	6.1	7.3	9.4	10.5	6.2	4.8
9	4.2	4.3	4.9	8.3	10.2	10.4	6.6	5.1
10	4.1	4.5	4.3	5.9	8.4	7.8	5.7	4.5
11	4.4	5.0	4.5	5.1	6.2	5.6	5.7	4.4
12	6.5	6.6	6.0	6.3	6.4	5.9	6.2	6.2
MEAN	5.3	5.6	6.3	7.7	9.0	8.9	6.6	5.6

TABLE 21

KALISPELL MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	125	143	112	119	118	108	100	107
2	45	39	42	52	69	53	38	44
3	32	30	31	52	86	74	47	51
4	31	32	47	120	133	150	65	42
5	23	37	57	75	102	96	36	21
6	24	23	34	56	99	85	25	24
7	22	29	52	58	72	141	30	23
8	15	25	27	37	72	85	31	19
9	24	17	21	58	105	90	36	36
10	26	35	36	42	70	59	35	25
11	29	37	35	37	43	36	48	33
12	69	74	65	68	55	46	48	78
MEAN	39	43	47	65	85	85	45	42

TABLE 22

MISSOULA MONTANA

DIURNAL VARIATION IN MEAN SPEED, BY MONTH
TIME OF DAY AM TO PM, SPEED IN MPH

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	6.3	7.1	6.4	6.8	7.8	6.7	6.7	6.7
2	4.6	4.2	3.9	4.4	4.8	4.9	4.7	4.9
3	5.1	4.5	4.2	6.3	7.6	9.2	7.6	5.8
4	5.8	5.5	5.4	9.0	11.4	13.1	8.8	6.3
5	5.5	4.7	4.7	7.1	9.5	11.6	9.7	5.9
6	5.0	4.4	5.2	7.7	9.5	11.5	9.3	6.1
7	4.4	4.0	4.8	6.2	10.0	12.8	10.0	5.9
8	4.9	3.3	3.7	5.7	8.3	12.5	10.1	6.3
9	5.0	5.1	5.0	6.7	8.9	10.0	7.6	5.2
10	5.2	4.7	4.2	6.1	7.6	8.2	5.7	5.1
11	5.0	4.2	4.3	5.2	6.6	6.8	4.5	5.0
12	5.0	5.6	4.8	5.1	5.4	5.5	5.1	5.7
MEAN	5.2	4.8	4.7	6.4	8.1	9.4	7.5	5.7

TABLE 23

MISSOULA MONTANA

DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH
TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ

MONTH	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
1	50	68	59	81	101	61	61	66
2	16	12	15	11	18	40	20	21
3	41	20	18	59	58	82	42	27
4	35	24	22	80	145	178	60	32
5	20	23	18	53	96	127	72	25
6	15	15	36	56	88	117	73	28
7	16	12	19	34	103	147	79	26
8	19	5	9	25	64	148	100	38
9	20	26	25	52	78	81	44	22
10	23	20	20	39	62	62	19	24
11	23	12	13	28	48	39	20	21
12	29	35	27	30	39	35	24	28
MEAN	26	23	23	46	75	93	51	30

TABLE 24. COEFFICIENTS AND EXPONENTS FOR THE PROBABILITY FUNCTION

$$F = aT^b$$

Location	Winds less than 6 knots		Winds less than 16 knots		Range of Valadity (hours) Winds less than 6 knots	Winds less than 16 knots
	a	b	a	b		
LIVINGSTON	0.079	-2.105	0.019	-1.26	1-22	1-50
GREAT FALLS	1.25	-2.28	0.00459	-1.09	3-60	3-150
BILLINGS	7.51	-3.17	0.0310	-1.043	3-39	3-150
GLASGOW	4.56	-2.75	0.0265	-0.944	3-50	3-150
MILES CITY	5.87	-2.95	0.0130	-0.737	3-40	3-150
HAVRE	3.36	-2.52	0.0240	-0.888	3-55	3-150
HELENA	1.12	-1.97	0.0173	-0.953	3-150	3-150
KALISPELL	0.797	-1.87			3-100	
MISSOULA	0.594	-1.78			3-100	
BOZEMAN	0.424	-2.40			1-50	

TABLE 25. TABULATION OF FIGURES AND TABLES AVAILABLE FOR EACH LOCATION

	A	B	C	D	E*	F*	G
LIVINGSTON	5	15	25				46
CUT BANK			26				
GREAT FALLS	6	16	27	38	8	9	47
BILLINGS	7	17	28	39	10	11	48
GLASGOW	8	18	29	40	12	13	49
MILES CITY	9	19	30	41	14	15	50
HAVRE	10	20	31	42	16	17	51
LEWISTOWN			32				
DILLON			33				
HELENA	11	21	34	43	18	19	52
KALISPELL	12	22	35	44	20	21	53
MISSOULA	13	23	36	45	22	23	54
BOZEMAN	14	24	37				55

Figure or Table

A. SPEED DURATION CURVE

B. POWER DURATION CURVE

C. SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY

D. DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY

E.* DIURNAL VARIATION IN MEAN SPEED, BY MONTH

F.* DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH

G. PROBABILITY OF OCCURANCE OF NO-ENERGY TIME SPAN

* Refers to Table numeration. All else are Figures.

TABLE 26. INCREASE IN POWER DENSITY WITH HEIGHT OVER FLAT OPEN COUNTRY

Height		% Increase in
Meters	Feet	Power Density
10	32.8	reference height
15.2	50.0	29
20.0	65.6	52
22.9	75.0	64
25.0	82.0	73
30.0	98.4	93
31.7	104.2	100
35.0	114.8	112
40	131.2	130
45	147.6	147
50	164	163

TABLE 27

TABULATION OF THIRTY WIND-ELECTRIC GENERATORS

		SYSTEM	DIAMETER	CAPACITY
1		AEROWATT 24 FP7	1.00	0.015
2	*	AEROWATT 150 FP7	2.00	0.100
3	*	WINDCHARGER	2.63	0.200
4		BUCKNELL		0.225
5	*	AEROWATT 300 FP7	3.20	0.275
6	*	SENCENBAUGH (AWES)	2.44	0.900
7	*	AEROWATT 1100 FP7	5.00	1.100
8	*	ELEKTRO WV 15G	3.00	1.200
9	*	KEDKO 1200	3.66	1.200
10	*	HELION 12 FTR	3.66	2.000
11	*	DUNLITE 2000	3.66	2.000
12	*	WINDWORKS (AWES)	3.66	2.000
13		DARIUS VERTICLE AXIS	3.66	2.000
14		WINDWORKS W JACOBS GEN.	3.66	3.000
15	*	JACOBS W.E. 3000	4.57	3.000
16		HELION 16 FTR	4.88	3.500
17	*	AEROWATT 4100 FP7	9.80	4.100
18		WINDWORKS POWR AT BLADES	3.66	4.500
19	*	ELEKTRO WV 35G	4.39	4.500
20	*	ELEKTRO WVG50G	5.00	6.000
21		HUTTER WE 10/G6	10.00	6.000
22		DANISH MILL	8.00	13.000
23		BRACE AIRSCREW	9.75	25.000
24		HUTTER-ALLGAIER LOW RANGE	35.00	90.000
25		HUTTER-ALLGAIER MID RANGE	35.00	90.000
26		HUTTER-ALLGAIER HI RANGE	35.00	90.000
27		GOULDING S 100 KW	18.29	100.000
28		ANDREAU-ENFIELD	24.00	100.000
29		THE GEDSER MILL	24.00	200.000
30		NASA 100 KW SYSTEM	37.80	100.000
31		HUTTER S 100 KW		100.000
32		PUTNAM REVISED DESIGN	53.34	1500.000

* ECONOMIC ANALYSIS AVAILABLE FOR THESE SYSTEMS
DIAMETER IN METRES ; CAPACITY IN KILOWATTS

TABLE 28

NUMERATION USED FOR LOCATIONS IN ENERGY OUTPUT TABLES

1	LIVINGSTON
2	GREAT FALLS
3	BILLINGS
4	GLASGOW
5	MILES CITY
6	HAVRE
7	HELENA
8	KALISPELL
9	MISSOULA
10	BOZEMAN

TABLE 29

MEAN POWER OUTPUT IN KW

READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLAS	MILC	HAVRE	HELNA	KAL	MSLA	BOZ	
1	.010	.010	.010	.010	.009	.009	.006	.005	.005	.005	1
2	.064	.059	.058	.057	.056	.052	.034	.031	.027	.027	2
3	.095	.078	.071	.070	.065	.065	.038	.033	.027	.024	3
4	.056	.045	.039	.039	.037	.036	.021	.018	.015	.014	4
5	.165	.155	.152	.150	.146	.140	.098	.089	.080	.078	5
6	.319	.250	.216	.219	.199	.204	.118	.096	.082	.076	6
7	.600	.501	.475	.465	.433	.428	.253	.222	.184	.167	7
8	.481	.373	.317	.322	.291	.300	.172	.140	.118	.108	8
9	.426	.323	.260	.269	.241	.250	.143	.114	.096	.089	9
10	.512	.372	.271	.287	.251	.266	.147	.115	.094	.085	10
11	.577	.416	.311	.329	.282	.307	.168	.129	.110	.092	11
12	.540	.396	.290	.309	.270	.284	.158	.125	.100	.090	12
13	1.570	1.067	.712	.765	.670	.707	.386	.299	.243	.224	13
14	.804	.584	.428	.453	.395	.418	.232	.181	.148	.133	14
15	1.251	.970	.833	.843	.764	.786	.450	.366	.309	.280	15
16	.900	.655	.480	.508	.445	.470	.261	.204	.167	.151	16
17	2.186	1.825	1.731	1.693	1.577	1.558	.923	.811	.670	.607	17
18	1.180	.868	.643	.681	.602	.632	.362	.286	.240	.223	18
19	1.239	.912	.686	.722	.638	.667	.374	.295	.241	.221	19
20	1.670	1.234	.939	.984	.874	.910	.513	.405	.333	.308	20
21	2.350	1.798	1.505	1.540	1.384	1.437	.823	.658	.564	.513	21
22	3.297	2.290	1.725	1.814	1.536	1.717	.930	.663	.614	.505	22
23	4.781	3.310	2.135	2.348	1.988	2.156	1.159	.882	.710	.629	23
24	30.778	23.128	20.482	20.515	18.375	19.205	11.062	8.708	7.691	6.368	24
25	38.046	29.498	25.519	25.745	23.188	23.958	13.670	11.191	9.444	8.328	25
26	44.300	36.810	33.954	33.546	31.640	31.050	18.660	15.954	13.326	12.986	26
27	18.165	11.692	6.484	7.570	6.124	7.142	3.629	2.299	1.986	1.788	27
28	9.987	5.895	2.577	3.167	2.562	2.924	1.418	.915	.704	.689	28
29	41.478	28.832	20.674	21.932	18.879	20.486	11.119	8.458	7.219	6.175	29
30	43.589	32.192	27.487	27.813	24.240	26.188	14.647	11.211	10.210	8.413	30
31	52.484	43.651	41.118	40.311	37.327	37.005	21.805	19.082	15.680	14.096	31
32	136.976	79.402	29.863	38.721	30.736	35.157	16.525	10.680	7.232	7.529	32

TABLE 30

MEAN MONTHLY ENERGY OUTPUT IN KWH

READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLAS	MIC	HAVRE	HELNA	KAL	MSLA	BOZ	
1	7	7	7	6	6	6	4	3	3	3	1
2	46	43	42	41	40	38	25	22	19	19	2
3	69	57	51	51	47	47	27	24	19	17	3
4	40	32	28	28	26	25	15	13	10	10	4
5	120	112	110	109	106	101	71	64	58	56	5
6	232	182	158	159	145	149	86	70	59	55	6
7	438	365	347	339	316	312	185	162	134	121	7
8	351	272	231	235	212	219	125	102	86	78	8
9	311	235	190	196	176	182	104	83	69	64	9
10	373	271	198	209	183	194	107	84	68	62	10
11	421	303	227	240	206	224	122	94	80	67	11
12	394	289	211	225	197	207	115	91	72	66	12
13	1147	779	520	558	489	516	282	218	177	163	13
14	587	426	312	330	288	305	169	132	108	97	14
15	913	708	608	615	558	573	328	267	225	204	15
16	657	478	350	371	324	343	190	149	121	110	16
17	1597	1332	1264	1237	1152	1138	674	592	489	443	17
18	861	634	469	497	439	461	264	208	175	163	18
19	905	666	501	527	466	487	273	215	176	161	19
20	1219	901	686	718	638	665	374	295	243	224	20
21	1716	1313	1099	1125	1010	1049	601	480	411	374	21
22	2408	1672	1260	1325	1122	1254	679	484	448	368	22
23	3492	2418	1559	1715	1452	1574	846	644	518	459	23
24	22483	16894	14962	14986	13422	14029	8080	6361	5617	4651	24
25	27792	21547	18641	18807	16938	17501	9986	8175	6898	6083	25
26	32361	26889	24803	24505	23113	22681	13630	11654	9734	9486	26
27	13269	8540	4736	5529	4473	5217	2650	1679	1451	1306	27
28	7295	4306	1882	2313	1871	2136	1036	668	513	503	28
29	30300	21061	15102	16021	13791	14964	8122	6178	5273	4510	29
30	31841	23516	20078	20317	17707	19130	10699	8189	7458	6145	30
31	38339	31886	30036	29447	27267	27032	15928	13939	11453	10296	31
32	100060	58003	21815	28286	22452	25682	12071	7801	5282	5499	32

TABLE 31

MEAN ANNUAL ENERGY OUTPUT IN KWH

READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLAS	MIC	HAV	HEL	KAL	MIS	BOZ	
1	91	85	84	83	81	76	51	46	39	40	1
2	559	517	510	499	487	458	301	275	232	233	2
3	834	684	623	617	572	566	332	288	234	213	3
4	487	392	342	341	321	311	185	161	128	124	4
5	1444	1355	1328	1317	1282	1223	854	778	697	682	5
6	2795	2189	1896	1916	1743	1788	1034	844	719	663	6
7	5259	4389	4164	4074	3794	3748	2220	1950	1611	1461	7
8	4219	3266	2778	2822	2552	2628	1511	1229	1037	946	8
9	3734	2827	2280	2358	2116	2195	1255	997	838	777	9
10	4487	3257	2377	2519	2203	2328	1292	1010	825	747	10
11	5053	3643	2727	2883	2472	2691	1475	1128	961	810	11
12	4736	3474	2543	2708	2367	2491	1387	1095	875	792	12
13	13764	9352	6241	6703	5872	6200	3385	2617	2131	1961	13
14	7047	5115	3749	3968	3464	3666	2030	1588	1297	1166	14
15	10963	8502	7298	7386	6700	6885	3945	3212	2705	2456	15
16	7892	5737	4210	4455	3897	4118	2284	1788	1460	1320	16
17	19166	15995	15174	14845	13824	13657	8090	7105	5871	5324	17
18	10339	7610	5636	5972	5274	5539	3174	2507	2105	1957	18
19	10862	7996	6013	6329	5595	5846	3280	2588	2116	1934	19
20	14636	10813	8235	8626	7664	7980	4497	3547	2923	2696	20
21	20603	15757	13193	13501	12127	12595	7217	5768	4940	4495	21
22	28905	20072	15121	15901	13467	15048	8148	5808	5381	4422	22
23	41909	29017	18716	20581	17430	18897	10156	7728	6220	5510	23
24	269802	202739	179546	179835	161074	168353	96967	76338	67415	55819	24
25	333513	258575	223696	225684	203265	210017	119834	98102	82782	73002	25
26	388335	322672	297637	294060	277359	272183	163571	139853	116811	113836	26
27	159233	102489	56837	66355	53684	62604	31810	20154	17412	15676	27
28	87542	51679	22586	27759	22458	25632	12432	8024	6167	6036	28
29	363600	252738	181231	192259	165495	179578	97473	74143	63282	54127	29
30	382101	282196	240946	243804	212486	229564	128394	98271	89498	73748	30
31	460074	382643	360438	353369	327207	324385	191142	167272	137447	123563	31
32	######	696039	261781	339432	269434	308184	144856	93616	63392	65997	32

TABLE 32

PERCENT SPECIFIC OUTPUT

KW MEAN OUTPUT / KW INSTALLED CAPACITY, PERCENT
READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLA	MIC	HAVR	HELN	KAL	MSLA	BOZ	
1	69.6	65.2	64.6	63.4	62.1	58.3	38.9	35.6	30.4	31.1	1
2	63.8	59.0	58.2	56.9	55.6	52.3	34.4	31.4	26.5	26.7	2
3	47.6	39.1	35.5	35.2	32.6	32.3	19.0	16.5	13.4	12.2	3
4	24.7	19.9	17.4	17.3	16.3	15.8	9.4	8.2	6.5	6.3	4
5	59.9	56.2	55.1	54.6	53.2	50.7	35.5	32.3	28.9	28.3	5
6	35.4	27.7	24.0	24.3	22.1	22.7	13.1	10.7	9.1	8.4	6
7	54.5	45.5	43.2	42.3	39.4	38.9	23.0	20.2	16.7	15.2	7
8	40.1	31.1	26.4	26.8	24.3	25.0	14.4	11.7	9.9	9.0	8
9	35.5	26.9	21.7	22.4	20.1	20.9	11.9	9.5	8.0	7.4	9
10	25.6	18.6	13.6	14.4	12.6	13.3	7.4	5.8	4.7	4.3	10
11	28.8	20.8	15.6	16.4	14.1	15.4	8.4	6.4	5.5	4.6	11
12	27.0	19.8	14.5	15.4	13.5	14.2	7.9	6.3	5.0	4.5	12
13	78.5	53.3	35.6	38.2	33.5	35.4	19.3	14.9	12.2	11.2	13
14	26.8	19.5	14.3	15.1	13.2	13.9	7.7	6.0	4.9	4.4	14
15	41.7	32.3	27.8	28.1	25.5	26.2	15.0	12.2	10.3	9.3	15
16	25.7	18.7	13.7	14.5	12.7	13.4	7.4	5.8	4.8	4.3	16
17	53.3	44.5	42.2	41.3	38.5	38.0	22.5	19.8	16.3	14.8	17
18	26.2	19.3	14.3	15.1	13.4	14.0	8.0	6.4	5.3	5.0	18
19	27.5	20.3	15.2	16.0	14.2	14.8	8.3	6.6	5.4	4.9	19
20	27.8	20.6	15.7	16.4	14.6	15.2	8.6	6.7	5.6	5.1	20
21	39.2	30.0	25.1	25.7	23.1	24.0	13.7	11.0	9.4	8.5	21
22	27.5	19.1	14.4	15.1	12.8	14.3	7.7	5.5	5.1	4.2	22
23	19.1	13.2	8.5	9.4	8.0	8.6	4.6	3.5	2.8	2.5	23
24	34.2	25.7	22.8	22.8	20.4	21.3	12.3	9.7	8.5	7.1	24
25	42.3	32.8	28.4	28.6	25.8	26.6	15.2	12.4	10.5	9.3	25
26	49.2	40.9	37.7	37.3	35.2	34.5	20.7	17.7	14.8	14.4	26
27	18.2	11.7	6.5	7.6	6.1	7.1	3.6	2.3	2.0	1.8	27
28	10.0	5.9	2.6	3.2	2.6	2.9	1.4	.9	.7	.7	28
29	20.7	14.4	10.3	11.0	9.4	10.2	5.6	4.2	3.6	3.1	29
30	43.6	32.2	27.5	27.8	24.2	26.2	14.6	11.2	10.2	8.4	30
31	52.5	43.7	41.1	40.3	37.3	37.0	21.8	19.1	15.7	14.1	31
32	9.1	5.3	2.0	2.6	2.0	2.3	1.1	.7	.5	.5	32

TABLE 33

SPECIFIC ENERGY OUTPUT IN KWH/ANNUM/KW

READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLA	MIC	HAVR	HELN	KAL	MSLA	BCZ	
1	6103	5711	5664	5555	5443	5109	3412	3122	2662	2728	1
2	5596	5172	5105	4990	4870	4580	3012	2755	2324	2338	2
3	4174	3423	3115	3088	2860	2832	1662	1442	1171	1069	3
4	2167	1744	1522	1517	1429	1386	823	718	571	554	4
5	5252	4928	4832	4789	4665	4447	3108	2830	2536	2482	5
6	3106	2432	2107	2129	1937	1987	1149	938	799	737	6
7	4781	3990	3786	3703	3449	3407	2018	1772	1465	1328	7
8	3516	2722	2315	2352	2127	2190	1259	1024	864	788	8
9	3112	2356	1900	1965	1763	1829	1045	831	698	648	9
10	2243	1628	1188	1259	1101	1164	646	505	412	373	10
11	2526	1821	1363	1441	1236	1345	737	564	480	405	11
12	2368	1737	1271	1354	1183	1245	693	547	437	396	12
13	6882	4676	3120	3351	2936	3100	1692	1308	1065	980	13
14	2349	1705	1249	1322	1154	1222	676	529	432	388	14
15	3654	2834	2432	2462	2233	2295	1315	1070	901	818	15
16	2255	1639	1203	1273	1113	1176	652	510	417	377	16
17	4674	3901	3700	3620	3371	3331	1973	1732	1432	1298	17
18	2297	1691	1252	1327	1172	1231	705	557	467	435	18
19	2413	1777	1336	1406	1243	1299	729	575	470	429	19
20	2439	1802	1372	1437	1277	1330	749	591	487	449	20
21	3433	2626	2198	2250	2021	2099	1202	961	823	749	21
22	2408	1672	1260	1325	1122	1254	679	484	448	368	22
23	1676	1160	748	823	697	755	406	309	248	220	23
24	2997	2252	1994	1998	1789	1870	1077	848	749	620	24
25	3705	2873	2485	2507	2258	2333	1331	1090	919	811	25
26	4314	3585	3307	3267	3081	3024	1817	1553	1297	1264	26
27	1592	1024	568	663	536	626	318	201	174	156	27
28	875	516	225	277	224	256	124	80	61	60	28
29	1818	1263	906	961	827	897	487	370	316	270	29
30	3821	2821	2409	2438	2124	2295	1283	982	894	737	30
31	4600	3826	3604	3533	3272	3243	1911	1672	1374	1235	31
32	800	464	174	226	179	205	96	62	42	43	32

TABLE 34

MEAN MONTHLY ENERGY OUTPUT PER UNIT AREA

KWH/MONTH-M2
READ TEN LOCATIONS ACROSS IN COLUMNS
READ THIRTY-TWO WIND SYSTEMS DOWN BY ROW

	LIV	G.F.	BILL	GLA	MIC	HAVR	HELN	KAL	MSLA	BOZ	
1	9.7	9.0	9.0	8.8	8.6	8.1	5.4	4.9	4.2	4.3	1
2	14.9	13.7	13.5	13.2	12.9	12.2	8.0	7.3	6.2	6.2	2
3	26.5	21.7	19.7	19.6	18.1	17.9	10.5	9.1	7.4	6.8	3
4											4
5	15.0	14.0	13.8	13.7	13.3	12.7	8.9	8.1	7.2	7.1	5
6	49.9	39.1	33.8	34.2	31.1	31.9	18.5	15.1	12.8	11.8	6
7	22.3	18.6	17.7	17.3	16.1	15.9	9.4	8.3	6.8	6.2	7
8	49.8	38.6	32.8	33.3	30.1	31.0	17.8	14.5	12.2	11.2	8
9	29.6	22.4	18.1	18.7	16.8	17.4	10.0	7.9	6.7	6.2	9
10	35.6	25.8	18.9	20.0	17.5	18.5	10.2	8.0	6.5	5.9	10
11	40.1	28.9	21.6	22.9	19.6	21.3	11.7	9.0	7.6	6.4	11
12	37.6	27.5	20.2	21.5	18.8	19.8	11.0	8.7	6.9	6.3	12
13	69.9	47.5	31.7	34.0	29.8	31.5	17.2	13.3	10.8	10.0	13
14	55.9	40.6	29.7	31.5	27.5	29.1	16.1	12.6	10.3	9.3	14
15	55.6	43.2	37.0	37.5	34.0	34.9	20.0	16.3	13.7	12.5	15
16	35.2	25.6	18.8	19.9	17.4	18.4	10.2	8.0	6.5	5.9	16
17	21.2	17.7	16.8	16.4	15.3	15.1	8.9	7.8	6.5	5.9	17
18	82.0	60.3	44.7	47.4	41.8	43.9	25.2	19.9	16.7	15.5	18
19	59.7	43.9	33.0	34.8	30.7	32.1	18.0	14.2	11.6	10.6	19
20	62.0	45.8	34.9	36.6	32.5	33.8	19.1	15.0	12.4	11.4	20
21	21.9	16.7	14.0	14.3	12.9	13.4	7.7	6.1	5.2	4.8	21
22	47.9	33.3	25.1	26.4	22.3	24.9	13.5	9.6	8.9	7.3	22
23	46.8	32.4	20.9	23.0	19.5	21.1	11.3	8.6	6.9	6.2	23
24	23.4	17.6	15.6	15.6	14.0	14.6	8.4	6.6	5.8	4.8	24
25	28.9	22.4	19.4	19.5	17.6	18.2	10.4	8.5	7.2	6.3	25
26	33.6	27.9	25.8	25.5	24.0	23.6	14.2	12.1	10.1	9.9	26
27	50.5	32.5	18.0	21.1	17.0	19.9	10.1	6.4	5.5	5.0	27
28	16.1	9.5	4.2	5.1	4.1	4.7	2.3	1.5	1.1	1.1	28
29	67.0	46.6	33.4	35.4	30.5	33.1	18.0	13.7	11.7	10.0	29
30	28.4	21.0	17.9	18.1	15.8	17.1	9.5	7.3	6.6	5.5	30
31											31
32	44.8	26.0	9.8	12.7	10.0	11.5	5.4	3.5	2.4	2.5	32

TABLE 35. "LOAD 1" - DISTRIBUTION OF ENERGY USE FOR AUTHOR'S FAMILY OF FOUR

time of day	% of daily load	kWh of Energy in 3-Hour Period JAN FEB	MAR APR	MAY JUN	JUL AUG	SEP OCT	NOV DEC
MN-3	3	0.361	0.282	0.182	0.187	0.287	0.305
3-6	6	0.722	0.564	0.365	0.375	0.574	0.610
6-9	25	3.008	2.351	1.521	1.562	2.392	2.540
9-12	12½	1.504	1.175	0.760	0.781	1.196	1.270
MD-3	6	0.722	0.564	0.365	0.375	0.574	0.610
3-6	20	2.407	1.881	1.216	1.249	1.913	2.032
6-9	15	1.805	1.410	0.912	0.937	1.435	1.524
9-12	12½	1.504	1.175	0.760	0.781	1.196	1.270

TABLE 36. "LOAD 2" - DISTRIBUTION OF ENERGY USE FOR AVERAGE MONTANA RESIDENT

time of day	% of daily load	kWh of Energy in 3-Hour Period JAN FEB	MAR APR	MAY JUN	JUL AUG	SEP OCT	NOV DEC
MN-3	3	0.865	0.673	0.436	0.448	0.686	0.730
3-6	6	1.730	1.345	0.871	0.897	1.317	1.461
6-9	25	7.207	5.606	3.630	3.737	5.713	6.086
9-12	12½	3.604	2.803	1.815	1.869	2.856	3.043
MD-3	6	1.730	1.345	0.871	0.897	1.371	1.461
3-6	20	5.766	4.485	2.904	2.990	4.570	4.869
6-9	15	4.324	3.363	2.178	2.242	3.428	3.652
9-12	12½	3.640	2.803	1.815	1.869	2.856	3.043

TABLE 37. LOAD FACTORS FOR INDEPENDENT SYSTEMS OPTION WITH "LOAD 1" AND "STOR 1" STORAGE SIZE

System #	Missoula	Helena	Havre	Billings	Great Falls
2	0.067	0.086	0.131	0.146	0.148
3	0.067	0.095	0.162	0.178	0.196
5	0.199	0.244	0.347	0.377	0.384
6	0.201	0.285	0.482	0.521	0.584
7	0.382	0.513	0.736	0.825	0.804
8	0.280	0.394	0.621	0.680	0.712
9	0.231	0.337	0.557	0.597	0.663
10	0.225	0.342	0.567	0.602	0.680
11	0.254	0.372	0.595	0.630	0.685
12	0.236	0.357	0.574	0.617	0.684
15	0.593	0.780	0.952	0.976	0.958
17	0.762	0.901	0.990	0.995	0.981
19	0.524	0.726	0.933	0.964	0.957
20	0.626	0.821	0.973	0.982	0.972

TABLE 38. LOAD FACTORS FOR INDEPENDENT SYSTEMS OPTION WITH "LOAD 2" AND "STOR 1" STORAGE SIZE

System #	Missoula	Helena	Havre	Billings	Great Falls
2	0.028	0.036	0.055	0.061	0.062
3	0.028	0.040	0.068	0.075	0.082
5	0.084	0.103	0.146	0.159	0.162
6	0.086	0.123	0.211	0.225	0.259
7	0.188	0.258	0.428	0.482	0.505
8	0.123	0.177	0.306	0.326	0.381
9	0.100	0.148	0.257	0.269	0.331
10	0.098	0.151	0.269	0.278	0.370
11	0.113	0.171	0.305	0.315	0.403
12	0.103	0.162	0.284	0.295	0.386
15	0.305	0.432	0.684	0.745	0.774
17	0.526	0.687	0.893	0.948	0.918
19	0.242	0.366	0.607	0.644	0.724
20	0.325	0.476	0.728	0.784	0.815

TABLE 39. LOAD FACTORS FOR SHARED NETWORK OPTION WITH "LOAD 1"

SYSTEM #	Missoula	Helena	Havre	Billings	Great Falls
2	0.064	0.083	0.126	0.141	0.143
3	0.064	0.090	0.152	0.168	0.184
5	0.185	0.225	0.314	0.343	0.349
6	0.154	0.214	0.349	0.396	0.433
7	0.232	0.324	0.501	0.600	0.611
8	0.185	0.256	0.411	0.479	0.510
9	0.163	0.226	0.368	0.421	0.461
10	0.149	0.210	0.350	0.403	0.445
11	0.148	0.208	0.350	0.402	0.446
12	0.155	0.219	0.362	0.419	0.460
15	0.254	0.361	0.546	0.664	0.663
17	0.319	0.441	0.640	0.779	0.754
19	0.230	0.324	0.501	0.604	0.615
20	0.257	0.365	0.550	0.670	0.668

TABLE 40. LOAD FACTORS FOR THE SHARED NETWORK OPTION WITH "LOAD 2"

SYSTEM #	Missoula	Helena	Havre	Billings	Great Falls
2	0.027	0.035	0.053	0.059	0.060
3	0.027	0.039	0.066	0.072	0.079
5	0.081	0.099	0.141	0.154	0.157
6	0.079	0.112	0.189	0.205	0.232
7	0.154	0.211	0.343	0.390	0.410
8	0.106	0.150	0.254	0.279	0.317
9	0.088	0.127	0.217	0.235	0.277
10	0.083	0.123	0.214	0.231	0.285
11	0.092	0.133	0.234	0.253	0.307
12	0.087	0.129	0.223	0.243	0.298
15	0.189	0.265	0.424	0.500	0.528
17	0.260	0.364	0.550	0.665	0.665
19	0.159	0.224	0.369	0.425	0.465
20	0.190	0.266	0.426	0.501	0.529

TABLE 41. ANNUAL NUMBER OF DEEP CYCLES IN A STORAGE SYSTEM FOR AUTHOR's LOAD SCHEDULE

System#	STOR 1			STOR 2			STOR 3		
	MSLA	HAVR	GF	MSLA	HAVR	GF	MSLA	HAVR	GF
2	2911	2878	2887	2911	2878	2887	2910	2878	2887
3	2871	2751	2726	2871	2751	2725	2871	2750	2725
5	2725	2400	2309	2724	2399	2308	2723	2398	2308
6	2512	1736	1504	2510	1697	1447	2509	1690	1433
7	1856	850	659	1754	624	451	1714	520	353
8	2223	1235	1023	2209	1078	833	2207	1007	732
9	2409	1472	1213	2405	1368	1052	2403	1330	973
10	2388	1394	1118	2382	1266	909	2378	1212	806
11	2242	1253	1049	2223	1074	831	2220	981	706
12	2351	1375	1109	2338	1211	889	2335	1129	771
15	1095	133	110	972	44	47	924	20	35
17	615	26	48	471	3	24	385	0	17
19	1336	190	113	1259	76	49	1229	32	35
20	983	71	71	880	22	35	825	6	24

TABLE 42. ANNUAL NUMBER OF DEEP CYCLES IN A STORAGE SYSTEM FOR AVERAGE MONTANA RESIDENTIAL USE LOAD

SYS-TEM#	STOR 1			STOR 2			STOR 3		
	MSLA	HAVR	GF	MSLA	HAVR	GF	MSLA	HAVR	GF
2	2922	2921	2921	2922	2921	2921	2922	2921	2921
3	2922	2915	2918	2922	2915	2918	2922	2915	2918
5	2909	2868	2862	2909	2868	2862	2908	2868	2862
6	2831	2625	2559	2831	2625	2558	2830	2624	2624
7	2554	1998	1937	2553	1975	1920	2553	1964	1913
8	2741	2351	2246	2741	2343	2243	2740	2343	2242
9	2806	2494	2383	2805	2493	2382	2804	2492	2382
10	2791	2414	2189	2790	2404	2168	2788	2404	2166
11	2724	2267	2047	2723	2247	1998	2722	2241	1985
12	2773	2366	2135	2772	2346	2093	2772	2343	2082
15	2109	996	771	2098	848	587	2095	805	487
17	1341	318	234	1185	169	130	1123	96	85
19	2339	1267	969	2332	1140	776	2329	1095	671
20	2041	841	619	2025	665	420	2019	593	318

TABLE 43

DESCRIPTION OF ECONOMIC PARAMETERS

THE FOLLOWING 24 PAGES OF OUTPUT
GIVE THE COSTS IN CENTS PER KWH
OF ENERGY DELIVERED TO A RESIDENTIAL LOAD
BASED ON 1974 U.S. DOLLARS
FOR EACH OF 14 SYSTEMS AT 10 LOCATIONS.

THE CONDITIONS ARE LISTED AS FOLLOWS:

1 & 13	LOAD 1	STOR 1	LIFE 20
2 & 14	LOAD 1	STOR 1	LIFE 15
3 & 15	LOAD 1	STOR 1	LIFE 10
4 & 16	LOAD 1	STOR 2	LIFE 20
5 & 17	LOAD 1	STOR 2	LIFE 15
6 & 18	LOAD 1	STOR 2	LIFE 10
7 & 19	LOAD 1	STOR 3	LIFE 20
8 & 20	LOAD 1	STOR 3	LIFE 15
9 & 21	LOAD 1	STOR 3	LIFE 10
10 & 22	LOAD 1	STOR 0	LIFE 20
11 & 23	LOAD 1	STOR 0	LIFE 15
12 & 24	LOAD 1	STOR 0	LIFE 10

REPEAT AGAIN FOR LOAD 2 TO OBTAIN CONDITIONS 13-24

THE VARIABLES ARE:
LOAD 1: LOAD SCHEDULE FOR ALTHOR S FAMILY OF FOUR
LOAD 2: LOAD SCHEDULE FOR AVERAGE MONTANA RESIDENT
STOR 1: STORAGE CAPACITY AS IN APPENDIX B
STOR 2: STORAGE CAPACITY TWICE STOR 1
STOR 3: STORAGE CAPACITY 3 TIMES STOR 1
STOR 0: NO STORAGE, SHARED GRID SYSTEM USING
THE 8 KW INVERTER AVAILABLE FROM WINDWORKS
LIFE 20: 20 YEAR LIFE ON SYSTEM AND TOWER, 10 ON REST
LIFE 15: 15 YEAR LIFE ON SYSTEM AND TOWER, 10 ON REST
LIFE 10: 10 YEAR LIFE ON ALL COMPONENTS
EXCEPTION: 20 YR LIFE ON 8 KW INVERTER FOR ALL CONDITIONS

TABLE 44

ECONOMIC SECTION: CONDITION # 1

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	54•5	59•0	59•7	61•1	62•6	66•6	101•1	110•4	130•9	130•1	2
3	6•2	7•5	8•3	8•3	9•0	9•1	15•5	17•8	21•9	24•0	3
5	22•3	23•7	24•2	24•4	25•1	26•3	37•2	41•1	45•8	46•8	5
6	6•0	7•5	8•4	8•4	9•3	9•1	14•9	18•6	21•9	23•7	6
7	26•9	31•2	30•4	31•2	33•6	34•1	41•0	54•3	65•7	72•5	7
8	6•9	8•9	9•3	9•3	10•5	10•2	18•1	19•1	22•6	24•8	8
9	5•4	7•0	7•8	7•7	8•7	8•4	14•3	17•1	20•3	21•9	9
10	3•7	5•0	5•6	5•4	6•3	6•0	9•7	12•3	15•1	16•7	10
11	12•4	15•5	16•8	16•3	19•4	17•8	27•1	35•6	41•9	49•7	11
12	3•5	4•5	5•0	4•8	5•6	5•3	8•8	10•4	13•1	14•4	12
15	21•9	19•3	18•9	18•4	19•9	19•4	23•7	26•2	31•1	34•3	15
17	58•6	60•0	59•1	57•4	58•8	59•5	65•4	63•8	77•2	85•2	17
19	22•5	22•8	22•6	21•5	24•4	23•3	30•0	34•1	41•7	45•7	19
20	32•1	34•2	33•9	32•0	35•6	34•2	40•6	43•9	53•3	57•8	20

TABLE 45

ECONOMIC SECTION: CONDITION # 2

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BCZ	
2	65•6	71•0	71•9	73•5	75•4	80•1	121•7	132•9	157•6	156•6	2
3	7•6	9•2	10•2	10•3	11•1	11•2	19•0	21•9	26•9	29•5	3
5	28•7	30•6	31•1	31•4	32•3	33•9	47•9	52•9	59•0	60•3	5
6	7•2	9•1	10•2	10•2	11•3	11•0	18•0	22•5	26•4	28•7	6
7	32•4	37•6	36•6	37•6	40•5	41•0	49•4	65•4	79•2	87•3	7
8	8•6	10•9	11•4	11•4	12•9	12•5	22•3	23•6	27•9	30•6	8
9	6•5	8•4	9•4	9•2	10•4	10•0	17•1	20•4	24•2	26•1	9
10	4•0	5•4	6•1	5•9	6•9	6•5	10•6	13•5	16•5	18•2	10
11	15•1	18•8	20•5	19•8	23•6	21•7	33•0	43•4	51•0	60•5	11
12	3•7	4•8	5•3	5•1	6•0	5•7	9•4	11•1	14•0	15•4	12
15	23•8	21•0	20•6	20•1	21•7	21•1	25•8	28•6	33•9	37•4	15
17	70•0	71•6	70•5	68•6	70•2	71•0	78•1	76•2	92•2	101•7	17
19	25•3	25•6	25•5	24•2	27•5	26•3	33•9	38•5	47•1	51•5	19
20	35•1	37•4	37•0	34•9	38•9	37•3	44•3	47•9	58•2	63•1	20

TABLE 46

ECONOMIC SECTION: CONDITION # 3

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	87•7	94•9	96•2	98•4	100•8	107•2	162•8	177•8	210•8	209•5	2
3	10•4	12•7	13•9	14•1	15•2	15•4	26•1	30•0	37•0	40•5	3
5	41•5	44•2	45•1	45•5	46•7	49•0	69•3	76•6	85•5	87•3	5
6	9•7	12•2	13•7	13•7	15•2	14•8	24•2	30•3	35•6	38•6	6
7	33•0	50•3	49•1	50•4	54•3	55•0	66•1	87•7	106•1	116•9	7
8	11•8	15•1	15•8	15•8	17•8	17•3	30•7	32•5	38•4	42•2	8
9	8•6	11•2	12•4	12•2	13•8	13•3	22•6	27•1	32•2	34•7	9
10	4•7	6•3	7•2	6•9	8•0	7•6	12•4	15•7	19•2	21•3	10
11	20•5	25•6	27•9	26•9	32•1	29•5	44•9	59•0	69•3	82•2	11
12	4•2	5•4	6•0	5•8	6•8	6•4	10•6	12•6	15•7	17•4	12
15	27•8	24•4	24•0	23•4	25•3	24•6	30•1	33•3	39•6	43•6	15
17	92•7	94•9	93•5	90•9	93•0	94•1	103•5	101•0	122•2	134•8	17
19	31•0	31•4	31•3	29•7	33•7	32•2	41•5	47•2	57•7	63•1	19
20	40•9	43•6	43•2	40•7	45•4	43•6	51•8	56•0	67•9	73•6	20

TABLE 47

ECONOMIC SECTION: CONDITION # 4

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	57•3	62•0	62•8	64•3	65•9	70•0	106•4	115•8	137•3	136•4	2
3	8•0	9•7	10•7	10•8	11•6	11•8	20•0	22•9	28•2	30•9	3
5	24•3	25•9	26•5	26•7	27•4	28•7	41•0	44•9	50•1	51•2	5
6	7•4	9•3	10•6	10•5	11•6	11•3	19•3	23•5	27•6	29•9	6
7	27•8	32•6	31•9	32•5	34•6	35•0	50•6	56•5	68•3	75•3	7
8	8•1	10•2	10•8	10•8	12•1	11•7	19•2	23•1	27•3	30•0	8
9	6•7	8•7	10•0	9•7	10•9	10•5	17•9	22•2	26•4	28•5	9
10	5•4	7•2	8•5	8•1	9•3	8•8	15•3	19•2	23•5	25•9	10
11	14•4	17•9	20•0	19•2	22•6	20•7	34•7	44•2	51•9	61•6	11
12	5•5	6•7	7•7	7•4	8•5	8•1	13•6	16•8	21•1	23•2	12
15	24•2	23•4	23•2	22•4	23•9	23•3	27•5	30•6	36•3	40•0	15
17	67•6	70•5	70•2	67•9	69•2	70•1	73•4	70•8	85•6	94•4	17
19	26•6	26•8	26•8	25•2	28•1	26•9	34•1	39•3	48•0	52•5	19
20	39•2	42•2	42•1	39•6	43•6	41•9	47•3	51•9	63•0	68•3	20

TABLE 48

ECONOMIC SECTION: CONDITION # 5

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BCZ	
2	68.4	74.0	75.0	76.7	78.6	83.6	127.0	138.2	163.8	162.8	2
3	9.4	11.4	12.6	12.7	13.7	13.8	23.5	27.0	33.2	36.4	3
5	30.8	32.8	33.4	33.7	34.6	36.3	51.7	56.7	63.3	64.7	5
6	8.6	10.8	12.3	12.2	13.5	13.1	22.5	27.4	32.1	34.8	6
7	32.9	38.6	37.8	38.4	40.9	41.4	59.9	66.9	80.9	89.2	7
8	9.6	12.1	12.9	12.8	14.3	13.9	22.8	27.5	32.5	35.7	8
9	7.7	10.0	11.4	11.2	12.5	12.1	20.6	25.5	30.3	32.7	9
10	5.7	7.6	9.0	8.6	9.9	9.4	16.1	20.3	24.9	27.5	10
11	16.9	21.0	23.5	22.5	26.5	24.3	40.6	51.8	60.8	72.2	11
12	5.8	7.0	8.0	7.7	8.9	8.4	14.1	17.5	21.9	24.2	12
15	26.0	25.1	24.9	24.0	25.6	24.9	29.5	32.8	38.9	42.9	15
17	78.7	82.1	81.6	79.0	80.5	81.5	85.4	82.4	99.7	109.9	17
19	29.4	29.6	29.7	27.8	31.1	29.8	37.7	43.4	53.1	58.1	19
20	42.1	45.3	45.2	42.5	46.8	44.9	50.8	55.7	67.6	73.3	20

TABLE 49

ECONOMIC SECTION: CONDITION # 6

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	90•5	98•0	99•3	101•6	104•1	110•6	168•1	182•9	216•9	215•5	2
3	12•2	14•9	16•3	16•5	17•8	18•0	30•6	35•1	43•2	47•3	3
5	43•6	46•4	47•4	47•8	49•1	51•5	73•3	80•4	89•6	91•6	5
6	11•0	13•8	15•8	15•7	17•3	16•9	28•9	35•1	41•2	44•7	6
7	43•1	50•5	49•5	50•4	53•6	54•3	78•5	87•6	106•0	116•9	7
8	12•6	16•0	17•0	17•0	18•9	18•4	30•1	36•2	42•9	47•1	8
9	9•8	12•5	14•4	14•1	15•8	15•2	25•9	32•1	38•2	41•2	9
10	6•3	8•5	10•0	9•5	11•0	10•4	17•9	22•6	27•6	30•5	10
11	21•8	27•2	30•4	29•1	34•2	31•5	52•6	67•0	78•7	93•4	11
12	6•2	7•6	8•7	8•3	9•6	9•1	15•3	18•9	23•7	26•1	12
15	29•5	28•5	28•3	27•2	29•1	28•3	33•5	37•2	44•2	48•7	15
17	100•8	105•1	104•6	101•2	103•2	104•4	109•4	105•5	127•7	140•8	17
19	35•0	35•3	35•3	33•1	37•1	35•5	44•9	51•7	63•3	69•2	19
20	47•9	51•4	51•4	48•3	53•2	51•1	57•7	63•3	76•8	83•3	20

TABLE 50

ECONOMIC SECTION: CONDITION # 7

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	60.2	65.1	66.0	67.5	69.1	73.5	111.6	121.2	143.7	142.7	2
3	9.8	11.9	13.1	13.2	14.3	14.4	24.5	28.1	34.6	37.8	3
5	26.4	28.2	28.7	29.0	29.8	31.2	44.5	48.6	54.3	55.5	5
6	8.7	11.1	12.8	12.7	14.0	13.6	23.3	28.3	33.2	36.0	6
7	29.9	34.8	34.0	34.5	36.7	37.1	54.2	60.6	73.4	80.9	7
8	9.0	11.6	12.6	12.5	13.9	13.5	22.5	27.2	32.2	35.4	8
9	7.9	10.4	12.2	11.9	13.3	12.8	22.1	27.4	32.5	35.1	9
10	6.9	9.5	11.4	10.9	12.5	11.8	20.7	26.0	31.8	35.2	10
11	16.1	20.7	23.5	22.4	26.3	24.2	41.4	53.1	62.4	74.0	11
12	7.5	9.0	10.5	9.9	11.4	10.9	18.6	23.2	29.0	32.0	12
15	26.1	27.8	27.6	26.4	28.3	27.5	31.9	35.6	42.2	46.5	15
17	76.2	81.3	80.9	78.3	79.8	80.8	82.8	78.8	95.4	105.2	17
19	30.6	31.1	31.1	29.2	32.4	31.0	39.0	45.0	55.0	60.1	19
20	46.0	50.3	50.2	46.8	51.9	49.9	54.8	60.2	73.0	79.2	20

TABLE 51

ECONOMIC SECTION: CONDITION # 8

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	71•2	77•1	78•1	79•9	81•9	87•0	132•1	143•4	170•1	169•0	2
3	11•2	13•6	15•0	15•1	16•3	16•5	28•0	32•1	39•5	43•3	3
5	32•8	35•0	35•7	36•0	37•0	38•8	55•2	60•4	67•4	68•9	5
6	9•9	12•6	14•5	14•4	15•9	15•5	26•5	32•2	37•8	41•0	6
7	34•9	40•6	39•7	40•3	42•8	43•3	63•2	70•8	85•6	94•4	7
8	10•5	13•5	14•6	14•5	16•1	15•7	26•1	31•6	37•4	41•0	8
9	8•9	11•6	13•7	13•3	14•9	14•4	24•7	30•7	36•5	39•3	9
10	7•2	9•9	11•9	11•3	13•0	12•3	21•6	27•1	33•2	36•7	10
11	18•3	23•7	26•8	25•6	30•1	27•6	47•3	60•7	71•2	84•5	11
12	7•7	9•2	10•8	10•2	11•8	11•2	19•2	23•9	29•9	33•0	12
15	27•7	29•4	29•3	28•0	30•0	29•2	33•8	37•7	44•8	49•3	15
17	86•9	92•8	92•3	89•4	91•1	92•2	94•5	90•0	108•9	120•0	17
19	33•3	34•0	34•0	31•8	35•4	33•8	42•6	49•0	60•0	65•6	19
20	48•8	53•4	53•3	49•7	55•1	52•9	67•5	63•9	77•5	84•0	20

TABLE 52

ECONOMIC SECTION: CONDITION # 9

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	93•3	101•0	102•3	104•7	107•3	114•1	173•1	188•0	222•9	221•5	2
3	14•0	17•1	18•7	18•9	20•4	20•6	35•0	40•2	49•5	54•2	3
5	45•7	48•6	49•6	50•1	51•4	53•9	76•8	84•0	93•7	95•8	5
6	12•3	15•7	18•0	17•9	19•7	19•2	32•9	39•9	46•8	50•8	6
7	44•9	52•2	51•1	51•8	55•1	55•7	81•3	91•0	110•1	121•4	7
8	13•4	17•2	18•6	18•5	20•6	20•0	33•3	40•3	47•8	52•4	8
9	10•8	14•1	16•6	16•2	18•1	17•5	30•1	37•2	44•3	47•7	9
10	7•8	10•7	12•9	12•2	14•1	13•3	23•4	29•3	35•9	39•7	10
11	22•9	29•6	33•5	32•0	37•6	34•5	59•1	75•8	89•0	105•6	11
12	8•1	9•8	11•4	10•8	12•5	11•8	20•3	25•2	31•6	34•9	12
15	30•9	32•8	32•7	31•2	33•5	32•6	37•7	42•0	49•9	55•0	15
17	108•4	115•7	115•2	111•5	113•7	115•1	117•9	112•2	135•8	149•7	17
19	38•9	39•6	39•6	37•1	41•2	39•4	49•6	57•2	69•9	76•5	19
20	54•5	59•6	59•4	55•4	61•5	59•1	75•3	71•2	86•5	93•7	20

TABLE 53

ECONOMIC SECTION: CONDITION # 10

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	120.5	130.2	132.0	135.2	138.5	147.3	223.4	244.2	289.5	287.7	2
3	45.6	55.4	60.7	61.3	66.5	67.1	113.1	130.4	160.7	175.9	3
5	66.8	71.0	72.2	73.0	75.1	78.8	110.0	120.0	133.9	136.8	5
6	28.8	34.4	37.5	38.5	43.6	42.5	69.6	64.0	75.1	81.4	6
7	61.1	72.9	74.3	79.0	87.8	88.9	137.3	158.7	192.1	211.8	7
8	24.8	31.9	33.9	35.0	40.6	39.5	63.5	74.5	88.2	96.7	8
9	22.7	29.8	32.5	34.5	38.6	37.2	60.7	71.1	84.5	91.1	9
10	15.7	21.4	23.7	23.6	28.7	27.2	45.3	52.2	64.0	70.6	10
11	39.0	50.9	56.7	57.2	70.6	64.9	109.1	131.1	154.0	182.7	11
12	14.6	18.5	20.3	20.2	24.7	23.5	38.9	44.0	55.1	60.8	12
15	24.0	29.4	29.4	31.1	36.6	35.6	54.0	64.5	76.6	84.4	15
17	112.6	123.4	119.2	129.6	143.8	145.5	210.9	241.6	292.3	322.3	17
19	37.5	42.7	43.6	45.0	54.7	52.4	81.1	94.0	115.0	125.8	19
20	37.1	42.5	42.5	45.7	53.8	51.6	77.7	91.3	110.8	120.1	20

TABLE 54

ECONOMIC SECTION: CONDITION # 11

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	135.0	145.9	147.8	151.4	155.1	164.9	250.2	273.5	324.3	322.3	2
3	50.1	60.8	66.6	67.3	73.0	73.7	124.2	143.2	176.4	193.2	3
5	74.8	79.6	80.9	81.8	84.2	88.3	123.2	134.4	149.9	153.2	5
6	31.8	37.9	41.4	42.4	48.1	46.9	76.8	70.6	82.9	89.9	6
7	68.4	81.6	83.2	88.5	98.3	99.5	153.8	177.8	215.1	237.2	7
8	27.8	35.7	38.0	39.2	45.5	44.2	71.2	83.4	98.8	108.3	8
9	25.1	32.8	35.9	38.1	42.6	41.1	67.0	78.4	93.3	100.6	9
10	17.1	23.4	25.9	25.8	31.3	29.6	49.4	57.0	69.8	77.0	10
11	43.6	56.9	63.3	63.9	78.9	72.5	121.9	146.5	172.0	204.2	11
12	15.9	20.2	22.2	22.0	27.0	25.6	42.4	48.0	60.1	66.4	12
15	27.0	33.0	33.0	35.0	41.1	40.0	60.6	72.5	86.1	94.9	15
17	126.1	138.2	133.5	145.2	161.0	163.0	236.3	270.5	327.4	361.0	17
19	41.9	47.9	48.8	50.4	61.3	58.7	90.9	105.3	128.8	140.9	19
20	41.6	47.6	47.6	51.2	60.2	57.8	87.1	102.3	124.1	134.5	20

TABLE 55

ECONOMIC SECTION: CONDITION # 12

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	163•9	177•1	179•5	183•8	188•4	200•3	303•8	332•1	393•8	391•3	2
3	59•1	71•7	78•5	79•4	86•0	86•9	146•4	168•8	207•9	227•7	3
5	90•9	96•6	98•2	99•3	102•2	107•2	149•6	163•2	182•0	186•0	5
6	37•7	45•0	49•2	50•4	57•1	55•7	91•2	83•8	98•4	106•7	6
7	83•1	99•1	101•1	107•5	119•4	120•9	186•8	215•9	261•2	288•0	7
8	33•7	43•4	46•2	47•7	55•3	53•7	86•4	101•3	119•9	131•5	8
9	29•7	39•0	42•6	45•2	50•6	48•8	79•6	93•1	110•7	119•4	9
10	19•9	27•3	30•2	30•1	36•5	34•6	57•6	66•5	81•4	89•9	10
11	53•0	69•3	77•0	77•8	96•1	88•3	148•3	178•4	209•4	248•5	11
12	18•6	23•5	25•9	25•7	31•5	29•9	49•5	56•0	70•1	77•4	12
15	33•0	40•3	40•3	42•7	50•2	48•8	74•0	88•5	105•1	115•8	15
17	153•1	167•9	162•1	176•3	195•5	197•9	286•9	328•5	397•5	438•3	17
19	50•9	58•1	59•3	61•2	74•4	71•2	110•3	127•9	156•4	171•1	19
20	50•5	57•8	57•7	62•2	73•1	70•2	105•7	124•2	150•7	163•4	20

TABLE 56

ECONOMIC SECTION: CONDITION # 13

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BCZ	
2	54•6	59•0	59•7	61•1	62•6	66•6	101•1	110•3	130•8	130•0	2
3	6•1	7•5	8•2	8•3	9•0	9•1	15•4	17•7	21•9	23•9	3
5	22•0	23•5	23•9	24•2	24•8	26•0	37•2	40•8	45•5	46•5	5
6	5•5	7•1	8•1	8•1	8•9	8•7	14•9	18•2	21•4	23•2	6
7	17•4	20•7	21•8	22•4	24•2	24•5	40•7	46•1	55•8	61•5	7
8	5•4	6•9	8•1	8•0	8•9	8•6	14•9	18•2	21•6	23•6	8
9	4•5	5•9	7•3	7•0	7•9	7•6	13•2	16•5	19•6	21•2	9
10	2•8	3•8	5•1	4•8	5•5	5•2	9•4	11•8	14•5	16•0	10
11	7•9	11•0	14•1	13•4	15•8	14•5	25•9	33•5	39•3	46•7	11
12	2•6	3•3	4•4	4•1	4•8	4•5	7•9	10•0	12•5	13•8	12
15	8•8	10•0	10•4	10•4	11•6	11•3	17•9	21•4	25•4	27•9	15
17	24•3	26•8	25•9	25•9	27•2	27•5	35•8	38•7	46•8	51•6	17
19	10•9	12•6	14•2	13•6	15•7	15•0	24•9	30•9	37•8	41•3	19
20	13•2	17•1	17•8	17•3	19•9	19•1	29•2	35•4	43•0	46•6	20

TABLE 57

ECONOMIC SECTION: CONDITION # 14

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	65•6	71•0	71•9	73•5	75•4	80•1	121•7	132•8	157•4	156•4	2
3	7•5	9•2	10•1	10•2	11•0	11•1	19•0	21•8	26•9	29•4	3
5	28•4	30•2	30•8	31•1	32•0	33•5	47•9	52•6	58•7	59•9	5
6	6•7	41•1	9•8	9•8	10•7	10•5	18•0	22•0	25•8	28•0	6
7	20•9	25•0	26•2	27•0	29•1	29•5	49•0	55•5	67•2	74•1	7
8	6•7	8•5	10•0	9•9	11•0	10•6	18•3	22•4	26•6	29•2	8
9	5•4	7•0	8•7	8•4	9•4	9•1	15•8	19•7	23•5	25•3	9
10	3•1	4•2	5•6	5•3	5•5	5•2	10•2	12•9	15•8	17•5	10
11	9•6	13•4	17•1	16•4	19•2	17•7	31•5	40•8	47•9	56•9	11
12	2•7	3•6	4•6	4•4	5•1	4•8	8•5	10•6	13•3	14•7	12
15	9•6	10•9	11•3	11•3	12•6	12•3	19•5	23•3	27•6	30•4	15
17	29•0	32•0	31•0	30•9	32•5	32•9	42•8	46•2	55•9	61•6	17
19	12•2	14•2	16•0	15•3	17•6	16•9	28•1	34•8	42•6	46•6	19
20	14•4	18•7	19•4	18•9	21•7	20•9	31•9	38•7	46•9	50•9	20

TABLE 58

ECONOMIC SECTION: CONDITION # 15

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	87•8	94•9	96•2	98•4	100•8	107•2	162•8	177•6	210•6	209•3	2
3	10•4	12•6	13•9	14•0	15•1	15•3	26•0	29•9	36•8	40•4	3
5	41•1	43•8	44•6	45•1	46•3	48•5	69•4	76•1	84•9	86•8	5
6	9•0	11•5	13•2	13•1	14•4	14•1	24•2	29•6	34•7	37•7	6
7	28•1	33•5	35•1	36•1	39•0	39•5	65•6	74•4	90•0	99•3	7
8	9•2	11•8	13•7	13•6	15•1	14•7	25•3	30•9	36•6	40•2	8
9	7•1	9•4	11•5	11•2	12•5	12•0	20•9	26•2	31•1	33•6	9
10	3•6	4•9	6•5	6•2	7•1	6•7	11•9	15•1	18•5	20•4	10
11	13•1	18•2	23•3	22•2	26•1	24•0	42•8	55•4	65•1	77•2	11
12	3•1	4•0	5•2	4•9	5•7	5•4	9•6	12•0	15•0	16•5	12
15	11•2	12•7	13•2	13•2	14•7	14•3	22•7	27•1	32•2	35•5	15
17	38•4	42•4	41•1	41•0	43•0	43•5	56•7	61•2	74•0	81•6	17
19	15•0	17•4	19•6	18•8	21•6	20•7	34•4	42•7	52•2	57•1	19
20	16•8	21•8	22•6	22•1	25•4	24•4	37•3	45•2	54•8	59•4	20

TABLE 59

ECONOMIC SECTION: CONDITION # 16

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	57•4	62•0	62•8	64•3	65•9	70•0	106•3	115•8	137•3	136•4	2
3	7•9	9•7	10•6	10•7	11•6	11•7	19•9	22•9	28•2	30•9	3
5	24•1	25•7	26•2	26•4	27•1	28•5	40•7	44•6	49•8	50•8	5
6	7•0	8•9	10•3	10•2	11•2	10•9	18•8	22•9	26•9	29•2	6
7	19•2	22•9	24•1	24•7	28•2	28•5	45•1	51•1	61•9	68•2	7
8	6•6	8•5	9•9	9•8	10•8	10•5	18•2	22•3	26•4	28•9	8
9	5•9	7•7	9•5	9•2	10•3	9•9	17•3	21•6	25•7	27•7	9
10	4•3	5•9	8•0	7•6	8•7	8•2	14•7	18•6	22•7	25•1	10
11	9•7	13•5	17•7	16•8	19•7	18•1	32•7	42•3	49•7	58•9	11
12	4•0	5•3	7•1	6•7	7•6	7•3	13•0	16•2	20•3	22•4	12
15	9•8	11•6	12•3	12•2	13•6	13•2	21•7	26•1	31•0	34•2	15
17	27•5	30•7	30•0	29•4	30•7	31•0	39•2	42•3	51•2	56•5	17
19	11•7	14•1	16•4	15•7	17•9	17•1	29•6	36•7	44•9	49•1	19
20	15•4	20•0	21•0	20•2	23•2	22•3	35•3	43•4	52•6	57•1	20

TABLE 60

ECONOMIC SECTION: CONDITION # 17

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	68•5	74•0	75•0	76•7	78•6	83•6	126•8	138•2	163•8	162•8	2
3	9•3	11•4	12•5	12•6	13•6	13•8	23•4	26•9	33•2	36•3	3
5	30•5	32•5	33•1	33•4	34•3	36•0	51•4	56•3	62•9	64•2	5
6	8•2	10•4	12•0	11•9	13•1	12•7	21•9	26•7	31•4	34•0	6
7	22•8	27•2	28•5	29•3	33•4	33•8	53•4	60•5	73•2	80•7	7
8	7•8	10•1	11•8	11•6	12•9	12•5	21•7	26•5	31•4	34•4	8
9	6•8	8•9	10•9	10•6	11•8	11•4	19•9	24•8	29•5	31•8	9
10	4•6	6•3	8•5	8•0	9•2	8•7	15•6	19•6	24•0	26•5	10
11	11•4	15•8	20•7	19•7	23•1	21•2	38•3	49•6	58•2	69•1	11
12	4•2	5•5	7•4	6•9	8•0	7•6	13•5	16•9	21•1	23•3	12
15	10•5	12•4	13•1	13•1	14•6	14•2	23•3	28•0	33•3	36•7	15
17	32•0	35•7	34•9	34•2	35•7	36•1	45•6	49•3	59•6	65•7	17
19	12•9	15•6	18•2	17•4	19•8	19•0	32•7	40•6	49•7	54•3	19
20	16•5	21•4	22•5	21•7	24•9	23•9	37•8	46•6	56•5	61•3	20

TABLE 61

ECONOMIC SECTION: CONDITION # 18

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	90.6	98.0	99.3	101.6	104.1	110.6	167.9	182.9	216.9	215.5	2
3	12.2	14.8	16.3	16.4	17.7	17.9	30.5	35.0	43.1	47.2	3
5	43.2	46.0	46.9	47.3	48.6	51.0	72.8	79.8	89.1	91.0	5
6	10.5	13.4	15.4	15.2	16.8	16.3	28.2	34.3	40.3	43.7	6
7	29.8	35.6	37.4	38.4	43.8	44.3	70.0	79.3	96.0	105.8	7
8	10.3	13.3	15.6	15.4	17.0	16.5	28.6	35.0	41.4	45.4	8
9	8.5	11.2	13.8	13.3	14.9	14.4	25.0	31.2	37.1	40.0	9
10	5.1	6.9	9.4	8.9	10.2	9.6	17.3	21.8	26.7	29.5	10
11	14.7	20.5	26.8	25.5	29.8	27.4	49.6	64.1	75.3	89.4	11
12	4.5	5.9	7.9	7.5	8.6	8.2	14.6	18.2	22.8	25.2	12
15	12.0	14.1	14.9	14.9	16.5	16.1	26.4	31.8	37.8	41.6	15
17	41.0	45.7	44.7	43.8	45.7	46.3	58.4	63.1	76.4	84.2	17
19	15.4	18.6	21.6	20.7	23.6	22.6	39.0	48.4	59.2	64.7	19
20	18.7	24.4	25.6	24.6	28.3	27.2	43.0	52.9	64.2	69.6	20

TABLE 62

ECONOMIC SECTION: CONDITION # 19

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	60•2	65•1	66•0	67•5	69•1	73•5	111•6	121•2	143•7	142•7	2
3	9•7	11•9	13•0	13•2	14•2	14•4	24•4	28•0	34•4	37•7	3
5	26•2	27•9	28•5	28•7	29•5	30•9	44•2	48•4	54•0	55•2	5
6	8•5	10•8	12•4	12•3	13•5	13•2	22•7	27•6	32•4	35•2	6
7	21•1	25•2	26•5	27•1	29•2	29•6	49•6	56•2	68•1	75•0	7
8	7•8	10•0	11•7	11•6	12•8	12•5	21•6	26•3	31•2	34•2	8
9	7•3	9•6	11•8	11•4	12•7	12•3	21•4	26•6	31•6	34•1	9
10	5•9	8•1	10•9	10•3	11•8	11•2	20•1	25•2	30•9	34•1	10
11	11•7	16•2	21•4	20•3	23•7	21•8	39•6	51•0	59•9	71•1	11
12	5•4	7•3	9•8	9•2	10•6	10•1	18•0	22•4	28•0	30•9	12
15	11•2	13•4	14•3	14•3	16•0	15•5	25•8	31•1	36•9	40•7	15
17	30•5	34•9	34•5	33•8	34•6	35•0	43•8	47•5	57•5	63•4	17
19	12•7	15•8	18•9	18•1	20•6	19•7	34•4	42•7	52•2	57•1	19
20	17•8	23•1	24•4	23•7	27•0	26•0	41•8	51•5	62•5	67•7	20

TABLE 63

ECONOMIC SECTION: CONDITION # 20

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	71.3	77.1	78.1	79.9	81.9	87.0	132.1	143.4	170.1	169.0	2
3	11.2	13.6	14.9	15.1	16.3	16.4	27.9	32.0	39.4	43.2	3
5	32.5	34.7	35.4	35.7	36.6	38.4	54.9	60.1	67.0	68.5	5
6	9.6	12.3	14.1	14.0	15.4	15.0	25.8	31.4	36.9	40.0	6
7	24.6	29.4	30.9	31.7	34.1	34.5	57.8	65.6	79.4	87.6	7
8	9.1	11.6	13.6	13.4	14.9	14.5	25.0	30.5	36.2	39.6	8
9	8.1	10.7	13.2	12.8	14.3	13.8	23.9	29.8	35.4	38.2	9
10	6.2	8.4	11.4	10.8	12.3	11.7	20.9	26.3	32.2	35.6	10
11	13.4	18.5	24.4	23.2	27.1	24.9	45.2	58.3	68.4	81.2	11
12	5.6	7.5	10.1	9.5	10.9	10.4	18.5	23.1	28.9	31.9	12
15	11.9	14.2	15.2	15.2	16.9	16.5	27.3	33.0	39.2	43.2	15
17	34.8	39.9	39.4	38.5	39.5	40.0	50.0	54.2	65.6	72.4	17
19	13.9	17.3	20.6	19.7	22.5	21.5	37.5	46.6	57.0	62.3	19
20	18.9	24.5	25.9	25.1	28.7	27.6	44.4	54.6	66.3	71.9	20

TABLE 64

ECONOMIC SECTION: CONDITION # 21

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	93.4	101.0	102.3	104.7	107.3	114.1	173.1	188.0	222.9	221.5	2
3	14.0	17.0	18.7	18.9	20.4	20.6	34.9	40.1	49.3	54.0	3
5	45.2	48.2	49.1	49.6	50.9	53.4	76.3	83.5	93.2	95.2	5
6	11.9	15.2	17.5	17.4	19.1	18.6	32.0	39.0	45.7	49.6	6
7	31.6	37.8	39.8	40.7	43.8	44.4	74.4	84.4	102.2	112.6	7
8	11.6	14.9	17.4	17.2	19.0	18.5	31.9	39.0	46.2	50.6	8
9	9.9	13.0	16.0	15.5	17.3	16.7	29.1	36.2	43.0	46.4	9
10	6.7	9.1	12.3	11.7	13.4	12.6	22.6	28.5	34.8	38.5	10
11	16.7	23.1	30.5	28.9	33.9	31.1	56.4	72.8	85.5	101.5	11
12	5.9	7.9	10.7	10.0	11.5	11.0	19.6	24.4	30.5	33.7	12
15	13.3	15.8	16.9	16.9	18.9	18.4	30.5	36.8	43.7	48.1	15
17	43.4	49.7	49.1	48.1	49.3	49.9	62.4	67.7	81.9	90.3	17
19	16.2	20.1	24.0	23.0	26.2	25.1	43.7	54.3	66.4	72.6	19
20	21.1	27.3	28.9	28.0	32.0	30.7	49.5	60.9	74.0	80.2	20

TABLE 65

ECONOMIC SECTION: CONDITION # 22

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	120•1	130•0	131•7	134•7	138•0	146•8	223•2	244•0	289•2	287•4	2
3	44•1	53•8	59•1	59•6	64•4	65•0	110•8	127•7	157•3	172•2	3
5	62•1	66•1	67•5	68•1	69•9	73•4	104•7	115•0	128•3	131•2	5
6	21•1	26•7	30•3	30•3	33•7	32•8	55•7	67•5	79•2	85•9	6
7	37•9	45•4	47•8	49•4	53•7	54•3	88•2	100•0	121•1	133•5	7
8	17•1	21•5	24•4	24•5	27•6	26•8	45•3	54•3	64•3	70•5	8
9	16•3	20•7	24•5	24•1	27•4	26•4	45•2	55•0	65•4	70•5	9
10	11•3	14•0	17•2	16•7	19•7	18•6	32•4	39•1	47•9	52•8	10
11	24•0	31•0	37•7	36•8	44•2	40•6	71•6	88•2	103•5	122•9	11
12	9•7	11•9	14•6	14•2	16•8	15•9	27•6	32•8	41•0	45•3	12
15	12•8	15•4	16•3	17•0	19•7	19•2	30•7	36•3	43•1	47•5	15
17	50•8	58•5	58•5	62•2	69•8	70•7	107•0	123•6	149•5	164•9	17
19	21•3	23•7	25•9	26•0	31•2	29•8	49•0	56•6	69•2	75•7	19
20	18•0	22•5	23•7	24•1	29•0	27•9	44•6	51•7	62•8	68•1	20

TABLE 66

ECONOMIC SECTION: CONDITION # 23

	LIV	G•F•	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	134•5	145•6	147•5	150•9	154•6	164•4	250•0	273•2	323•9	321•9	2
3	48•4	59•1	64•9	65•5	70•7	71•4	121•6	140•2	172•7	189•1	3
5	69•6	74•1	75•5	76•3	78•3	82•1	117•3	128•8	143•7	146•9	5
6	23•2	29•5	33•4	33•5	37•1	36•2	61•5	74•4	87•4	94•8	6
7	42•5	50•8	53•6	55•3	60•1	60•8	98•8	112•0	135•6	149•5	7
8	19•2	24•0	27•3	27•4	30•9	30•0	50•8	60•8	72•1	79•0	8
9	18•0	22•8	27•0	26•6	30•2	29•1	49•9	60•7	72•1	77•8	9
10	12•3	15•3	18•8	18•2	21•5	20•3	35•4	42•7	52•2	57•7	10
11	26•8	34•6	42•1	41•1	43•5	40•0	80•0	98•5	115•7	137•3	11
12	10•6	13•0	16•0	15•5	18•3	17•4	30•1	35•7	44•7	49•4	12
15	14•4	17•3	18•3	19•1	22•1	21•5	34•5	40•8	48•5	53•4	15
17	56•9	65•5	65•6	69•7	78•2	79•1	119•8	138•4	167•5	184•7	17
19	23•8	26•5	29•0	29•1	34•9	33•4	54•9	63•4	77•6	84•8	19
20	20•2	25•2	26•6	27•0	32•5	31•2	50•0	57•9	70•3	76•2	20

TABLE 67

ECONOMIC SECTION: CONDITION # 24

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	163.4	176.7	179.1	183.2	187.7	199.6	303.5	331.8	393.3	390.9	2
3	57.1	69.6	76.5	77.2	83.3	84.2	143.3	165.2	203.5	222.9	3
5	84.5	89.9	91.7	92.7	95.1	99.8	142.4	156.5	174.5	178.4	5
6	27.6	35.0	39.7	39.7	44.1	43.0	73.0	88.4	103.8	112.5	6
7	51.6	61.7	65.0	67.2	73.0	73.9	120.0	136.0	164.6	181.5	7
8	23.3	29.2	33.1	33.3	37.5	36.4	61.6	73.9	87.5	95.9	8
9	21.4	27.1	32.1	31.6	35.9	34.6	59.2	72.0	85.6	92.3	9
10	14.4	17.8	21.9	21.3	25.1	23.7	41.3	49.8	60.9	67.3	10
11	32.6	42.1	51.3	50.0	60.1	55.2	97.4	119.9	140.8	167.1	11
12	12.4	15.2	18.6	18.0	21.3	20.3	35.1	41.7	52.2	57.6	12
15	17.6	21.2	22.4	23.3	27.0	26.3	42.1	49.8	59.2	65.2	15
17	69.1	79.5	79.6	84.6	94.9	96.1	145.5	168.1	203.4	224.3	17
19	28.9	32.2	35.3	35.4	42.4	40.6	66.7	77.0	94.2	103.0	19
20	24.5	30.6	32.3	32.8	39.5	37.9	60.7	70.4	85.4	92.6	20

TABLE 68. MONTHLY ELECTRIC ENERGY DISTRIBUTION FOR THE SHARED NETWORK OPTION AT GREAT FALLS USING SELECTED WIND SYSTEMS

	Wind System	Wind Energy to Load kWh/mo	Utility Energy to Load kWh/mo	Wind Energy to Network kWh/mo
		(LF x LOAD)	(1-LF) x LOAD	(Table 30) - (LF x LOAD)
LOAD 1	10	121	150	209
	12	125	146	225
	20	181	90	900
LOAD 2	10	185	465	145
	12	194	456	156
	20	344	306	737

TABLE 69. MONTHLY ELECTRIC ENERGY COST DISTRIBUTION FOR THE SHARED NETWORK OPTION AT GREAT FALLS USING SELECTED WIND SYSTEMS

($/mo)

	Wind System	1 Cost of Wind Energy to Load	2 Cost of Utility Energy to Load	3 Credit for Wind Energy to Network	4 User Payment to Utility (4-2-3)	5 Wind Energy System Cost (5=1+4)	6 Utility Energy Costs	7 Investment to Savings Ratio 5/(6-4)
LOAD 1	10	27.10	7.20	4.18	2.87	29.97	13.01	2.96
	12	24.38	7.01	4.50	2.36	28.88	13.01	2.71
	20	64.07	4.32	18.00	-13.77	50.30	13.01	1.88
LOAD 2	10	27.01	18.83	2.90	16.17	43.18	26.33	4.25
	12	24.25	18.47	3.12	15.58	39.83	26.33	3.71
	20	64.33	12.39	14.74	-2.00	62.33	26.33	2.20

TABLE 70

MINIMUM RESIDENTIAL WIND ENERGY COSTS
FOR INDEPENDENT SYSTEMS, STOR 1, 20 YR LIFE
(¢/kWh)

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	50.7	54.9	55.6	56.9	58.3	62.0	94.3	103.0	122.2	121.4	2
3	5.7	7.0	7.7	7.7	8.3	8.4	14.4	16.6	20.4	22.3	3
5	20.5	21.8	22.3	22.5	23.1	24.2	34.6	38.0	42.4	43.4	5
6	5.1	6.5	7.5	7.4	8.2	8.0	13.7	16.8	19.8	21.4	6
7	15.5	18.6	19.6	20.0	21.5	21.7	36.7	41.8	50.5	55.7	7
8	4.9	6.3	7.4	7.3	8.0	7.8	13.6	16.7	19.7	21.7	8
9	4.1	5.4	6.6	6.4	7.2	6.9	12.1	15.2	18.1	19.5	9
10	2.4	3.4	4.6	4.4	5.0	4.7	8.5	10.9	13.3	14.7	10
11	6.8	9.4	12.6	11.9	13.9	12.8	23.3	30.5	35.8	42.5	11
12	2.1	2.9	3.9	3.7	4.2	4.0	7.2	9.1	11.4	12.6	12
15	5.5	7.0	8.2	8.1	8.9	8.7	15.2	18.6	22.1	24.4	15
17	10.0	11.9	12.6	12.9	13.8	14.0	23.6	26.9	32.5	35.8	17
19	6.5	8.9	11.8	11.2	12.6	12.1	21.6	27.3	33.4	36.6	19
20	7.4	10.0	13.1	12.5	14.1	13.5	24.0	30.5	37.0	40.1	20

TABLE 71

MINIMUM RESIDENTIAL WIND ENERGY COSTS
FOR THE SHARED NETWORK OPTION, 20 YR LIFE

(¢/kWh)

	LIV	G.F.	BILL	GLAS	MIC	HAVR	HELN	KAL	MSLA	BOZ	
2	108.1	117.0	118.5	121.2	124.2	132.1	200.9	219.6	260.3	258.7	2
3	39.7	48.4	53.2	53.7	57.9	58.5	99.7	114.9	141.5	155.0	3
5	55.7	59.4	60.6	61.1	62.7	65.8	94.2	103.4	115.4	117.9	5
6	17.3	22.1	25.5	25.2	27.7	27.0	46.7	57.1	67.1	72.7	6
7	27.5	32.9	34.7	35.5	38.1	38.6	65.1	74.1	89.7	98.9	7
8	12.5	16.2	19.0	18.7	20.7	20.1	34.9	43.0	50.9	55.8	8
9	11.9	15.7	19.5	18.9	21.0	20.3	35.5	44.6	53.1	57.2	9
10	6.9	9.5	13.0	12.3	14.0	13.3	23.9	30.6	37.5	41.4	10
11	14.6	20.3	27.1	25.6	29.9	27.5	50.1	65.4	76.8	91.2	11
12	5.8	8.0	10.9	10.2	11.7	11.1	19.9	25.2	31.6	34.9	12
15	5.8	7.4	8.7	8.6	9.4	9.2	16.0	19.7	23.4	25.7	15
17	15.8	18.9	19.9	20.3	21.9	22.1	37.3	42.5	51.4	56.7	17
19	7.9	10.7	14.2	13.5	15.3	14.6	26.0	33.0	40.4	44.2	19
20	6.3	8.5	11.2	10.7	12.0	11.6	20.5	26.0	31.6	34.2	20

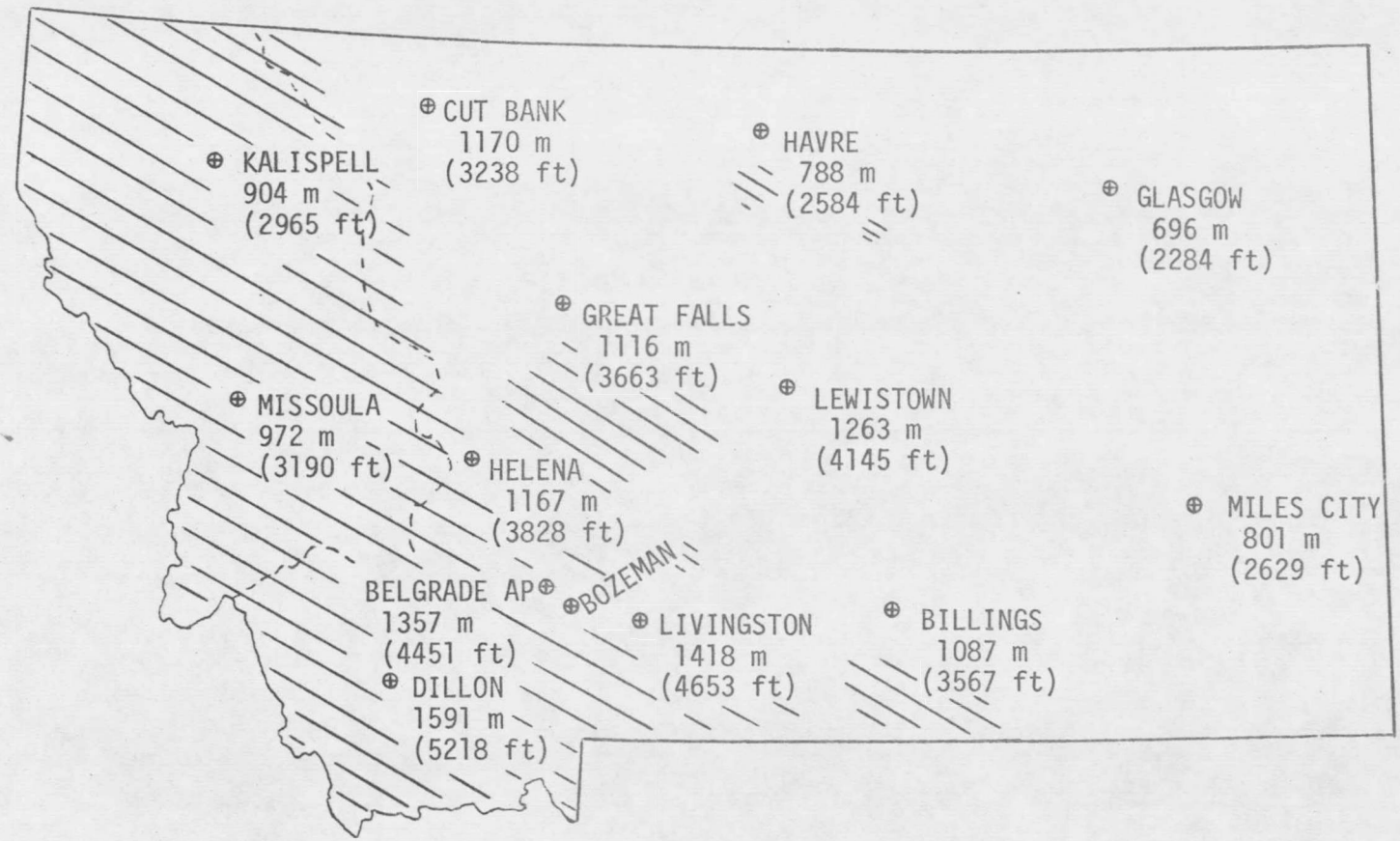


FIGURE 1 LOCATIONS OF AVAILABLE WIND DATA IN MONTANA

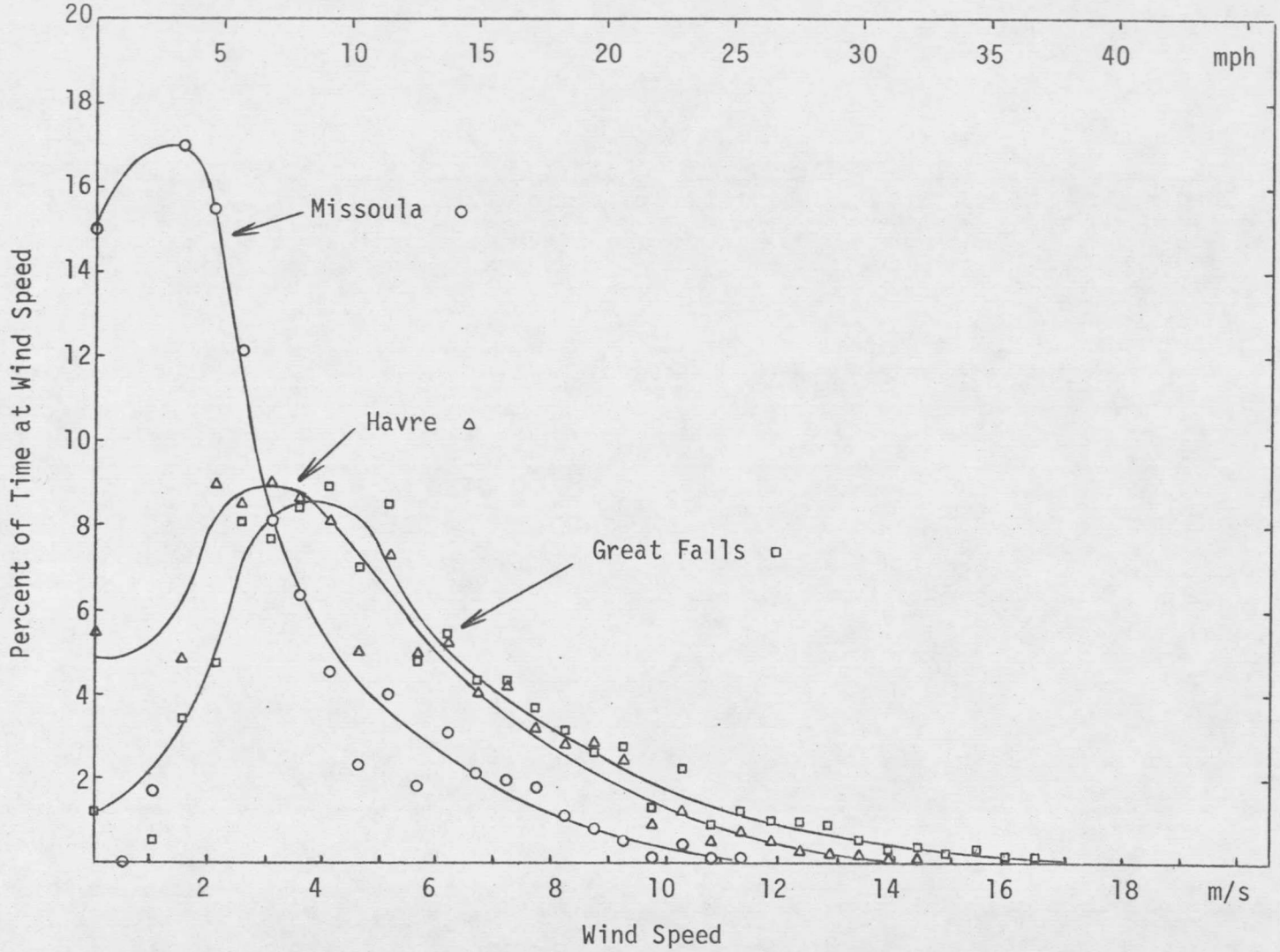


FIGURE 2 FREQUENCY DISTRIBUTION OF WIND SPEEDS

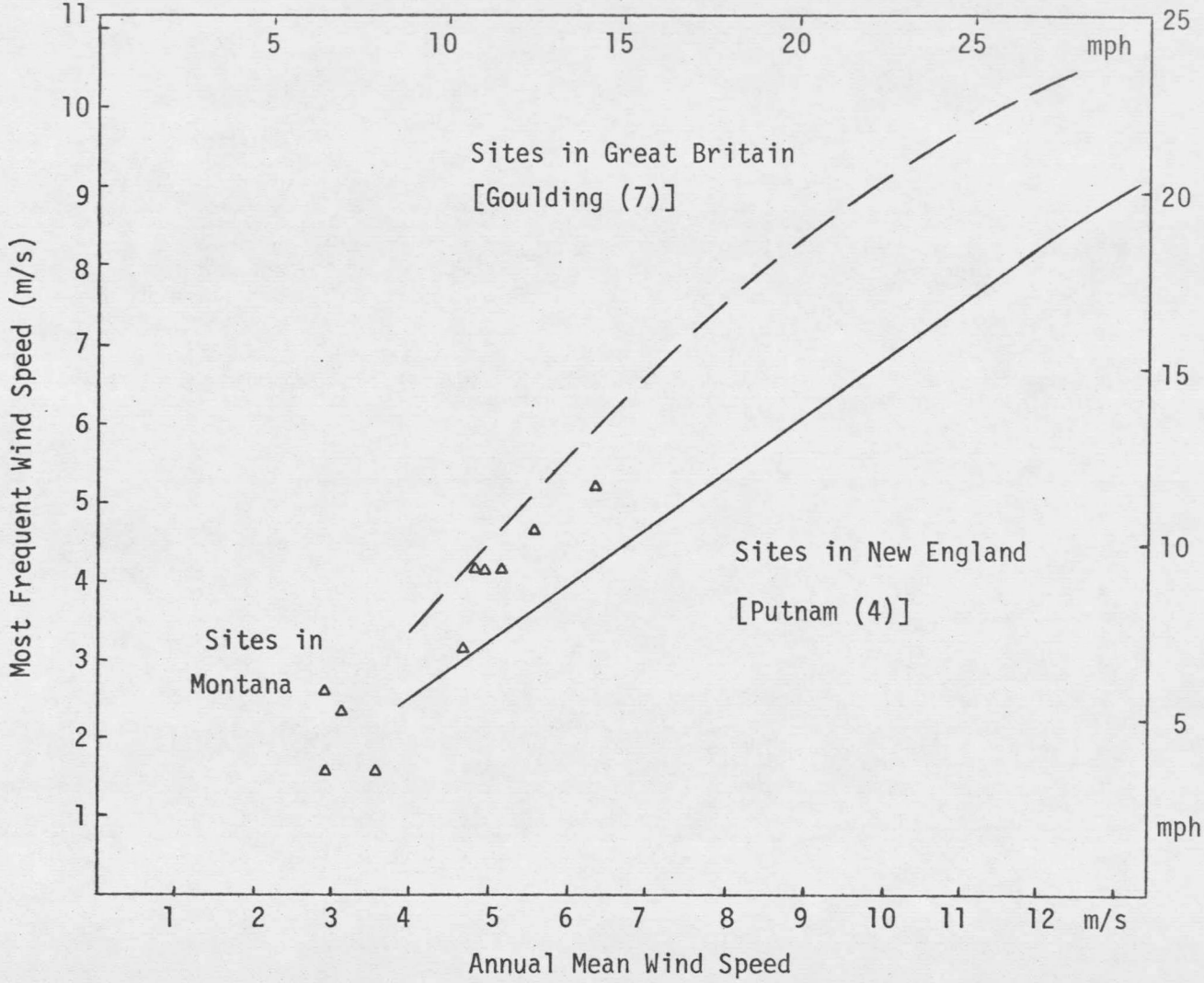


FIGURE 3 RELATIONSHIP BETWEEN MOST FREQUENT WIND SPEED AND ANNUAL MEAN WIND SPEED

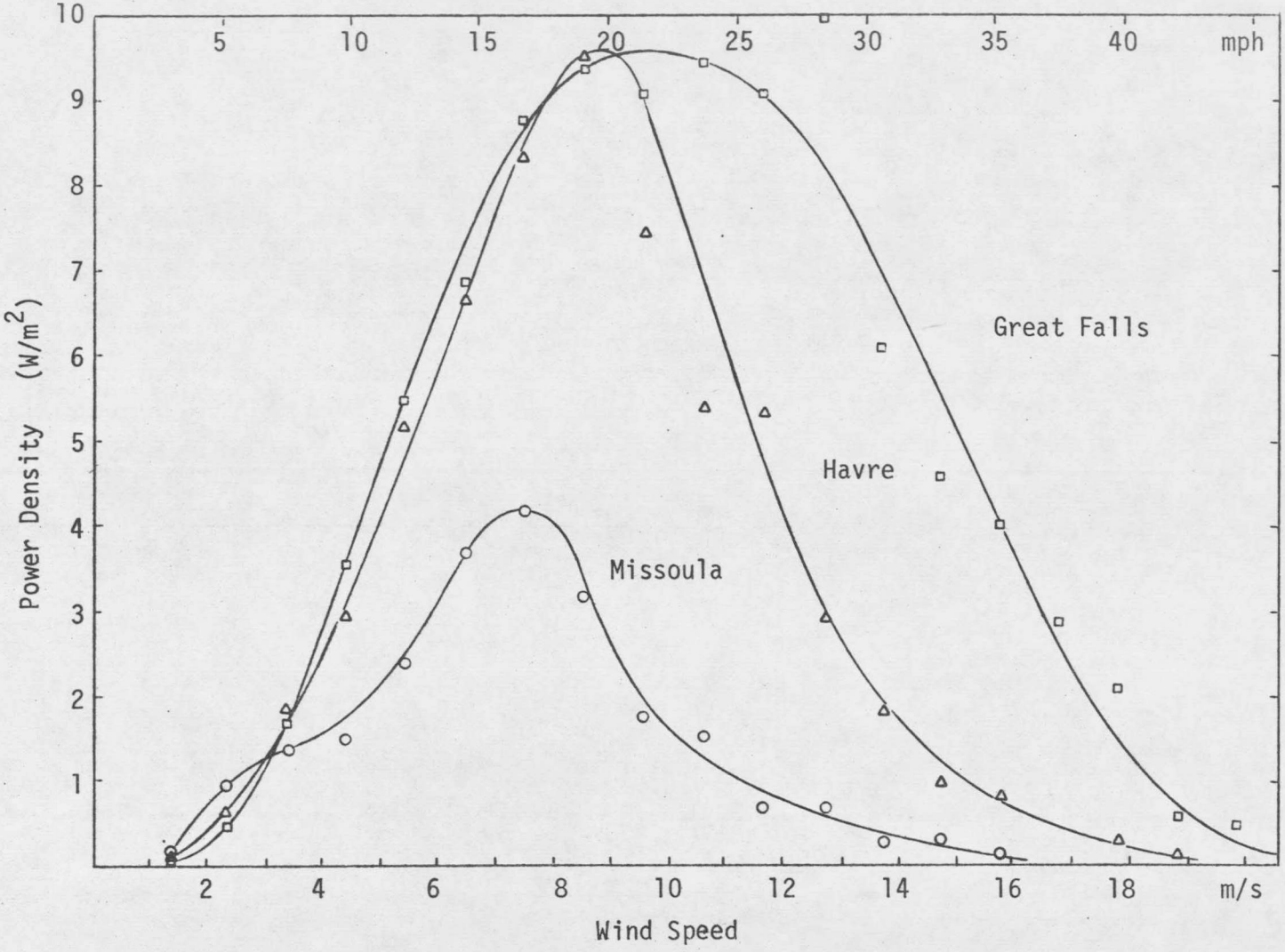


FIGURE 4 DISTRIBUTION OF POWER WITH WIND SPEED

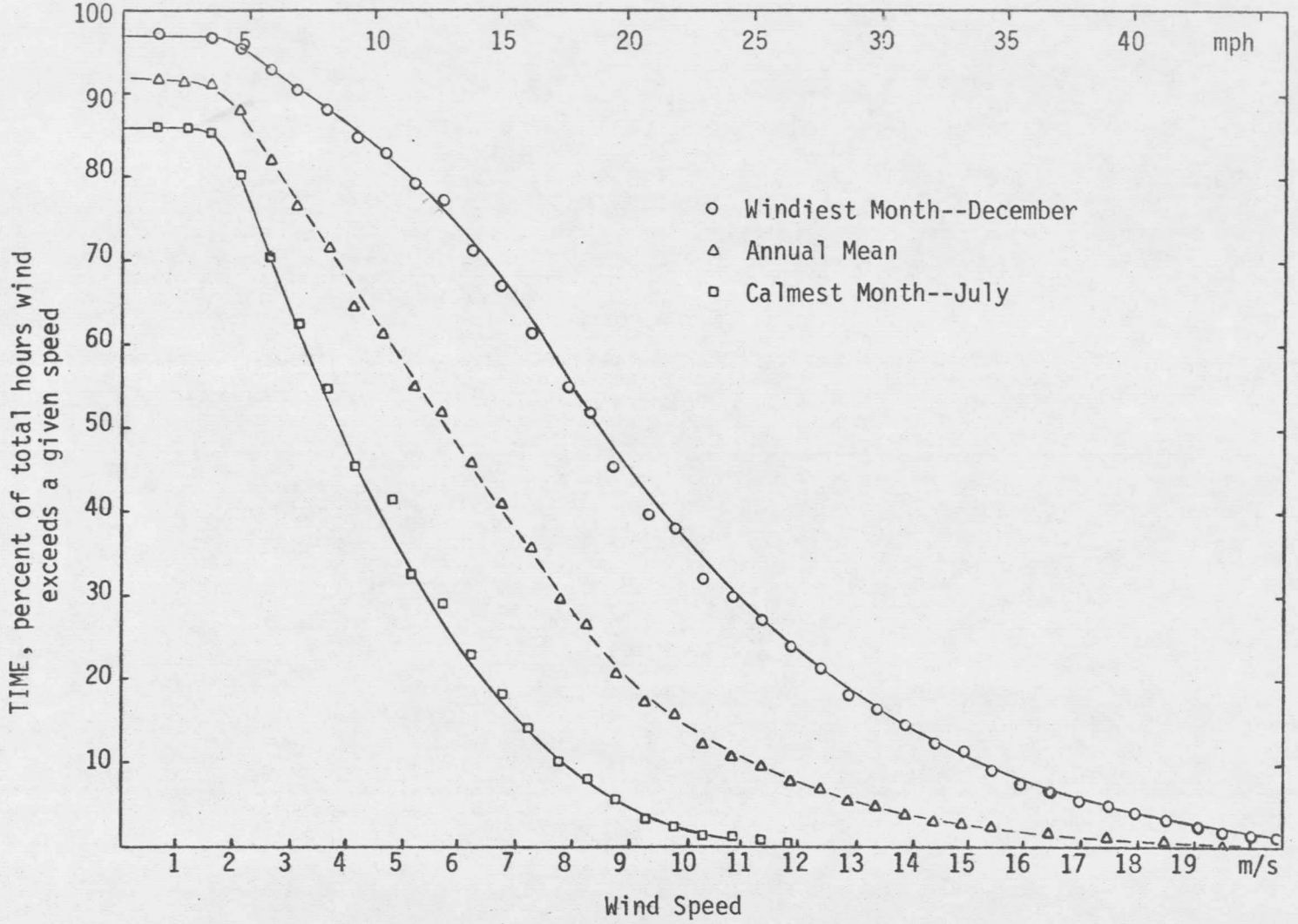


FIGURE 5 SPEED DURATION CURVE FOR LIVINGSTON

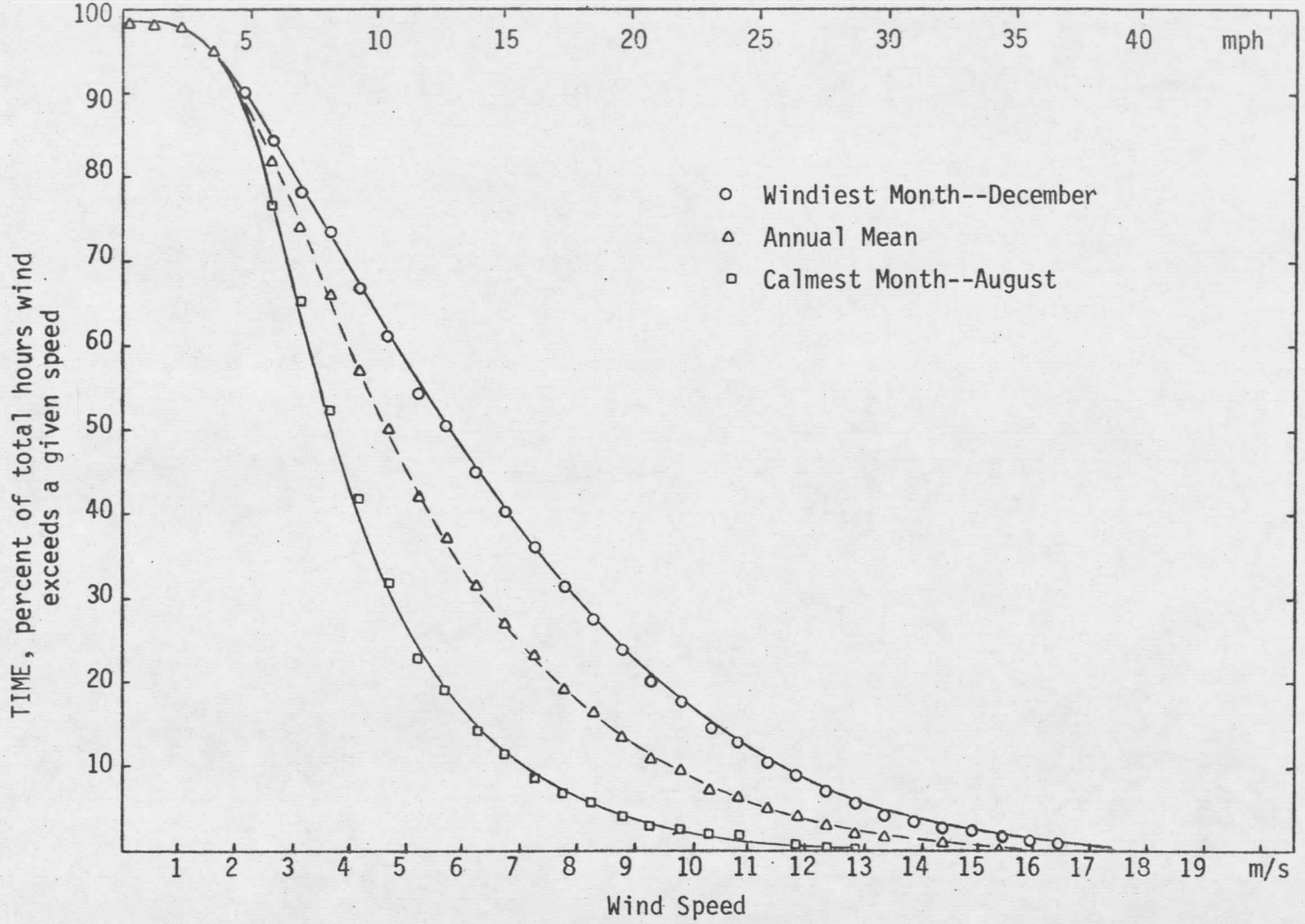


FIGURE 6 SPEED DURATION CURVE FOR GREAT FALLS

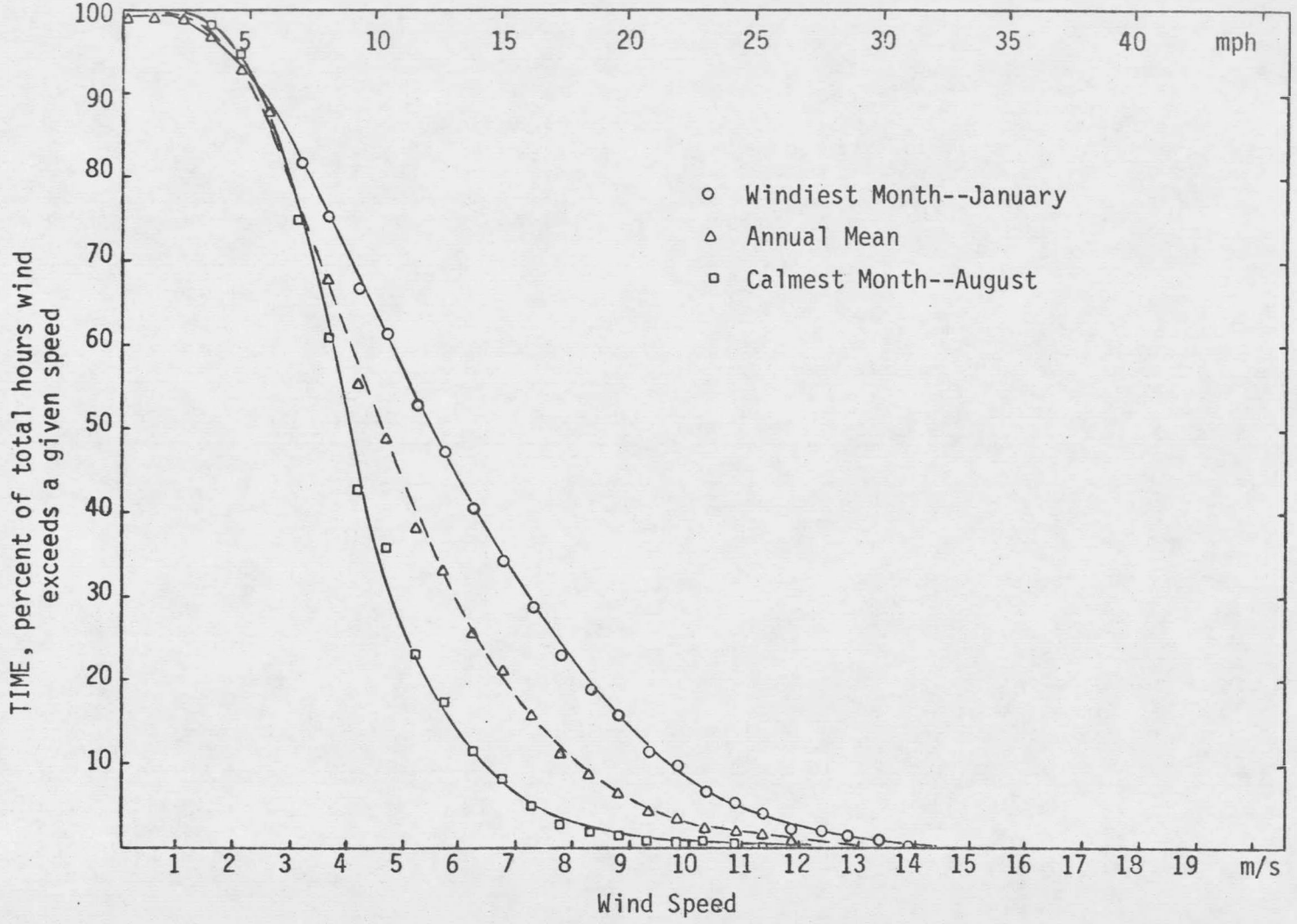


FIGURE 7 SPEED DURATION CURVE FOR BILLINGS

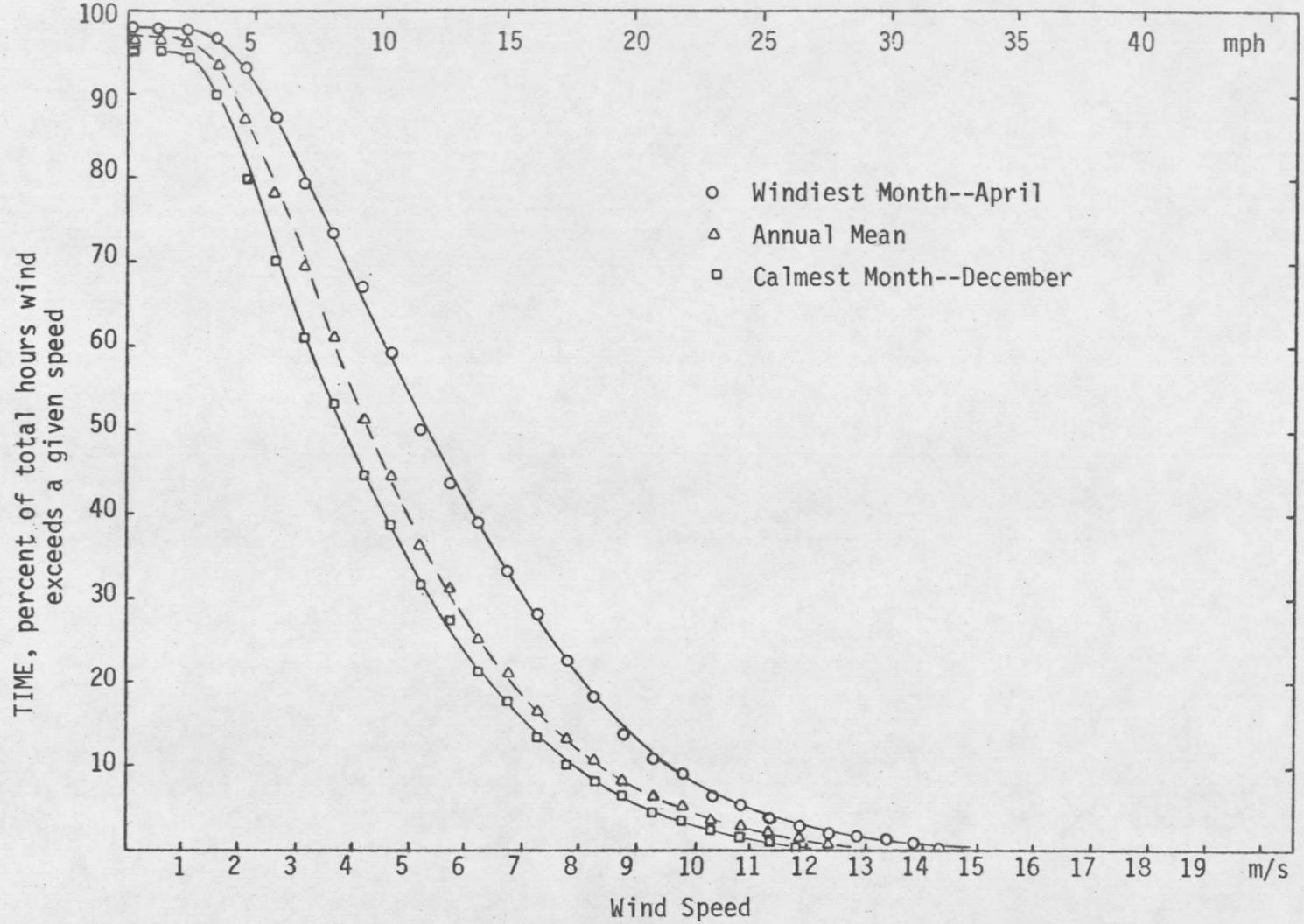


FIGURE 8 SPEED DURATION CURVE FOR GLASGOW

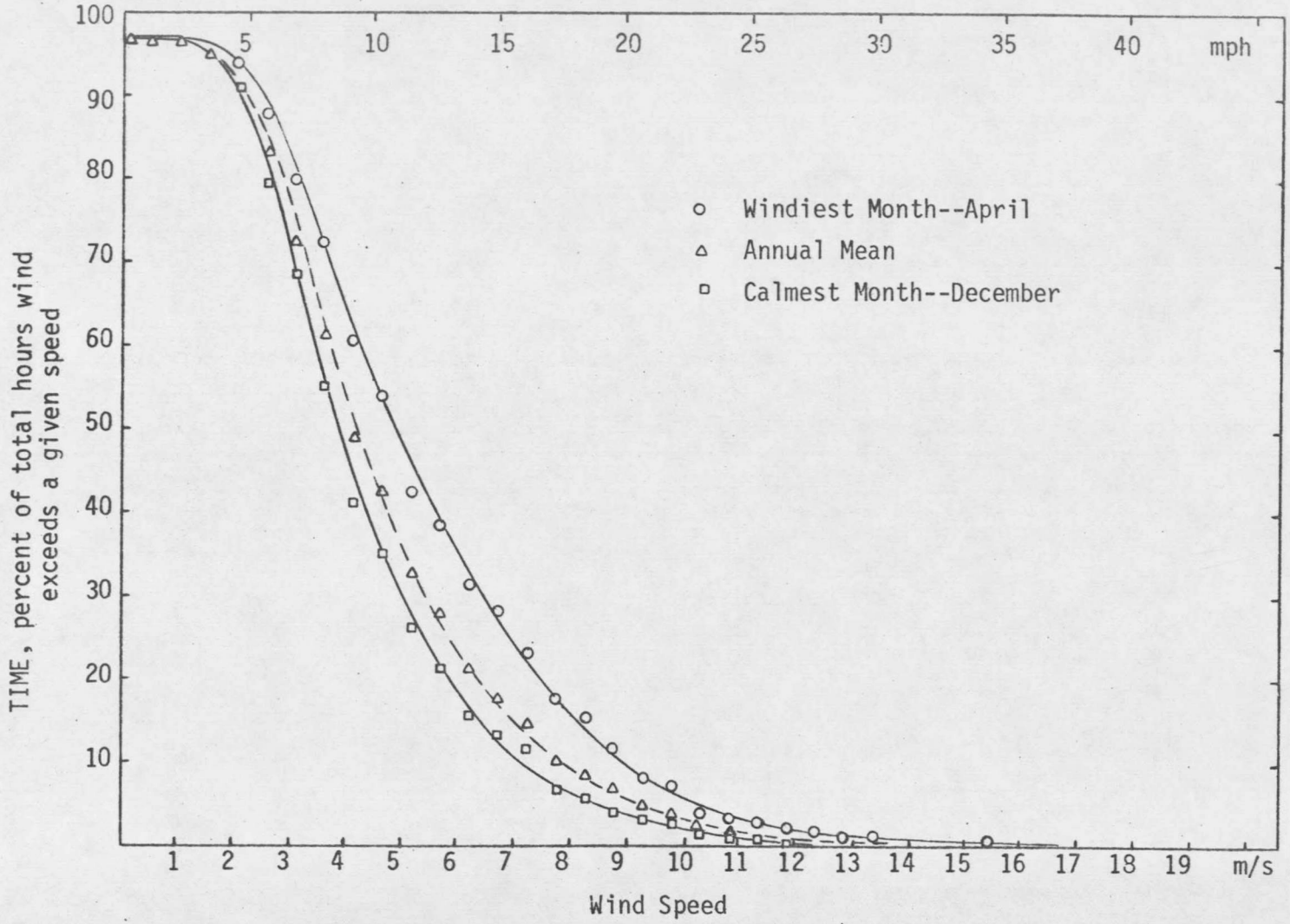


FIGURE 9 SPEED DURATION CURVE FOR MILES CITY

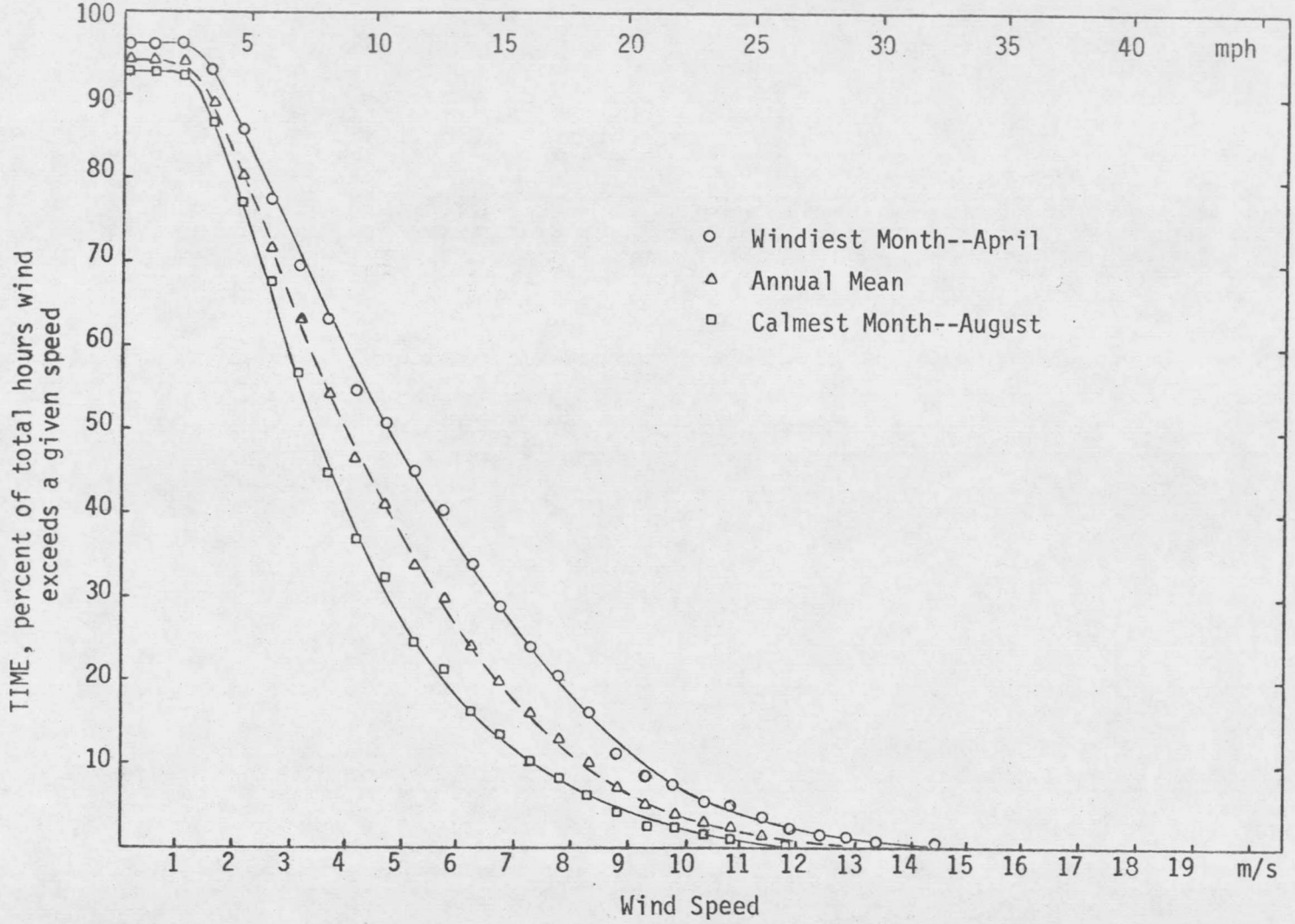


FIGURE 10 SPEED DURATION CURVE FOR HAVRE

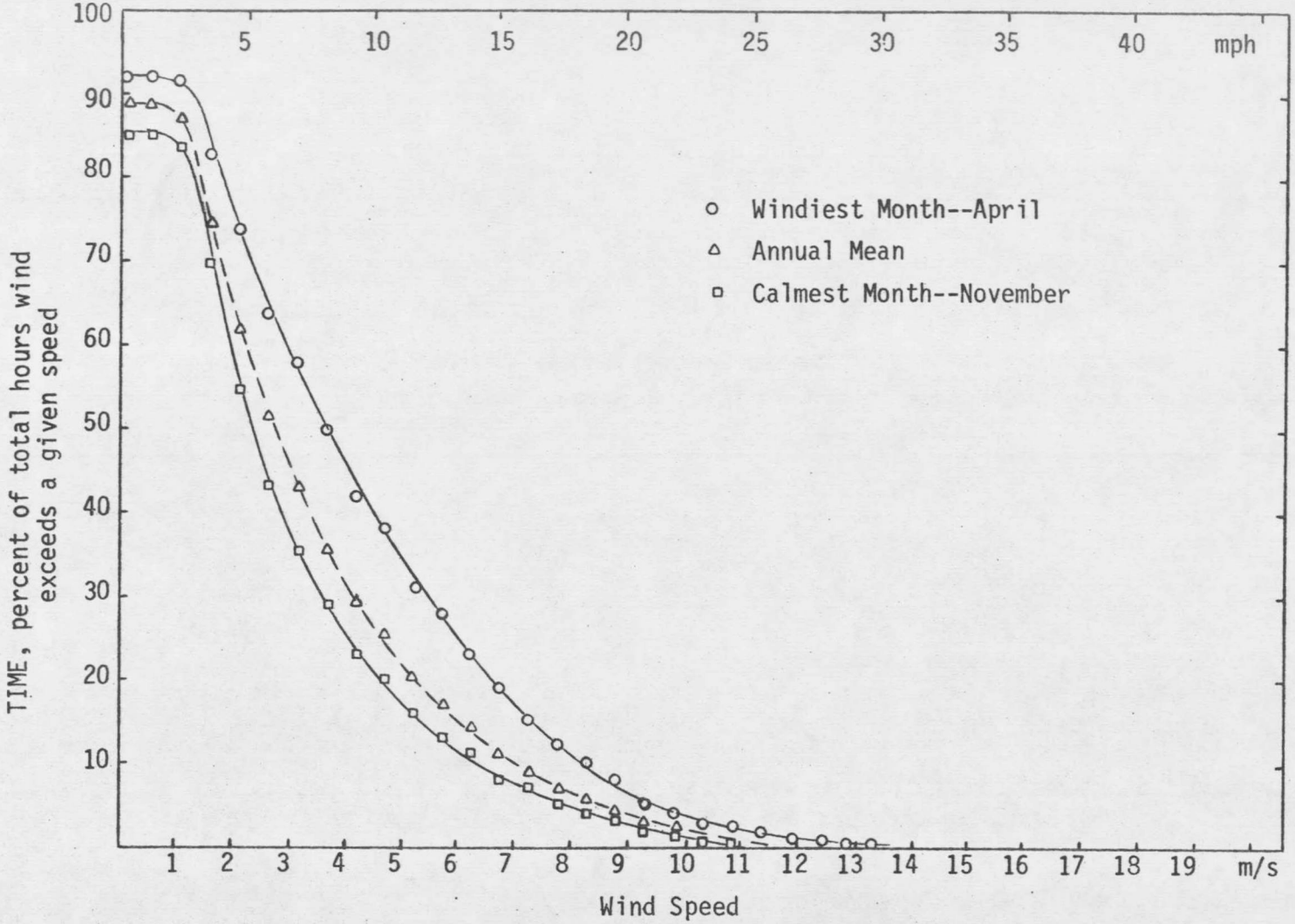


FIGURE 11 SPEED DURATION CURVE FOR HELENA

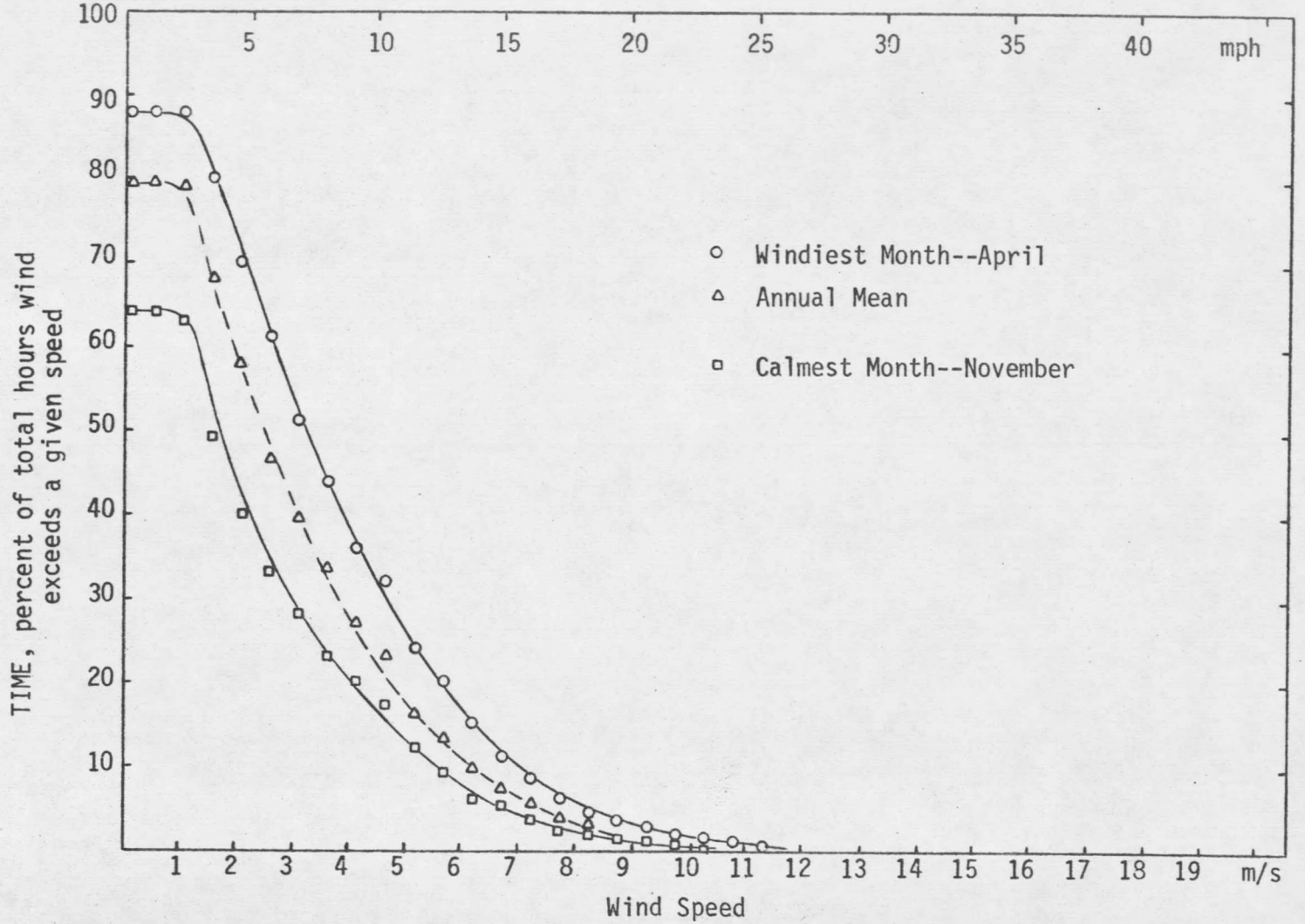


FIGURE 12 SPEED DURATION CURVE FOR KALISPELL

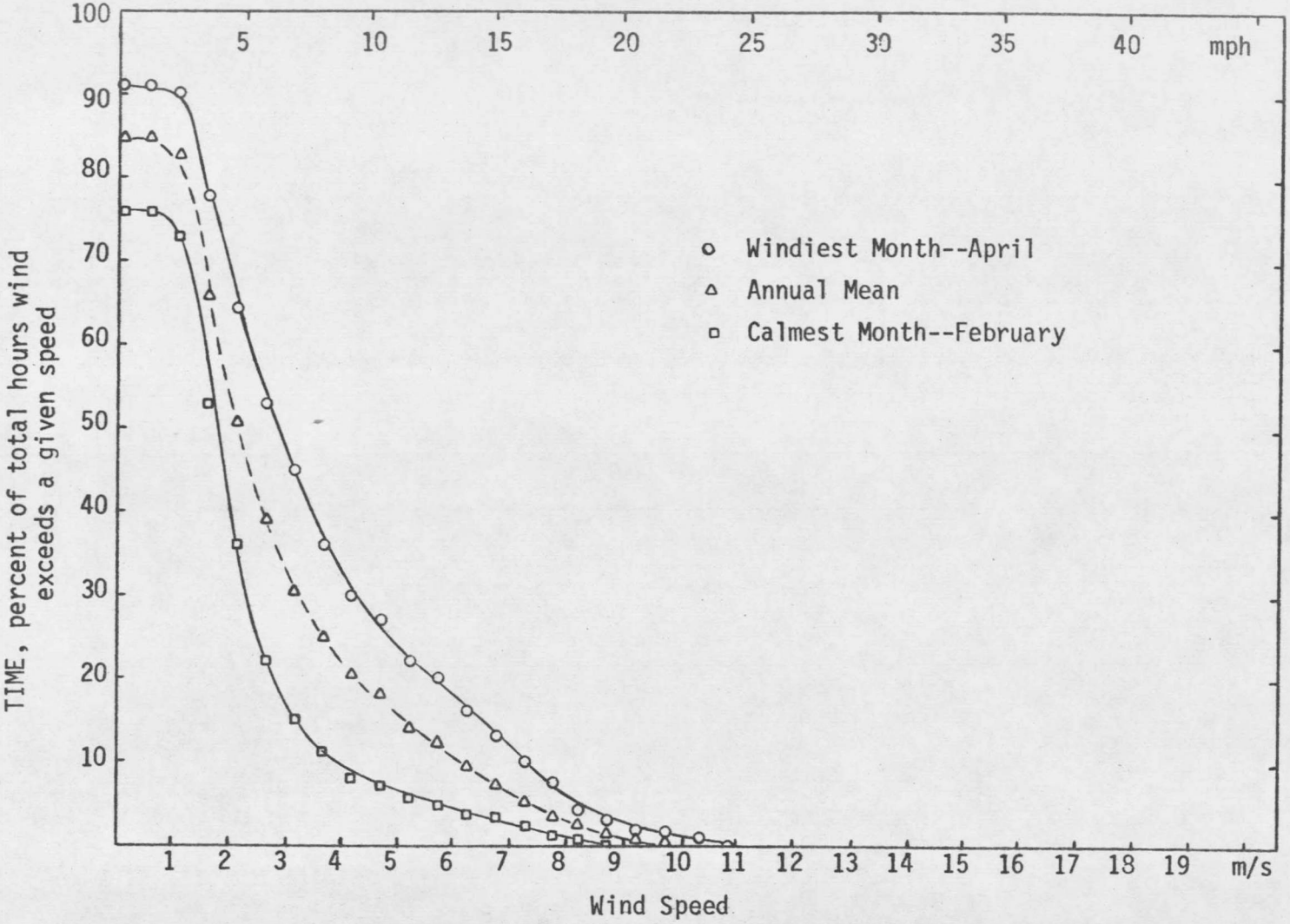


FIGURE 13 SPEED DURATION CURVE FOR MISSOULA

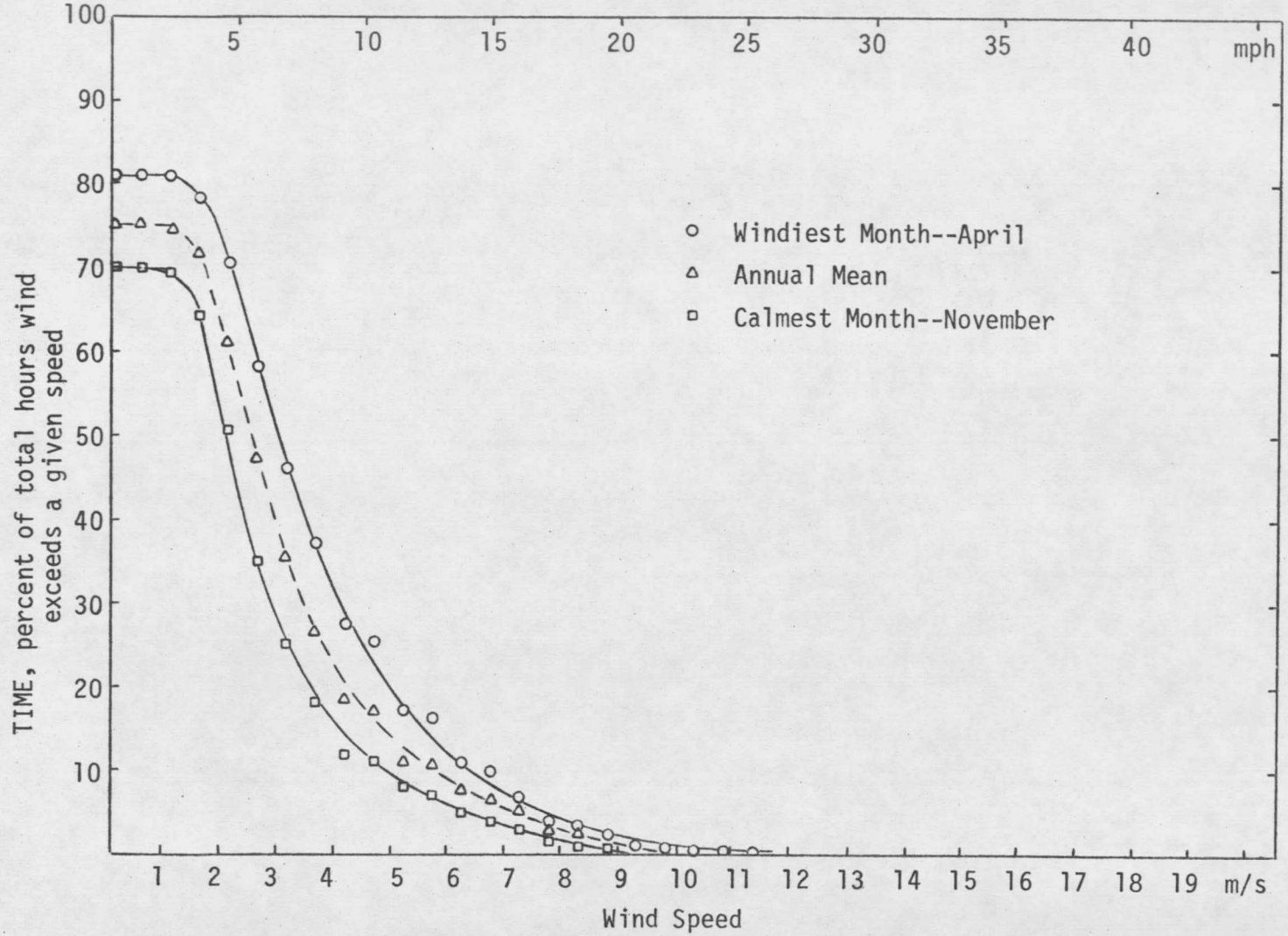


FIGURE 14 SPEED DURATION CURVE FOR BOZEMAN

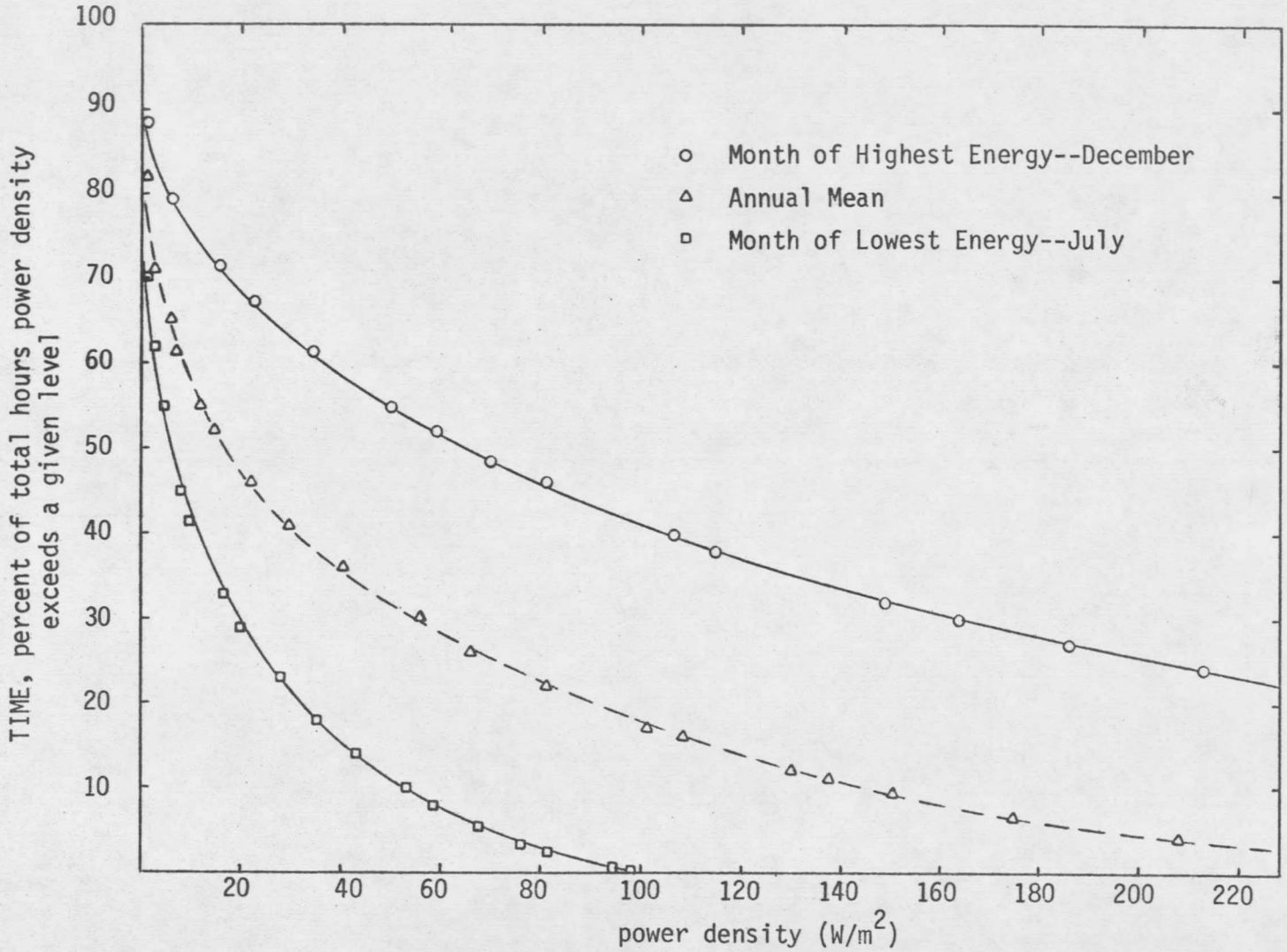


FIGURE 15 POWER DURATION CURVE FOR LIVINGSTON

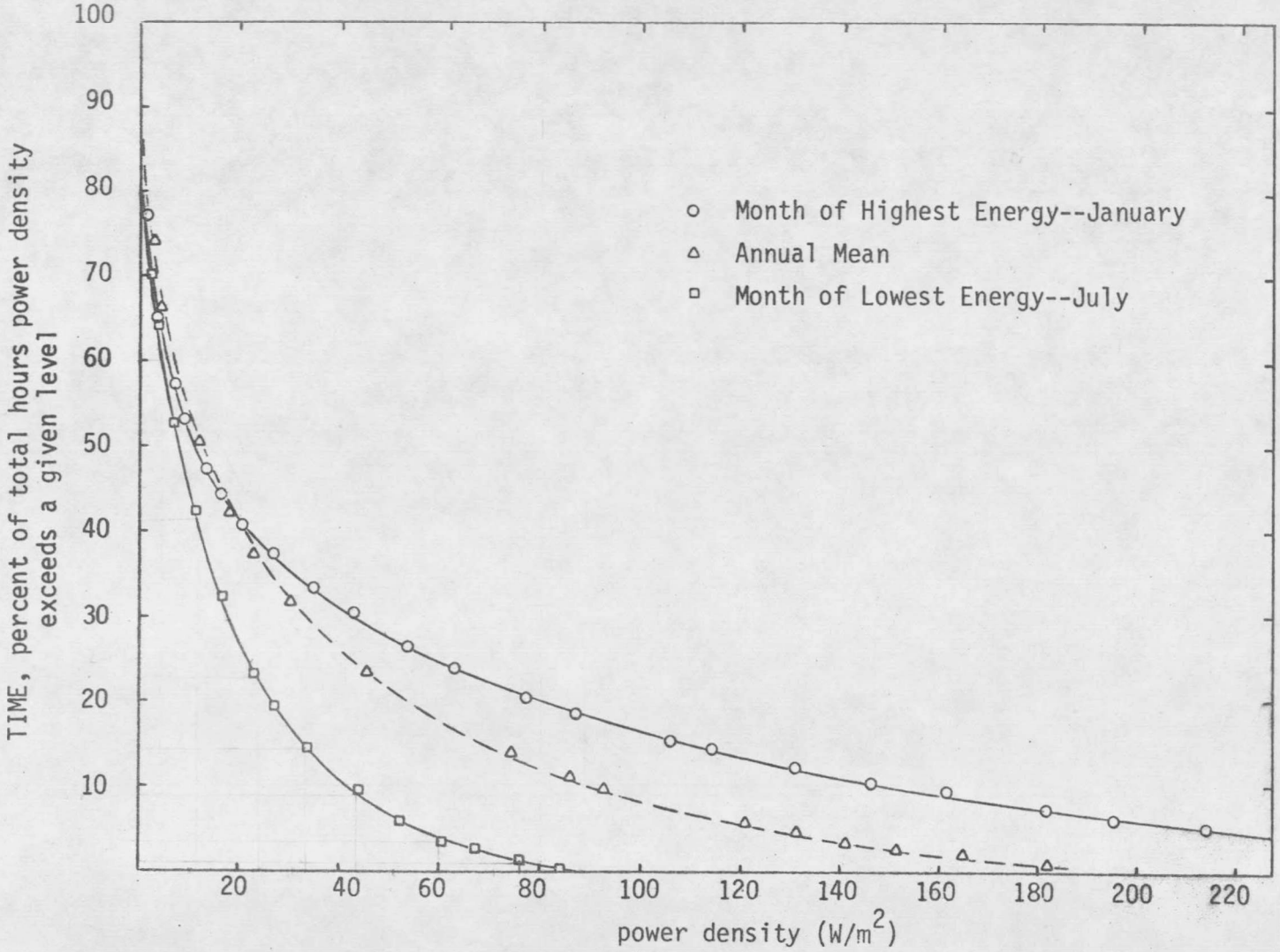


FIGURE 16 POWER DURATION CURVE FOR GREAT FALLS

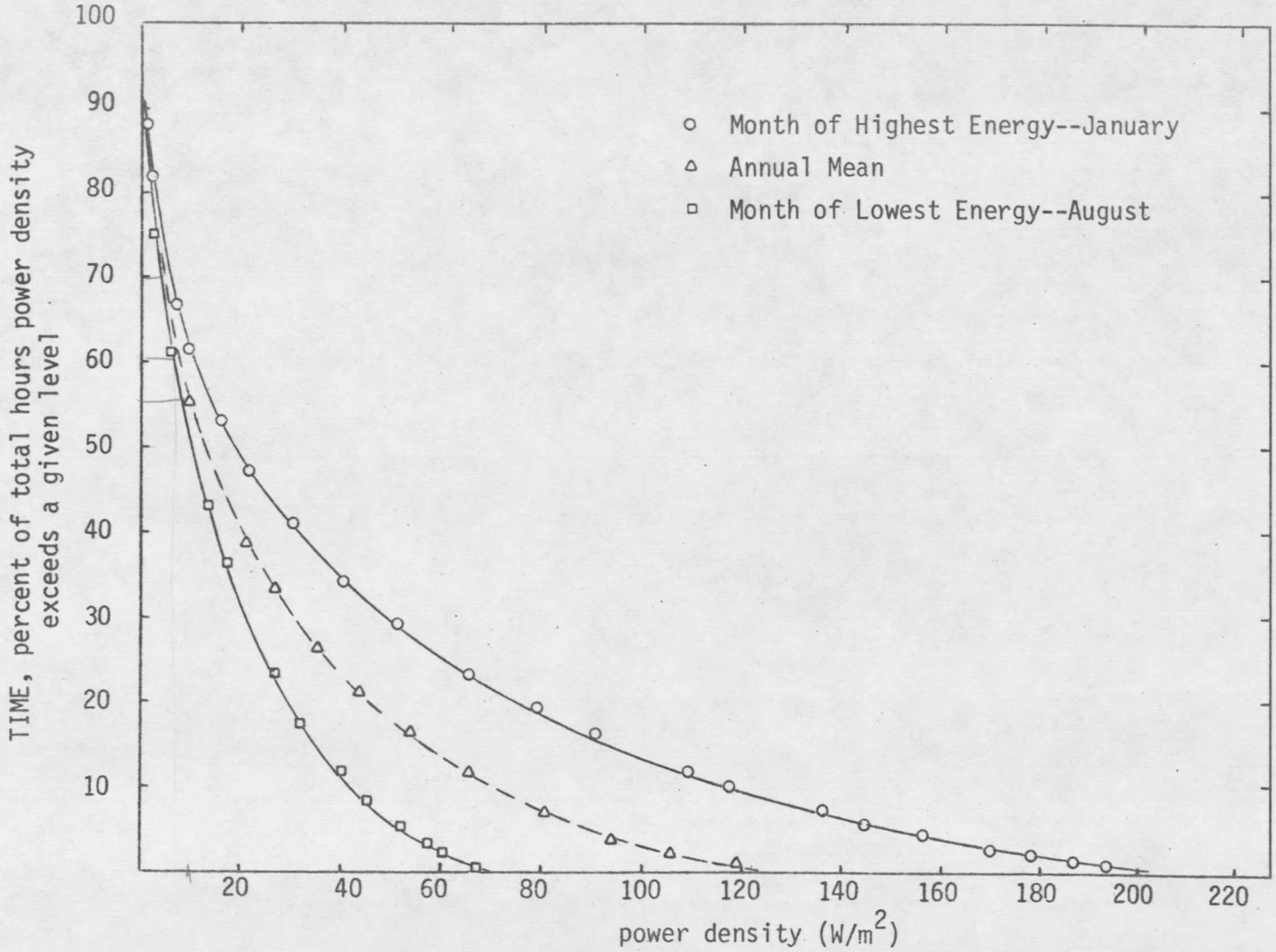


FIGURE 17 POWER DURATION CURVE FOR BILLINGS

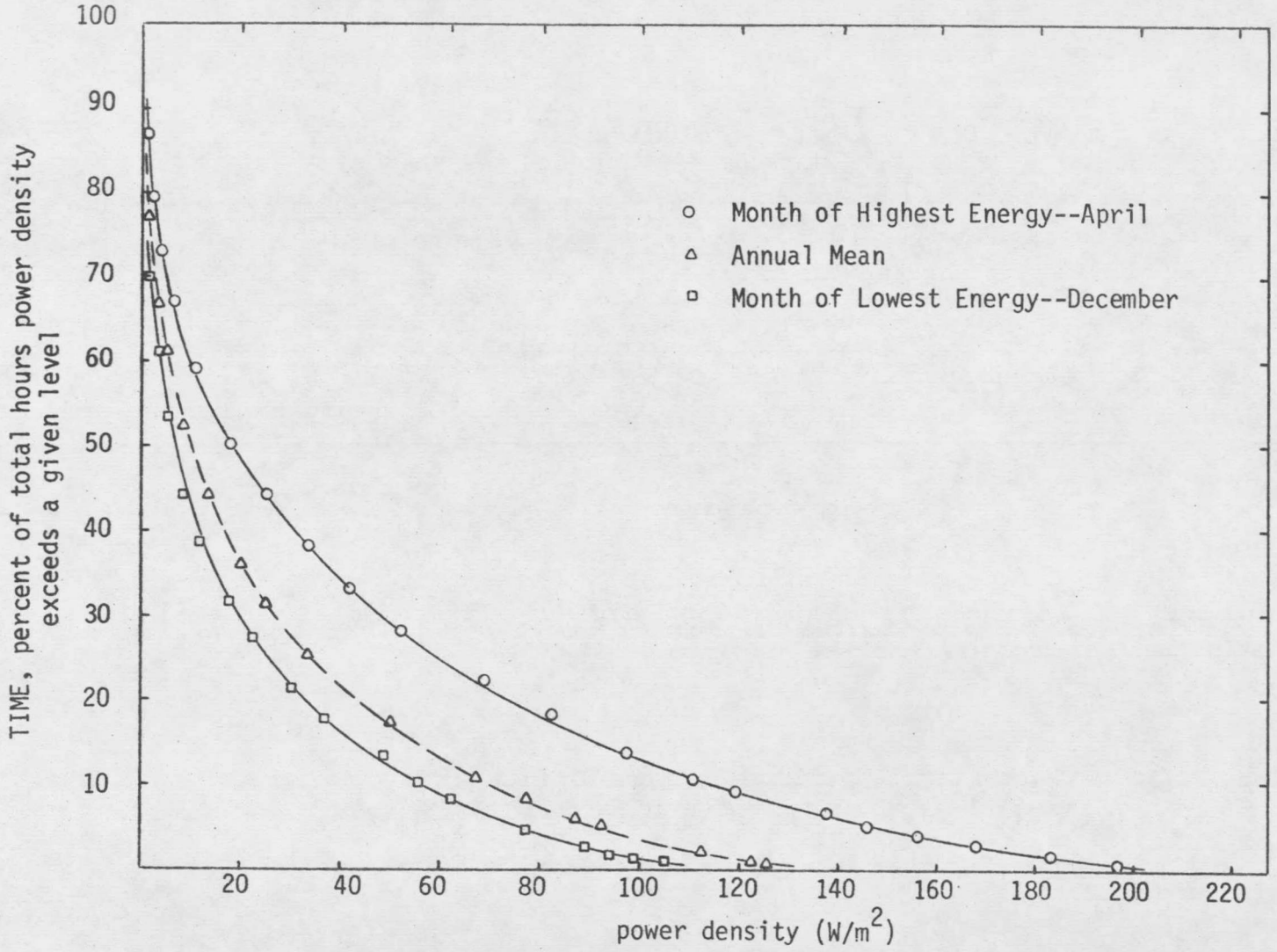


FIGURE 18 POWER DURATION CURVE FOR GLASGOW

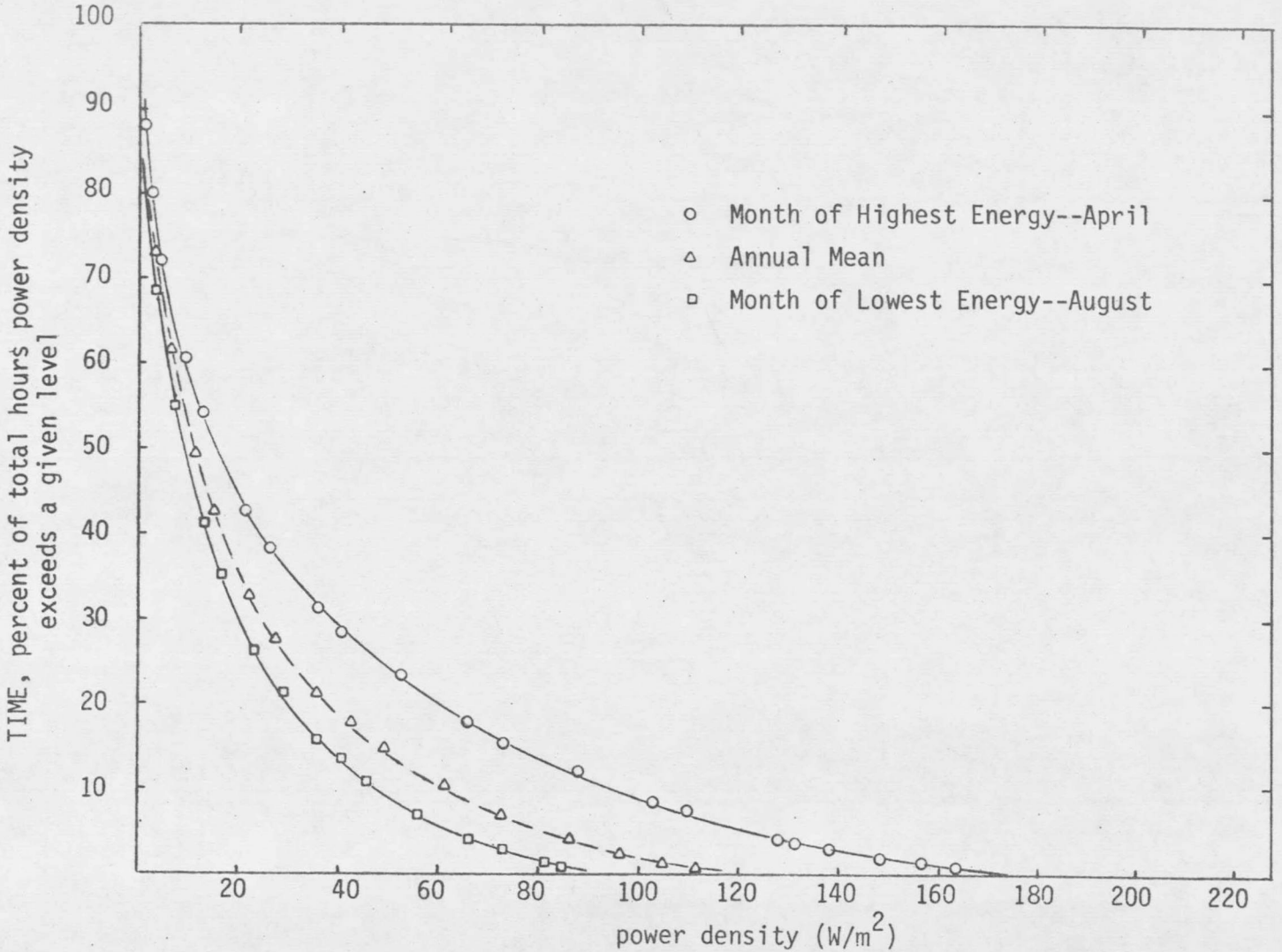


FIGURE 19 POWER DURATION CURVE FOR MILES CITY

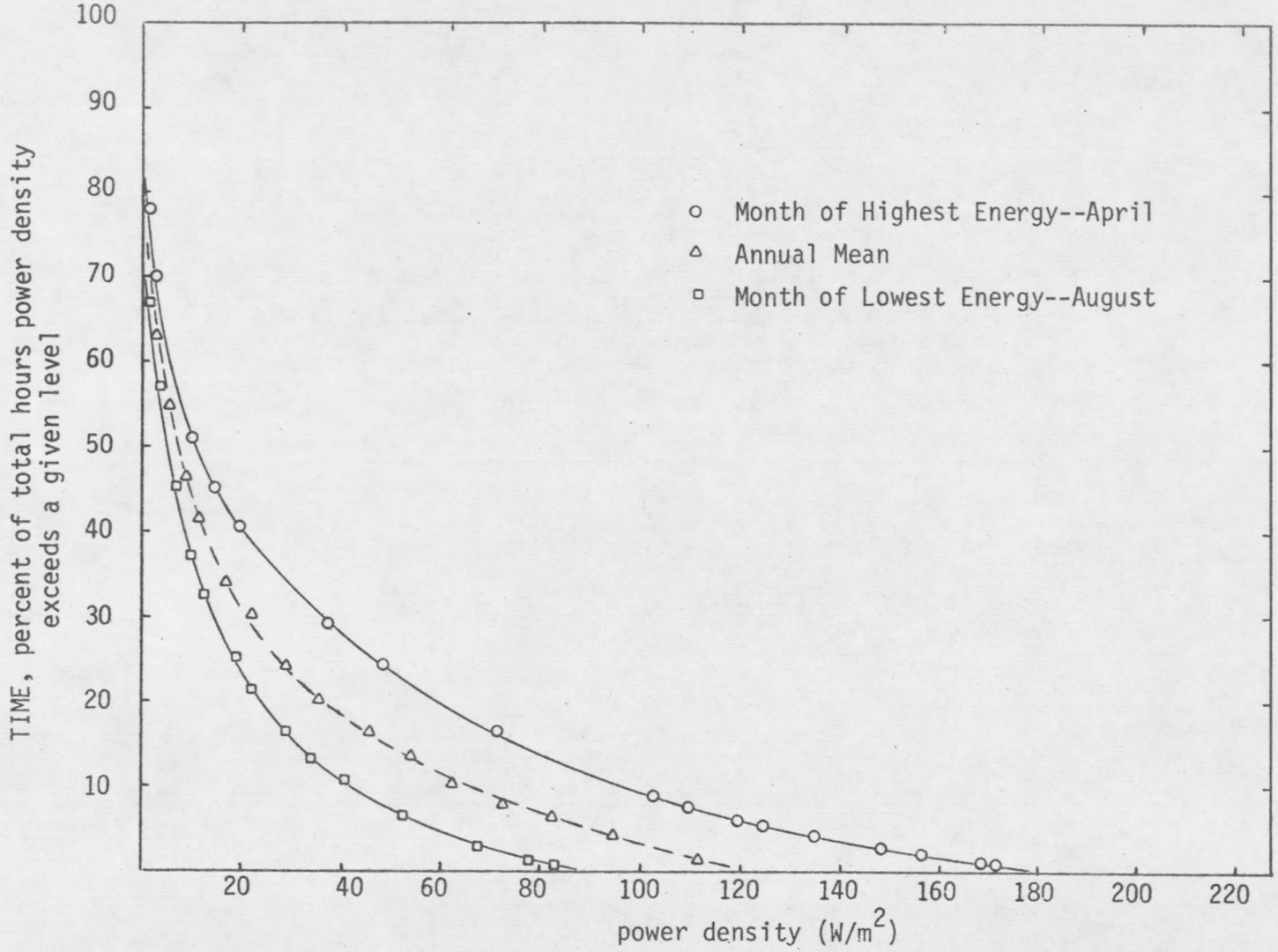


FIGURE 20 POWER DURATION CURVE FOR HAVRE

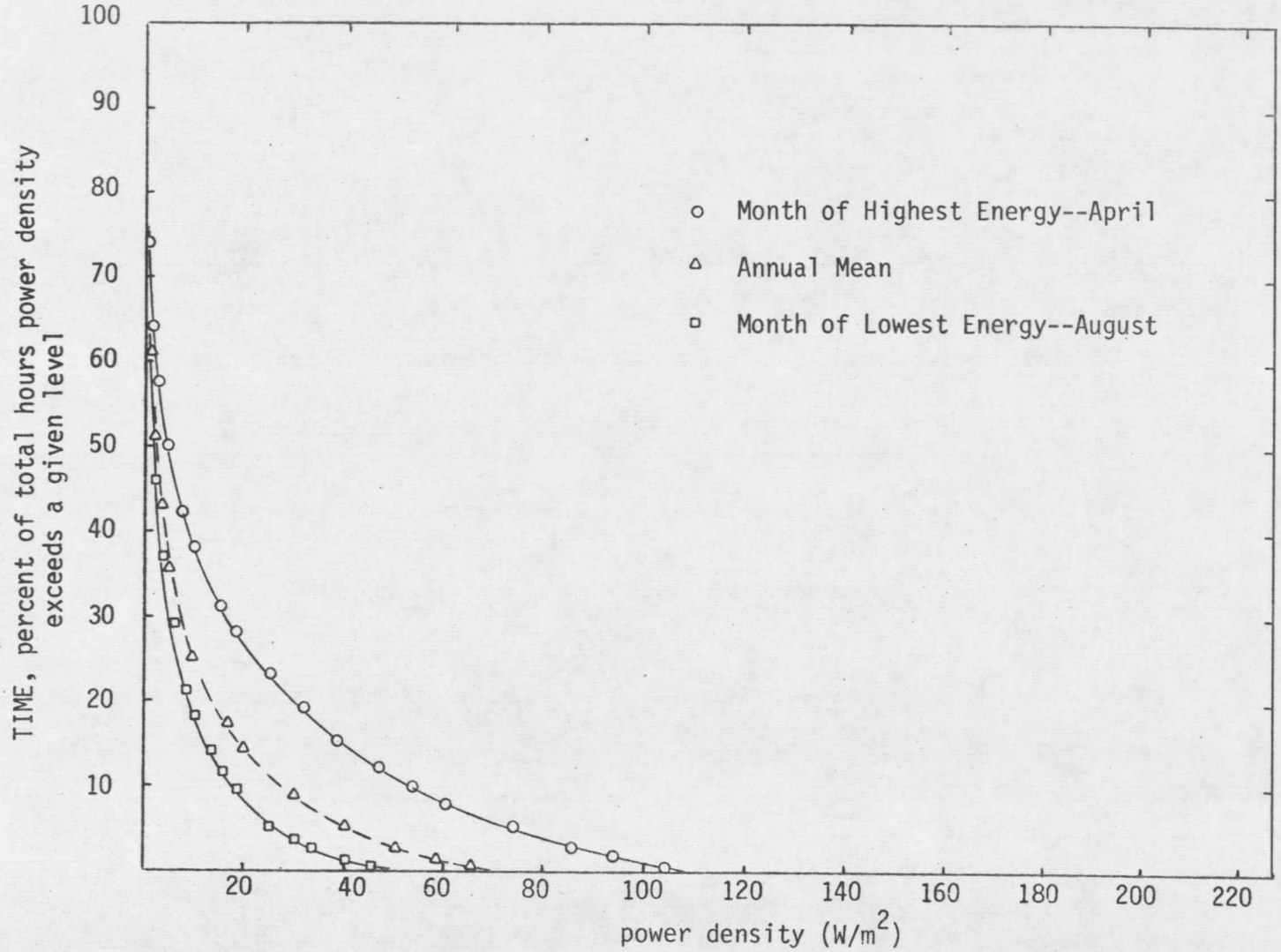


FIGURE 21 POWER DURATION CURVE FOR HELENA

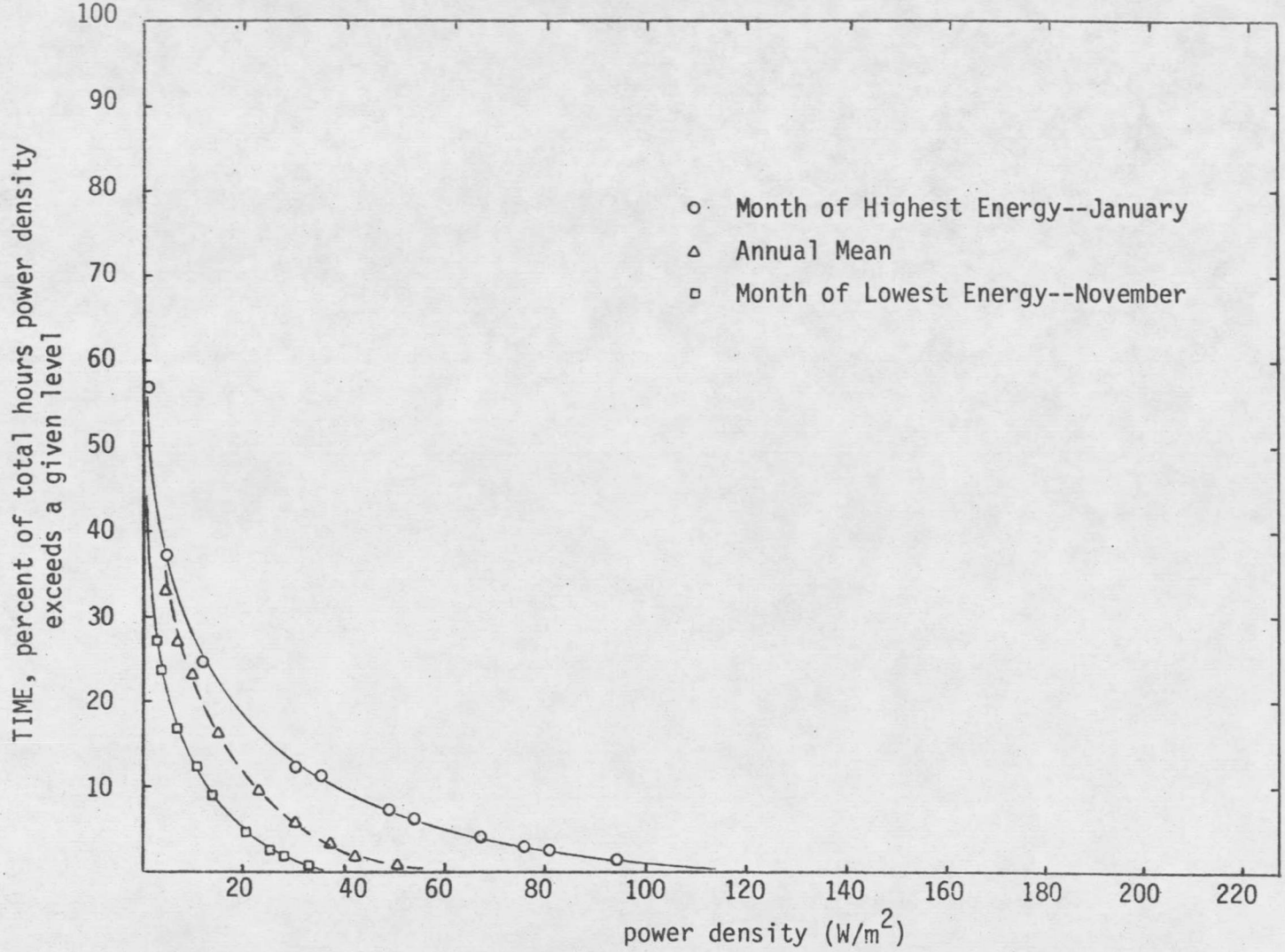


FIGURE 22 POWER DURATION CURVE FOR KALISPELL

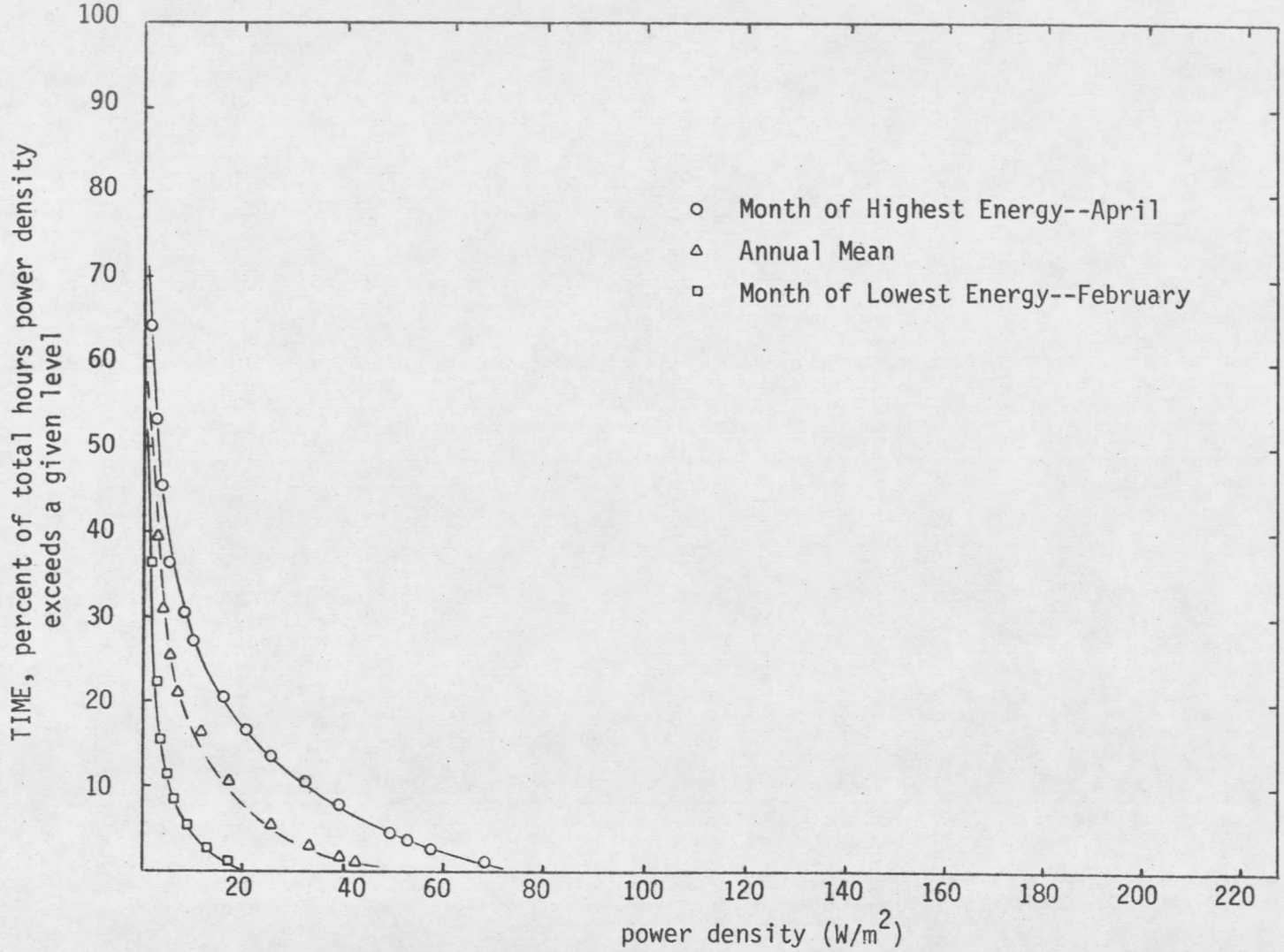


FIGURE 23 POWER DURATION CURVE FOR MISSOULA

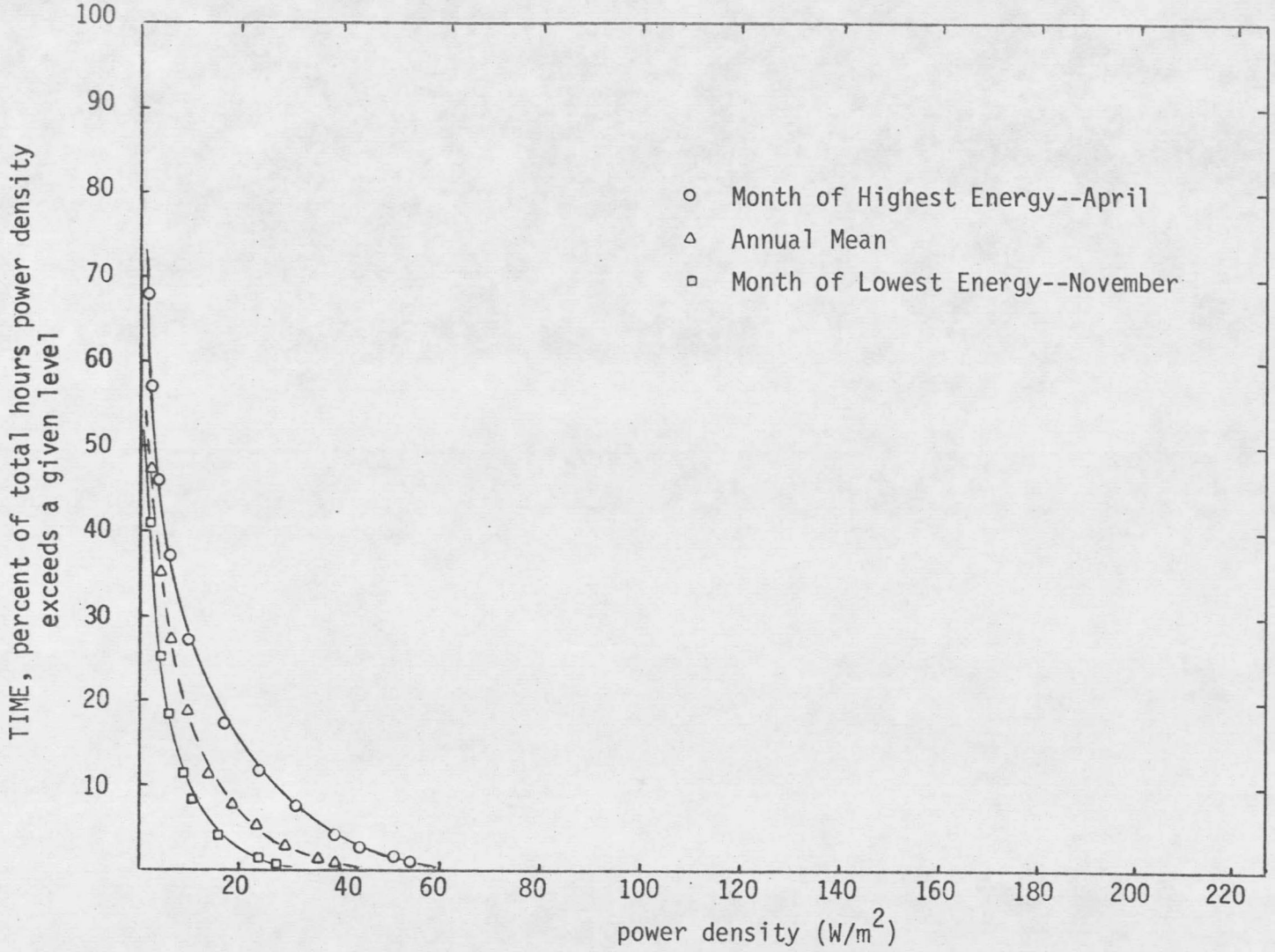


FIGURE 24 POWER DURATION CURVE FOR BOZEMAN

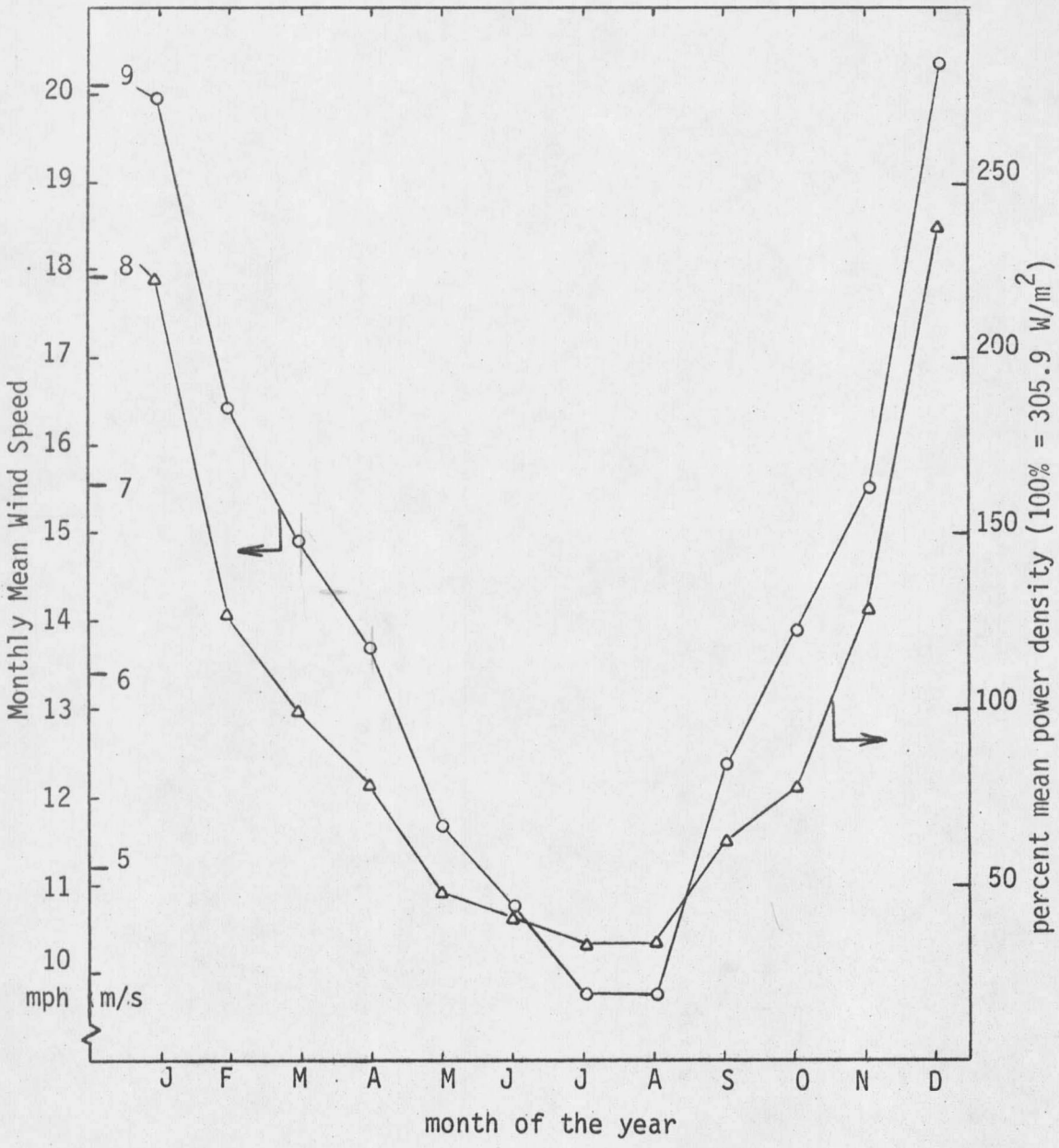


FIGURE 25 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT LIVINGSTON

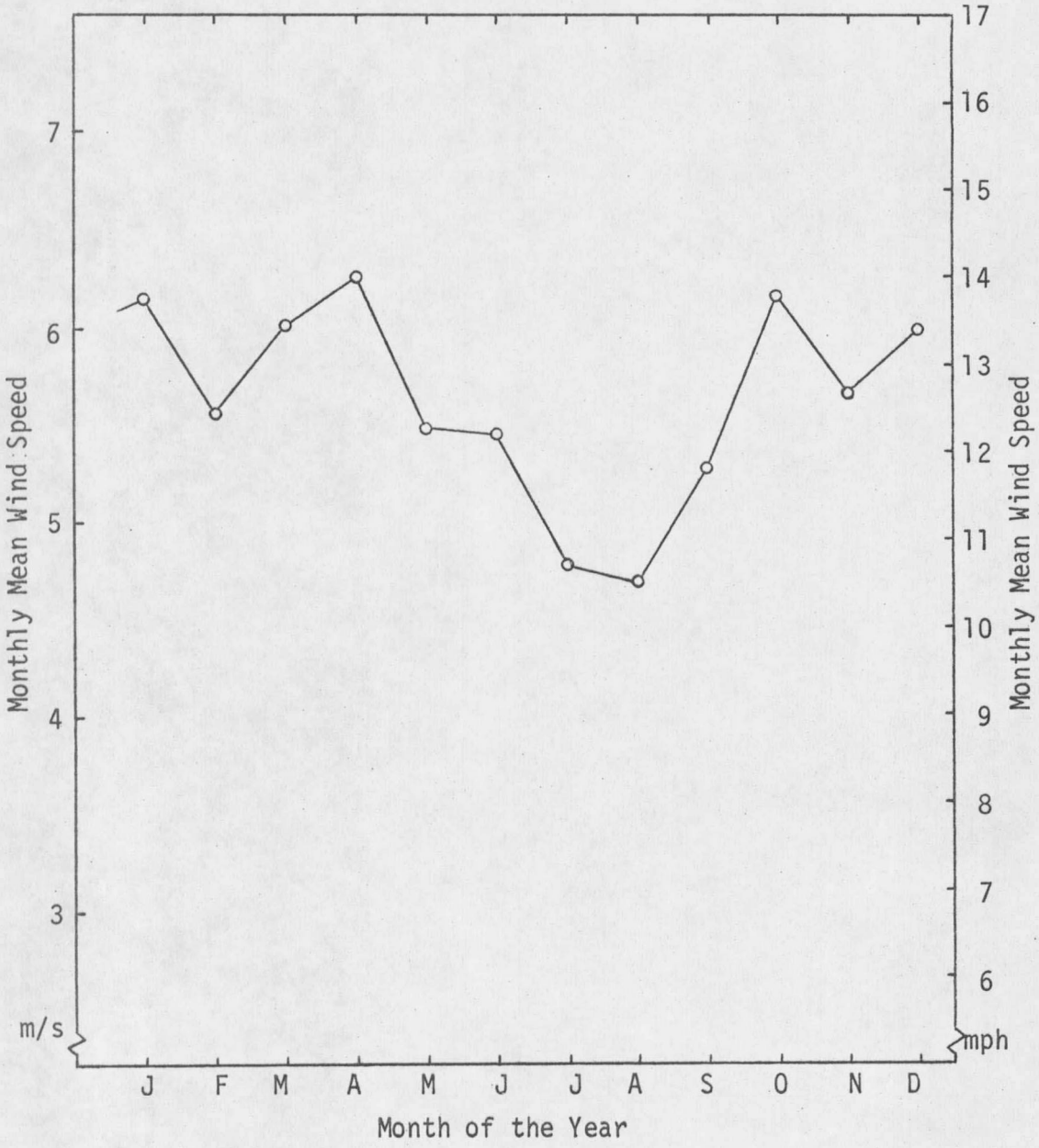


FIGURE 26 SEASONAL VARIATION IN MEAN WIND SPEED AT CUT BANK

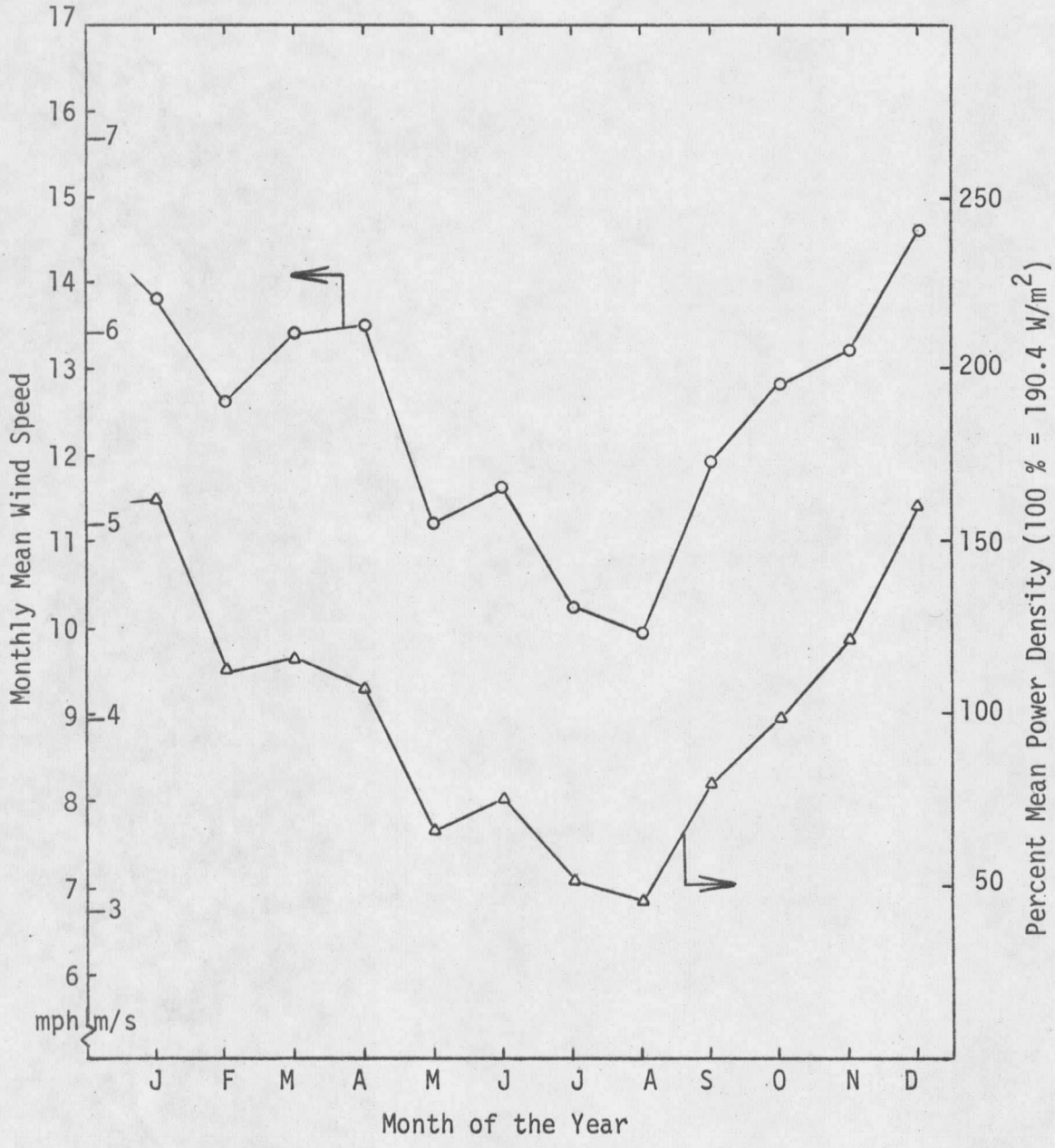


FIGURE 27 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT GREAT FALLS

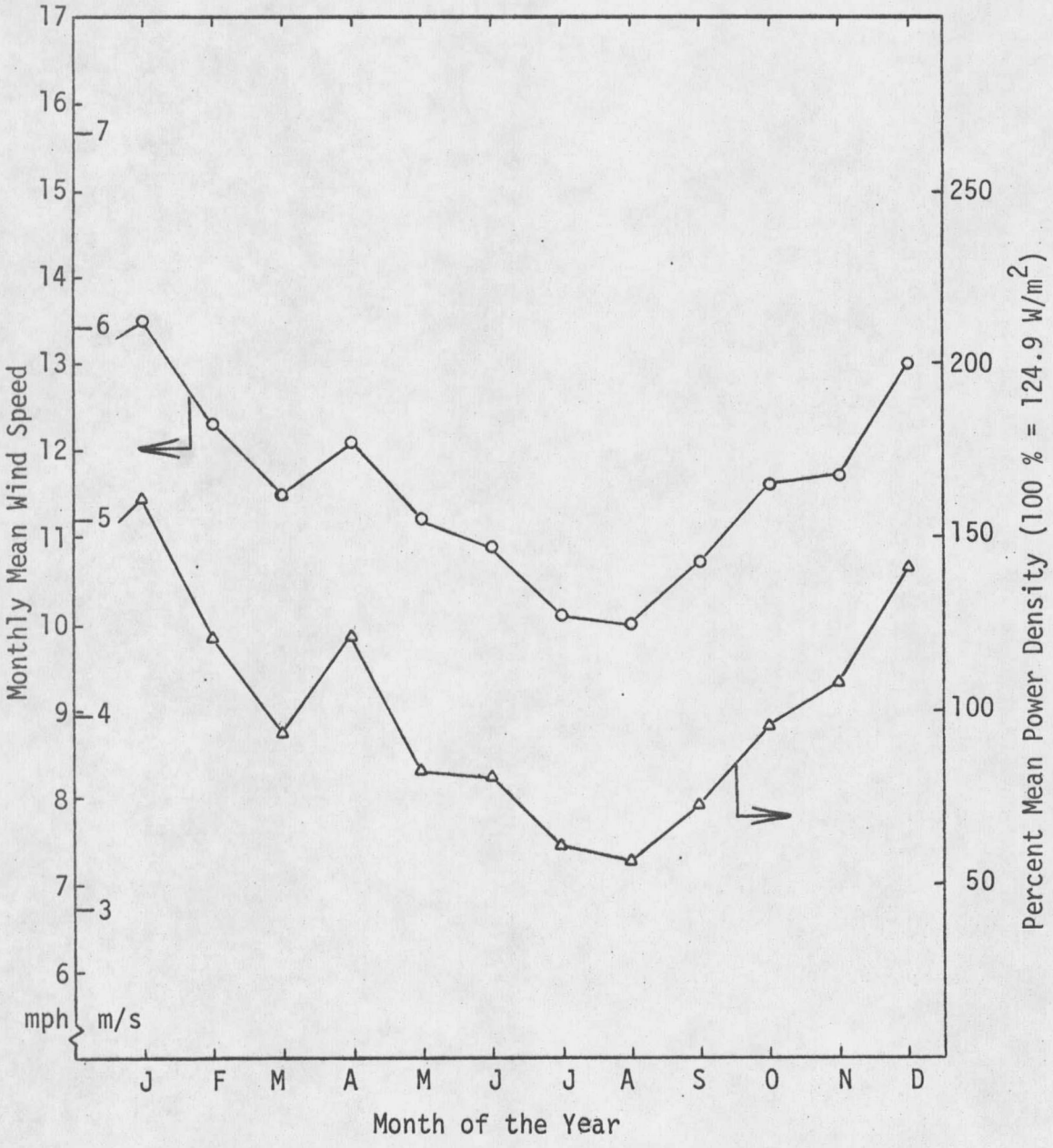


FIGURE 28 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT BILLINGS

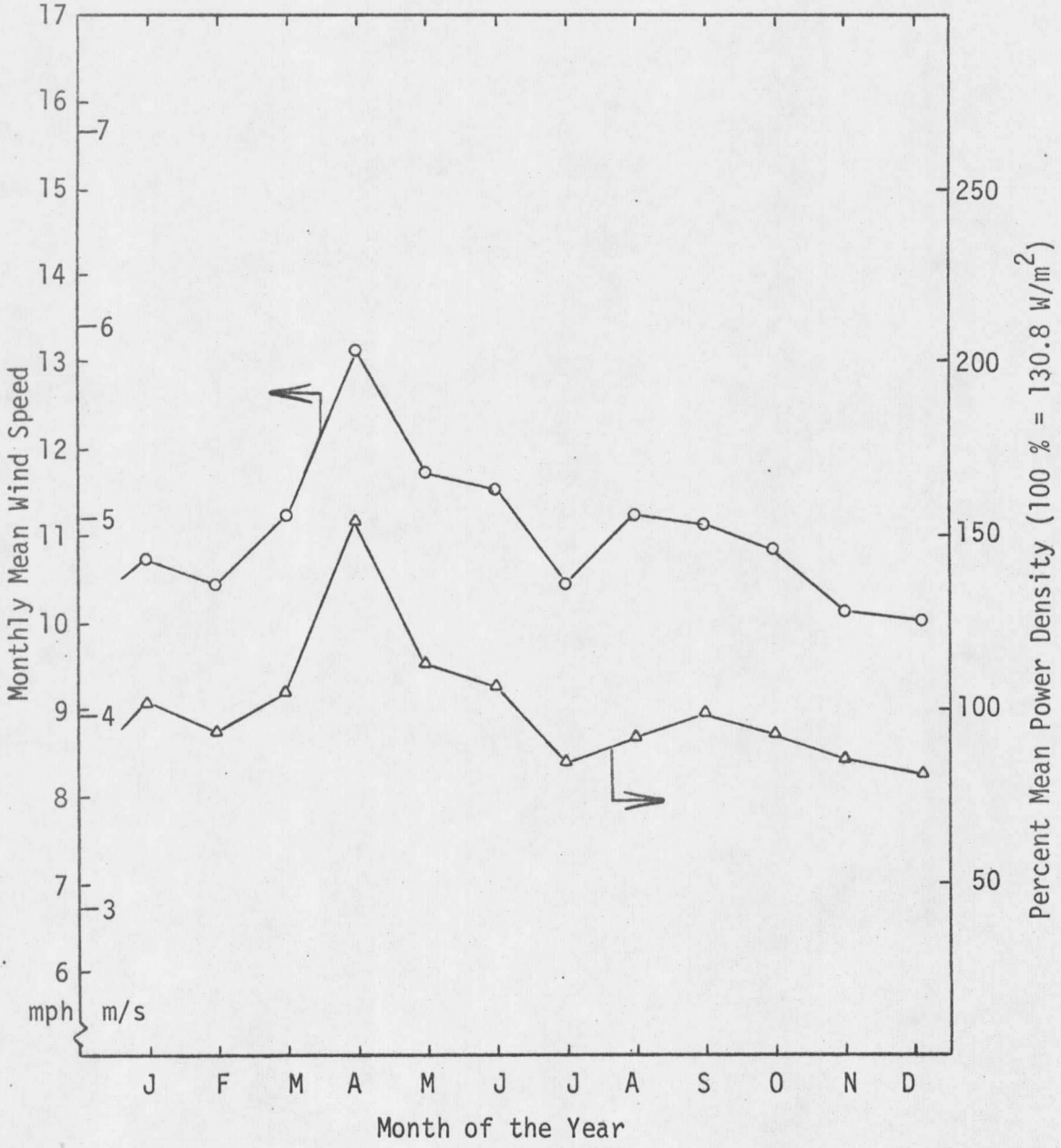


FIGURE 29 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT GLASGOW

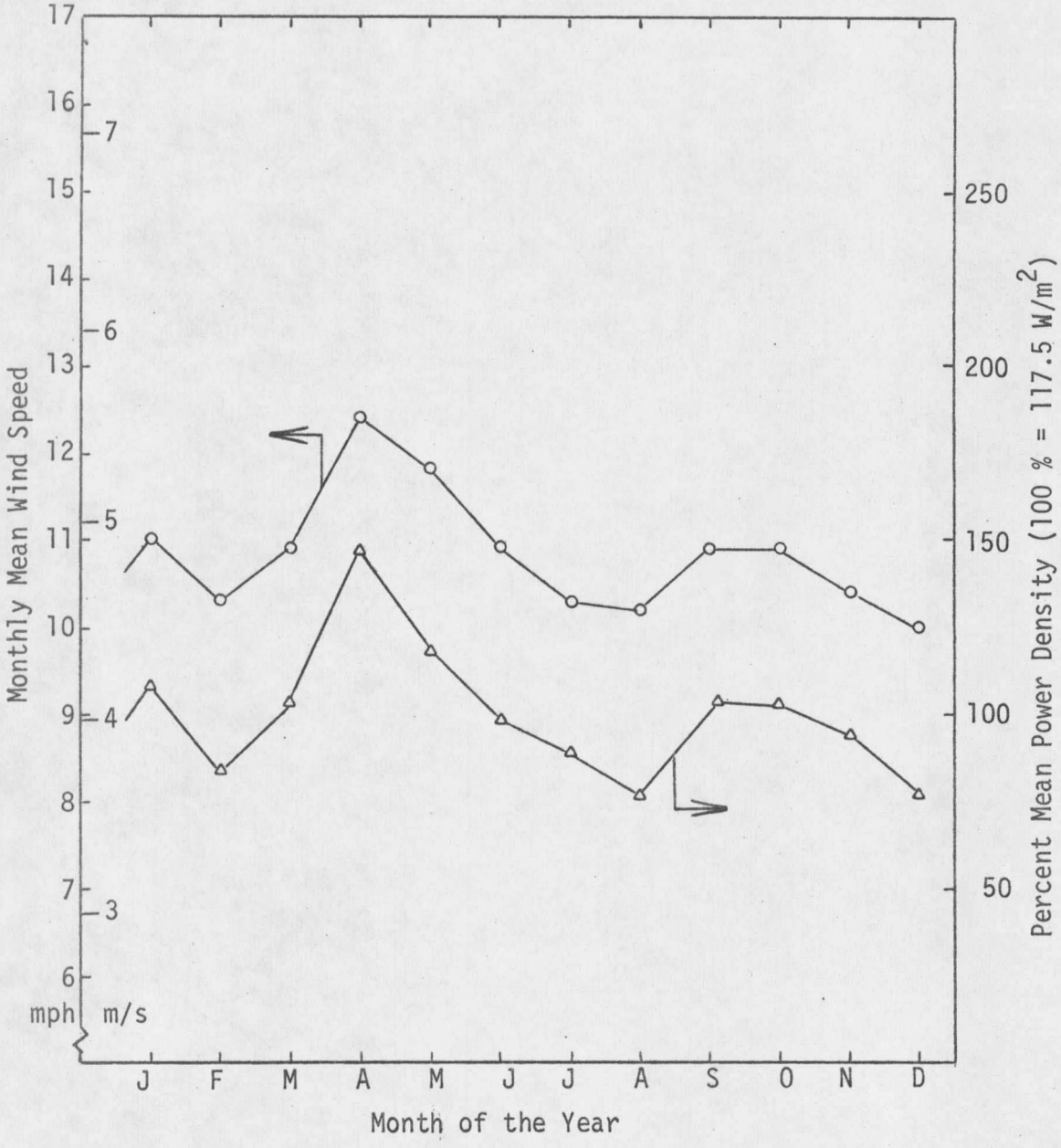


FIGURE 30 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT MILES CITY

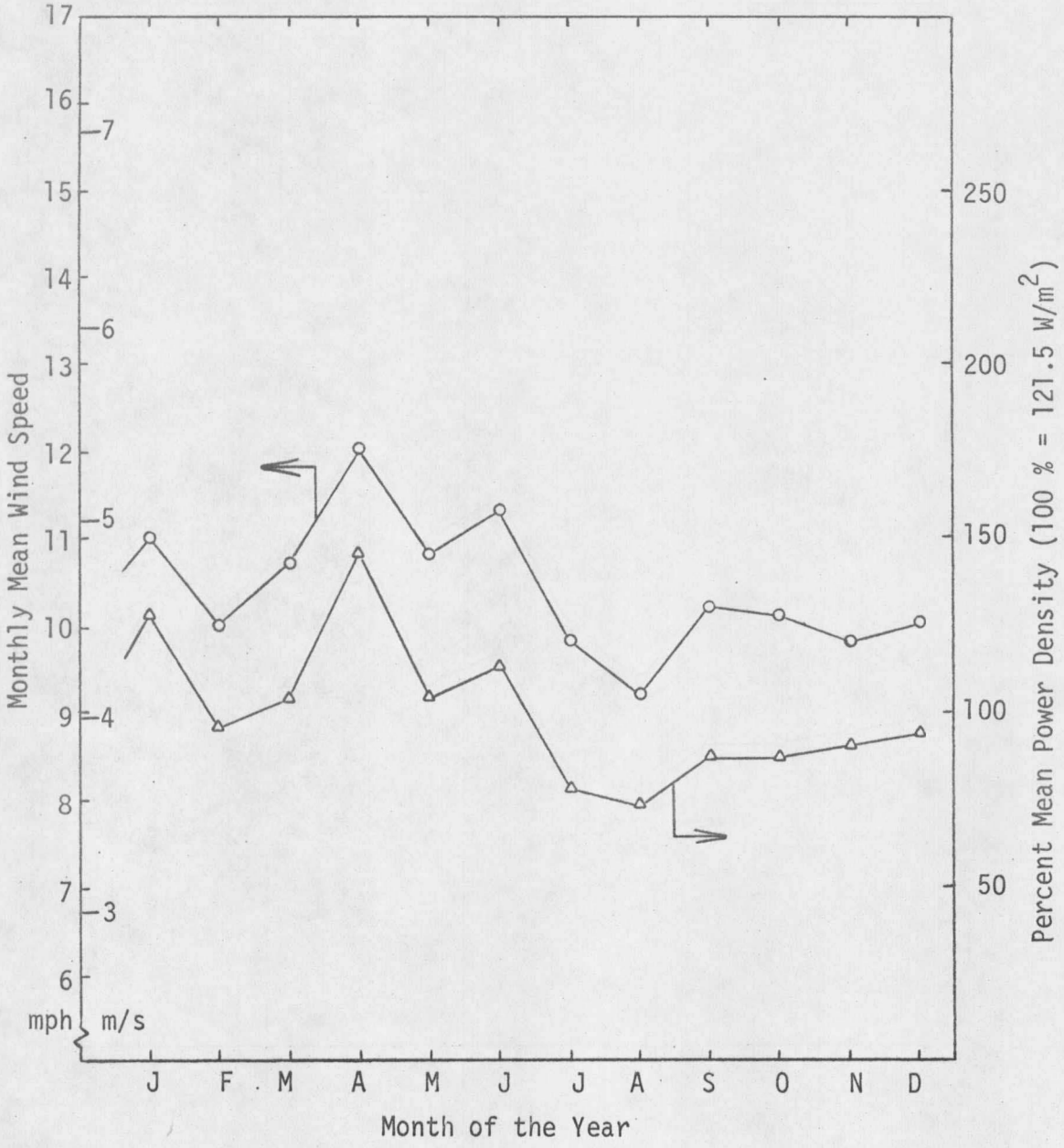


FIGURE 31 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT HAVRE

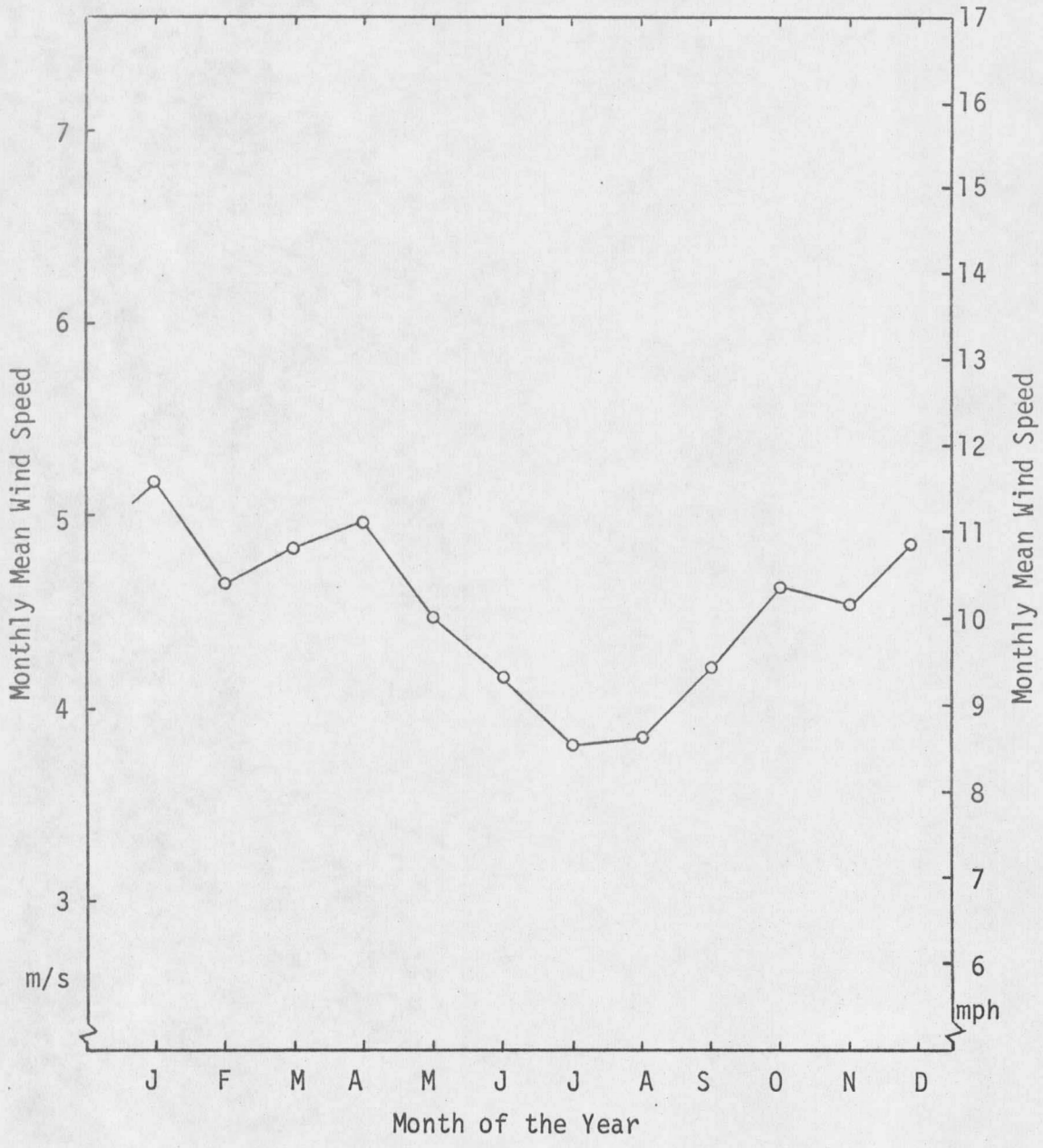


FIGURE 32 SEASONAL VARIATION IN MEAN WIND SPEED AT LEWISTOWN

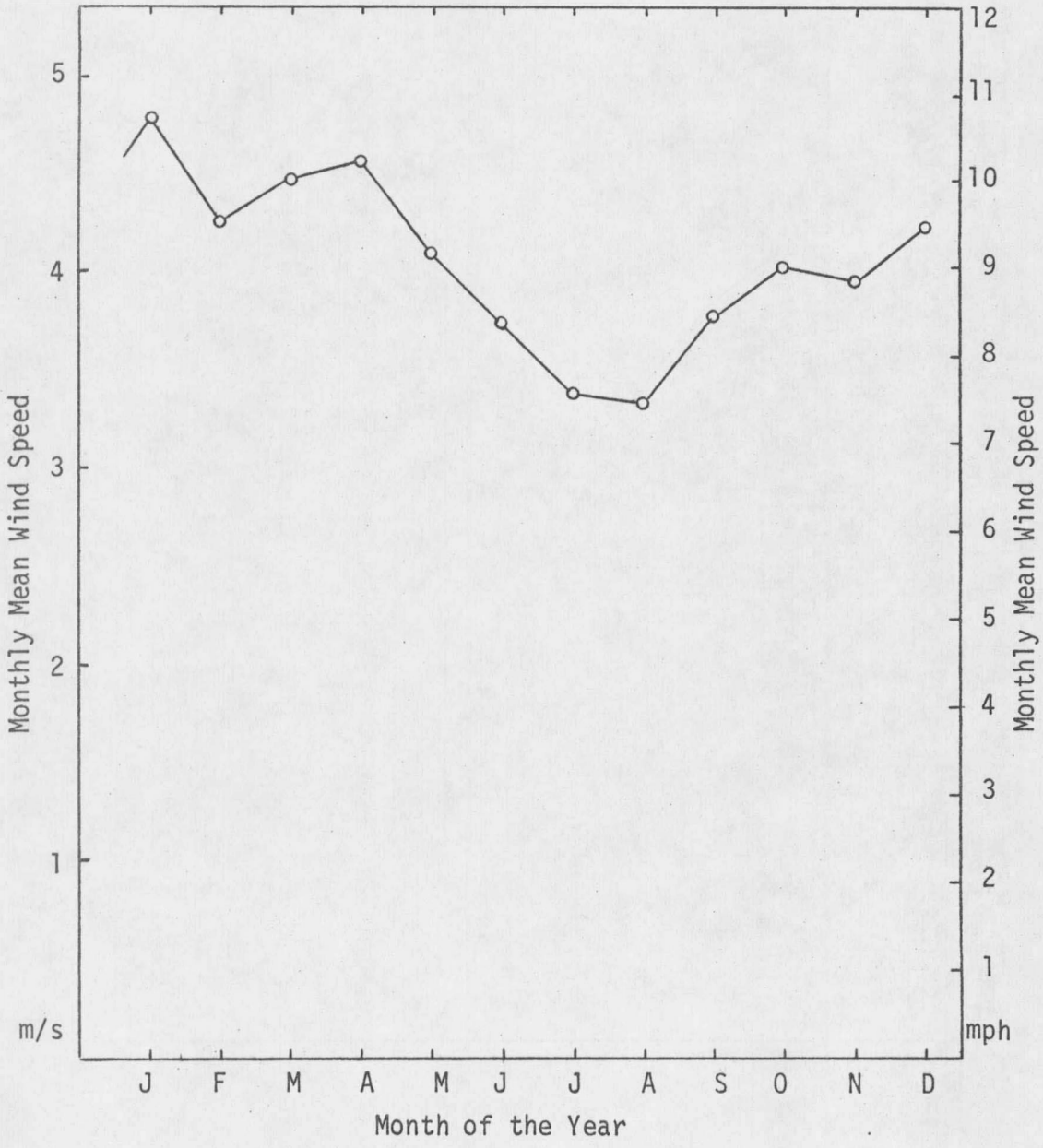


FIGURE 33 SEASONAL VARIATION IN MEAN WIND SPEED AT DILLON

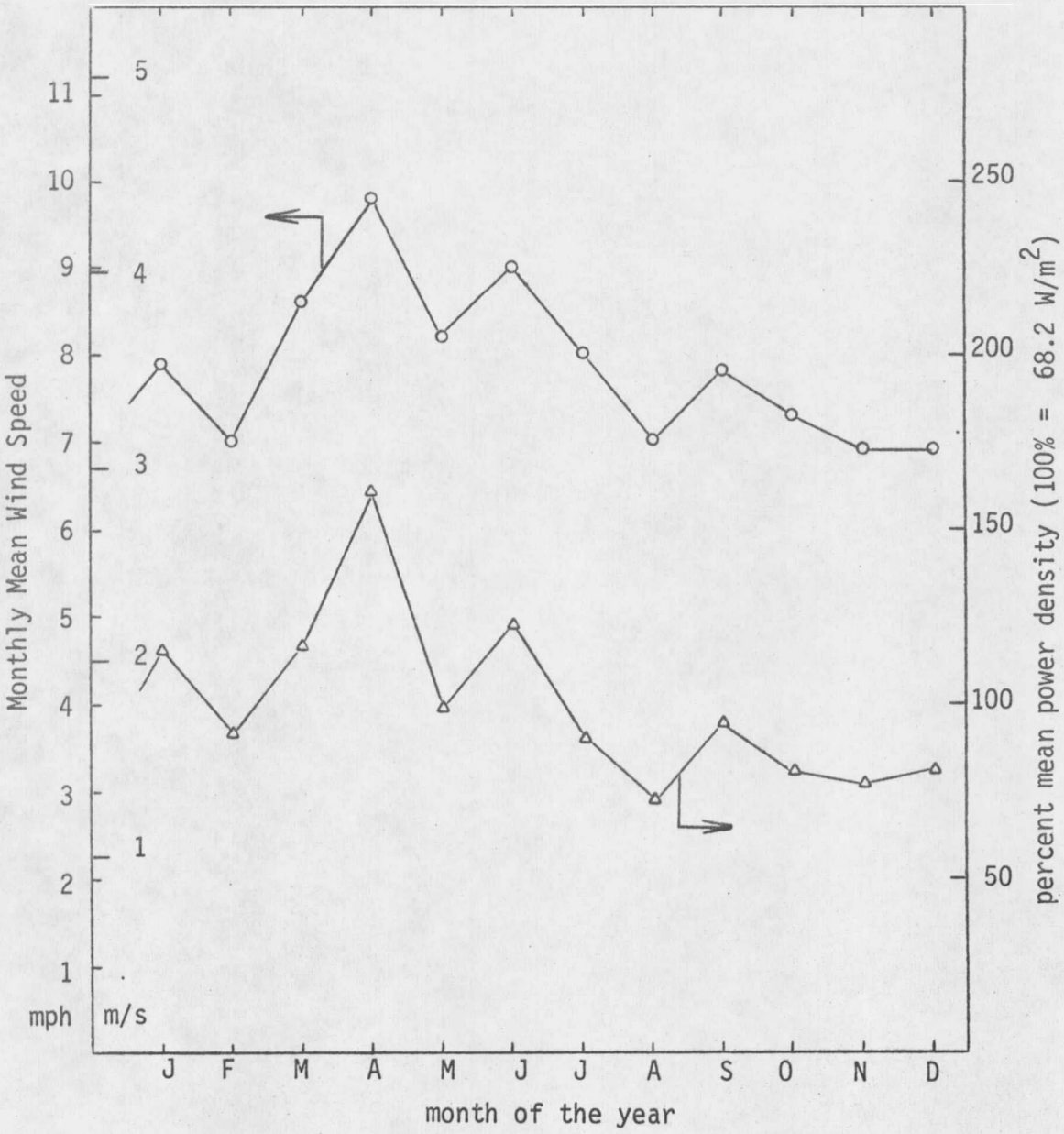


FIGURE 34 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT HELENA

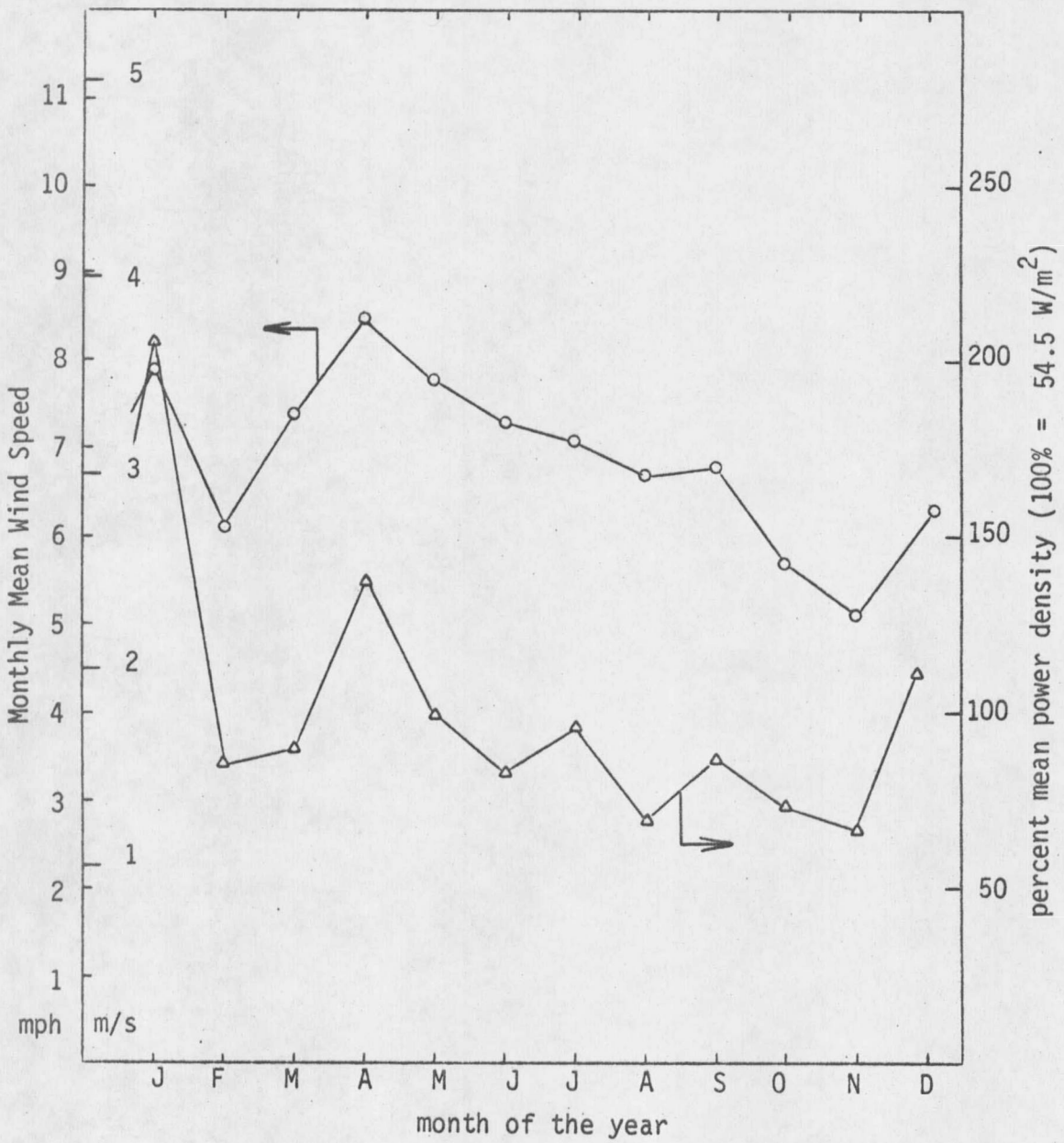


FIGURE 35 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT KALISPELL

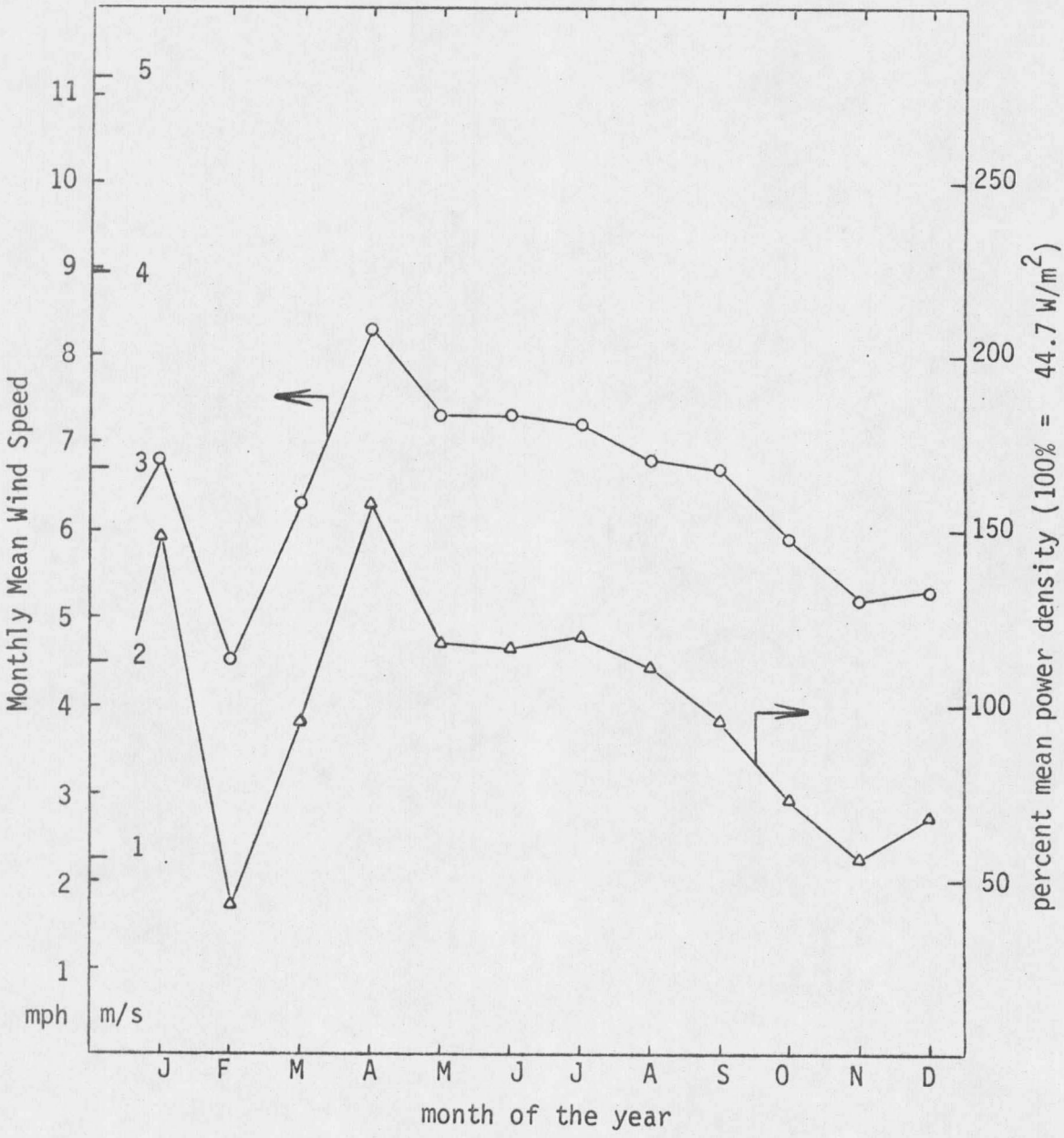


FIGURE 36 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT MISSOULA

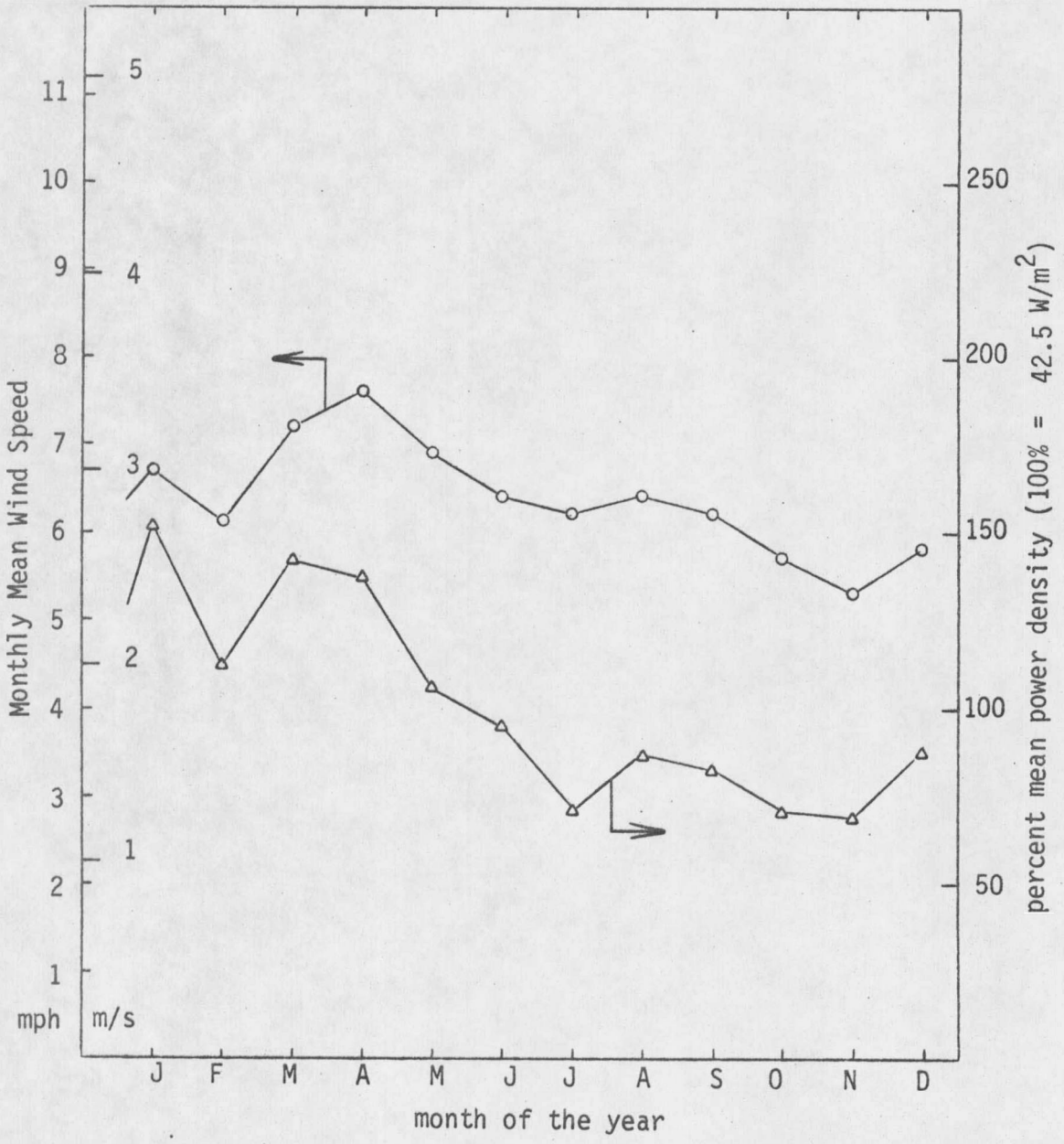


FIGURE 37 SEASONAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT BOZEMAN

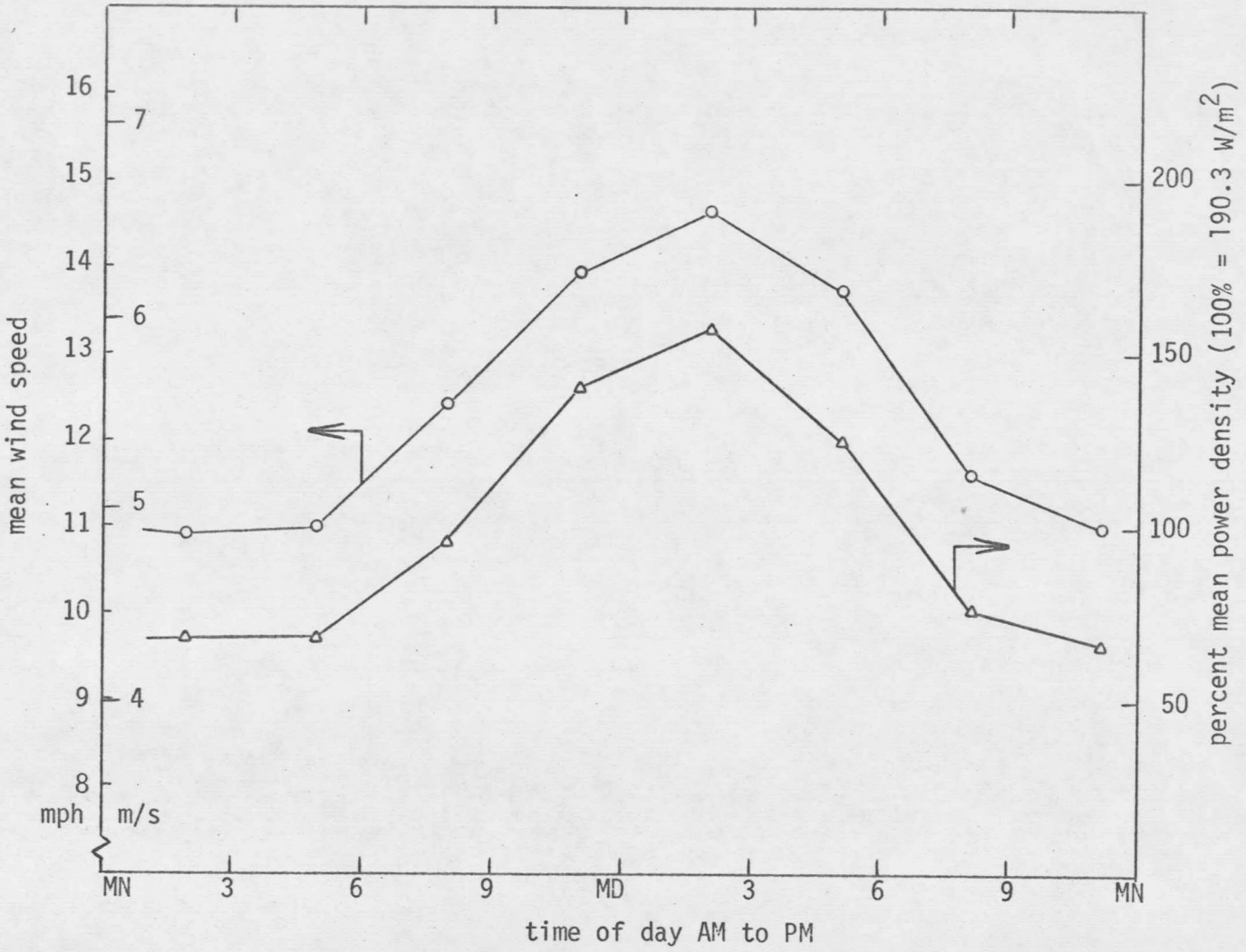


FIGURE 38 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT GREAT FALLS

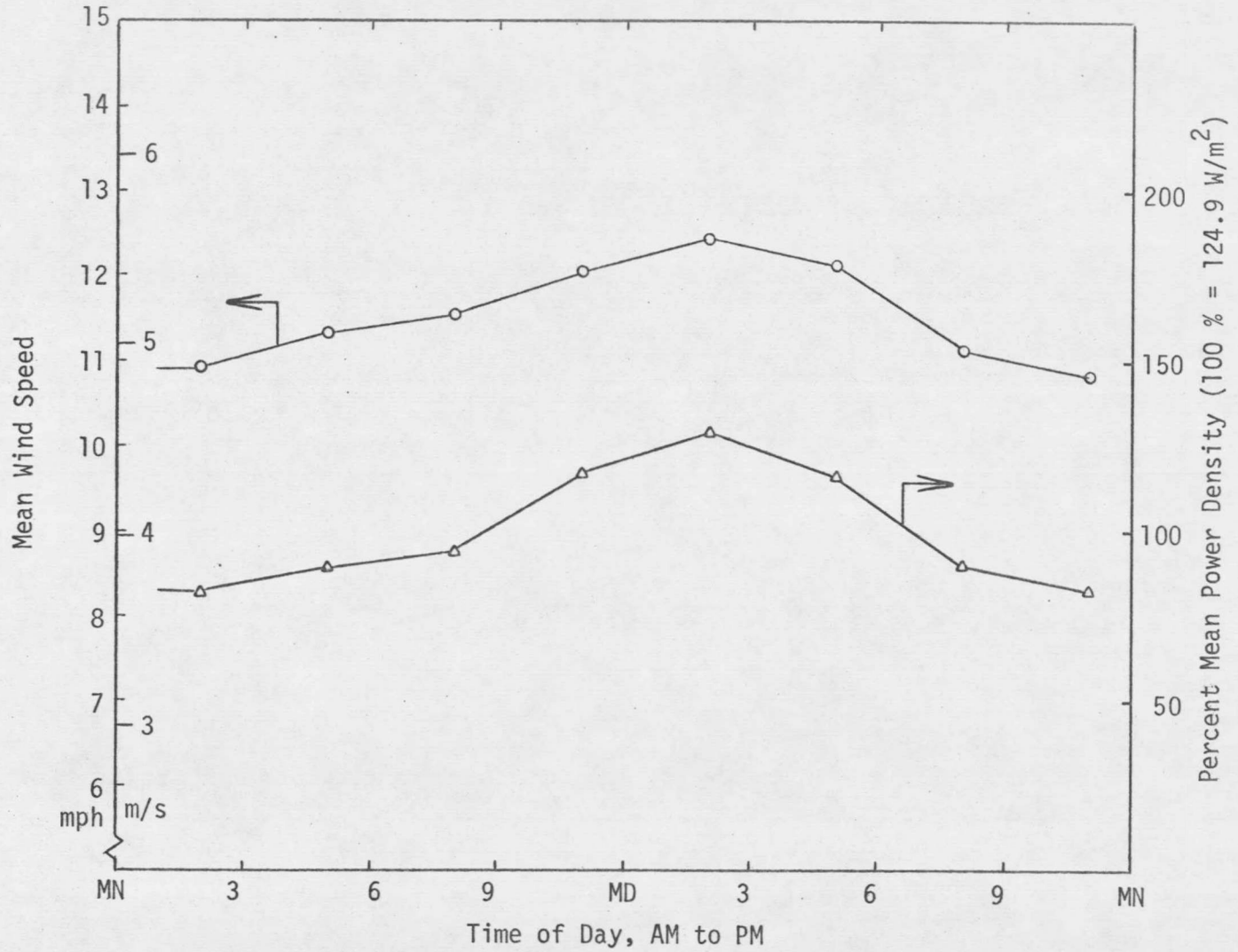


FIGURE 39 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT BILLINGS

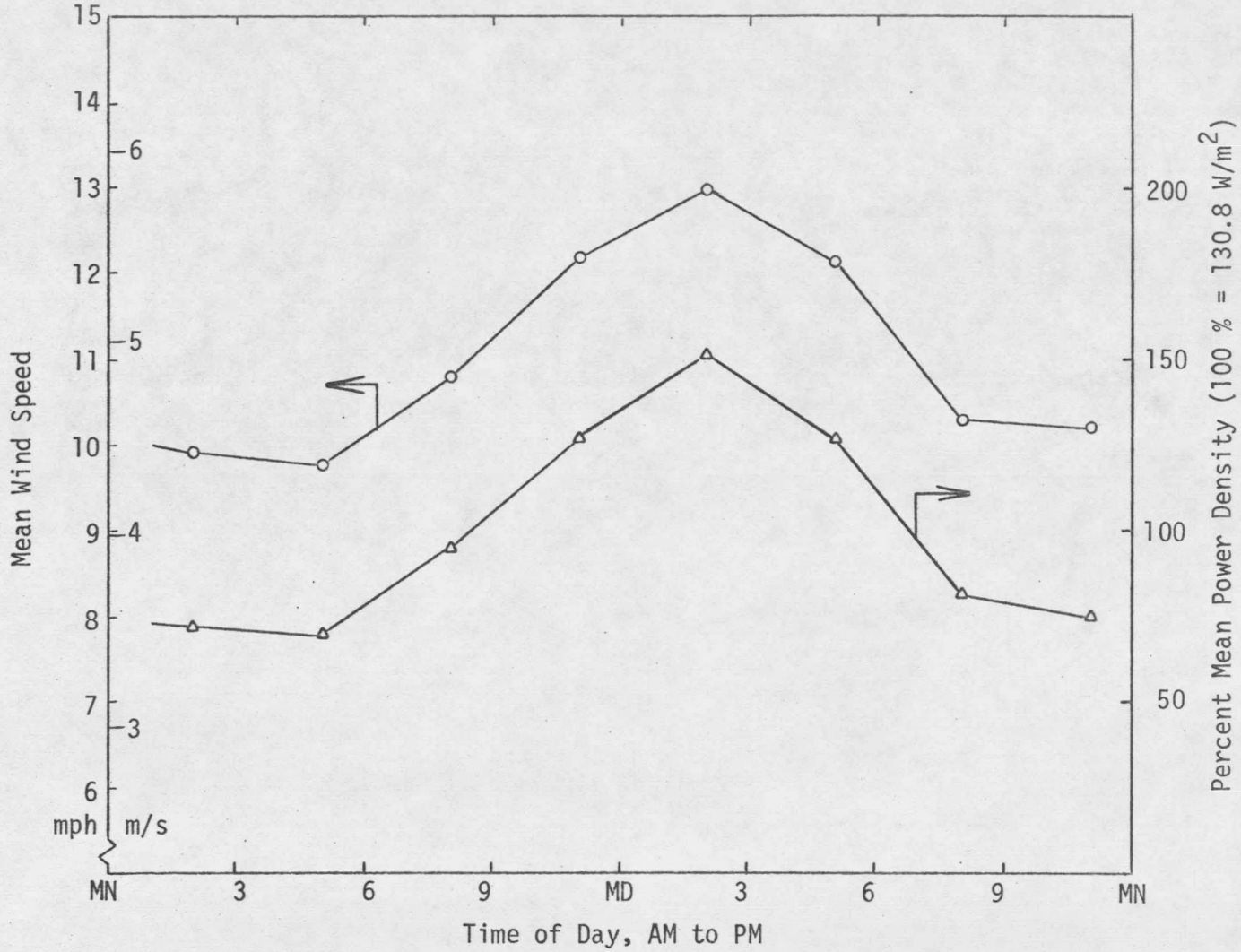


FIGURE 40 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT GLASGOW

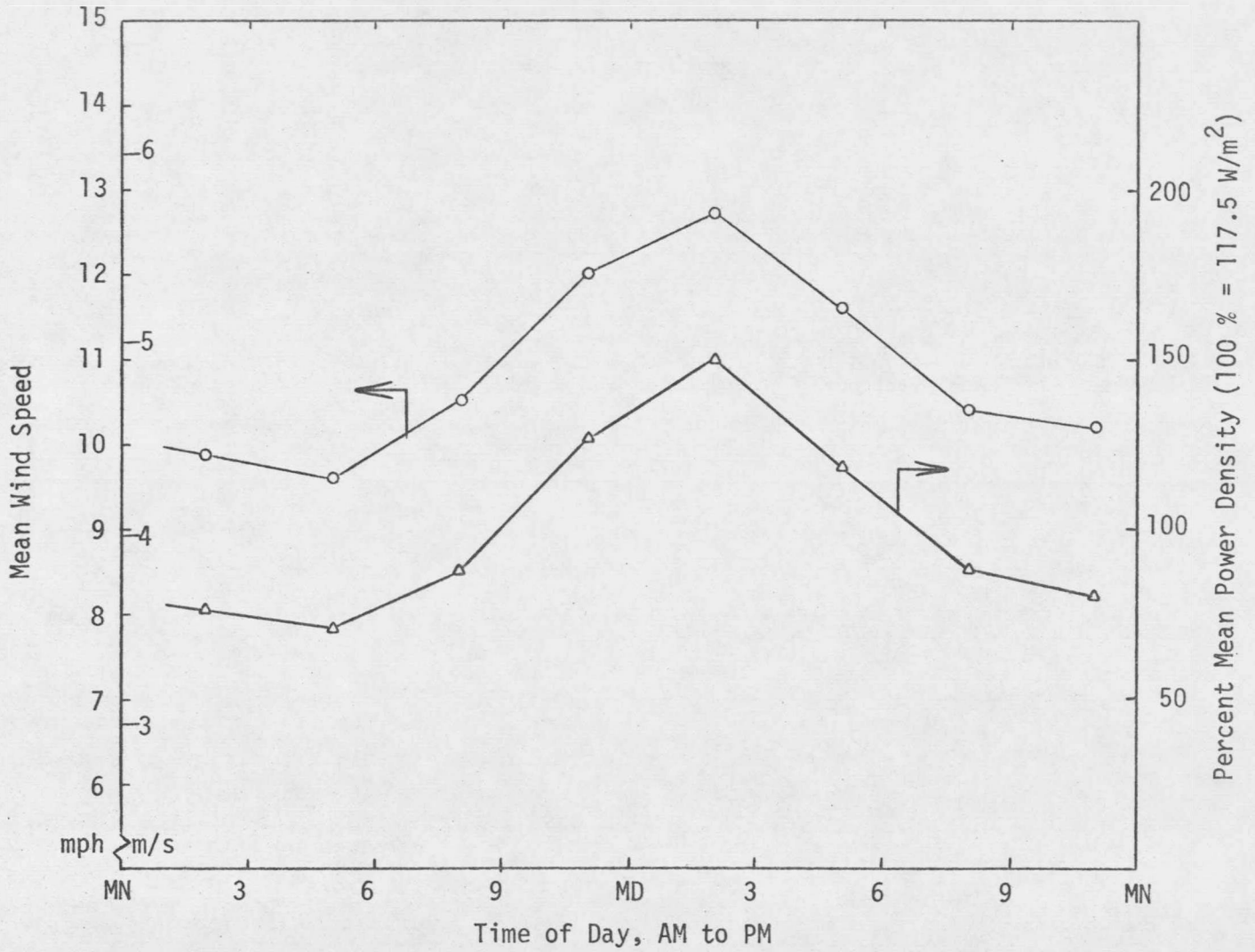


FIGURE 41 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT MILES CITY

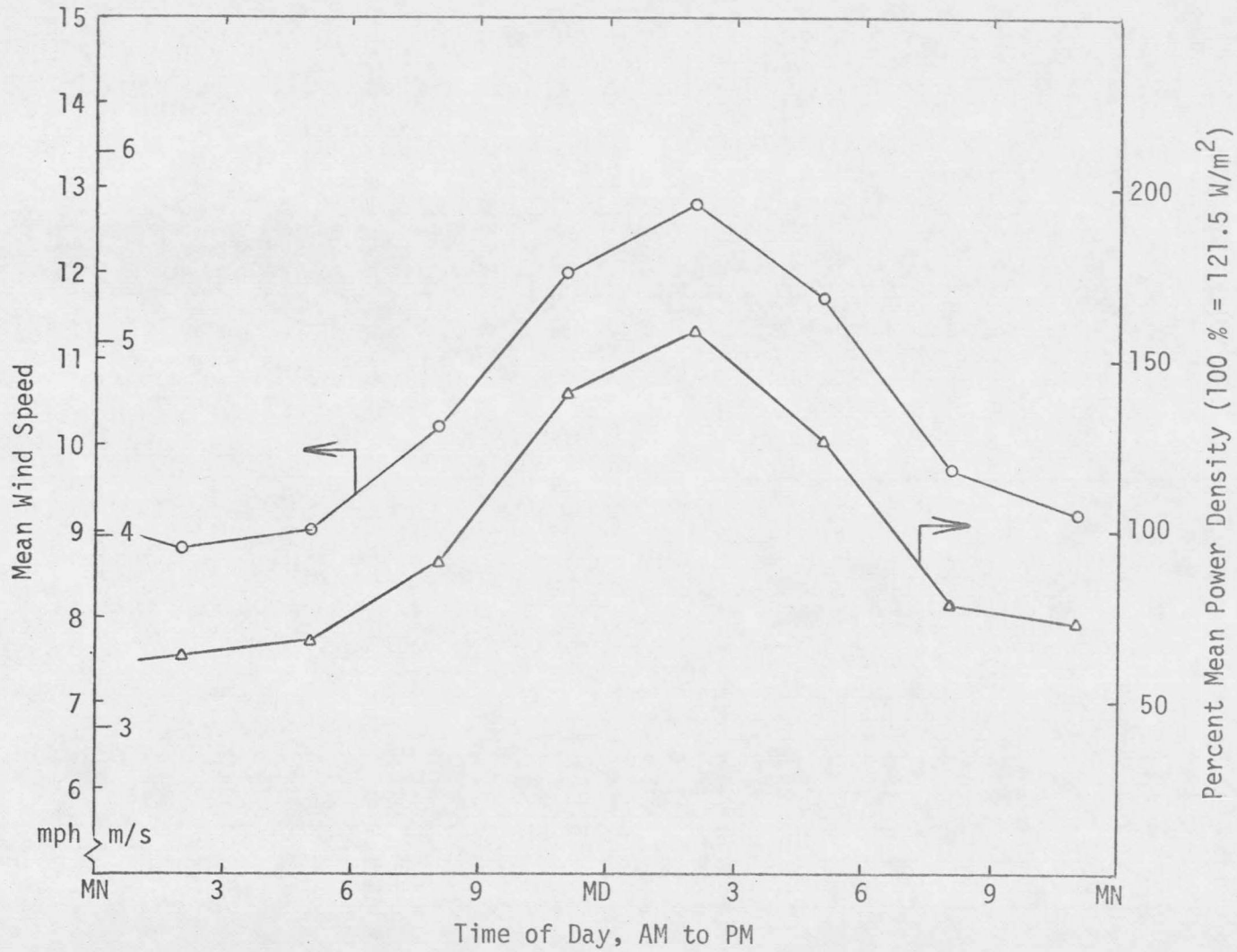


FIGURE 42 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT HAVRE

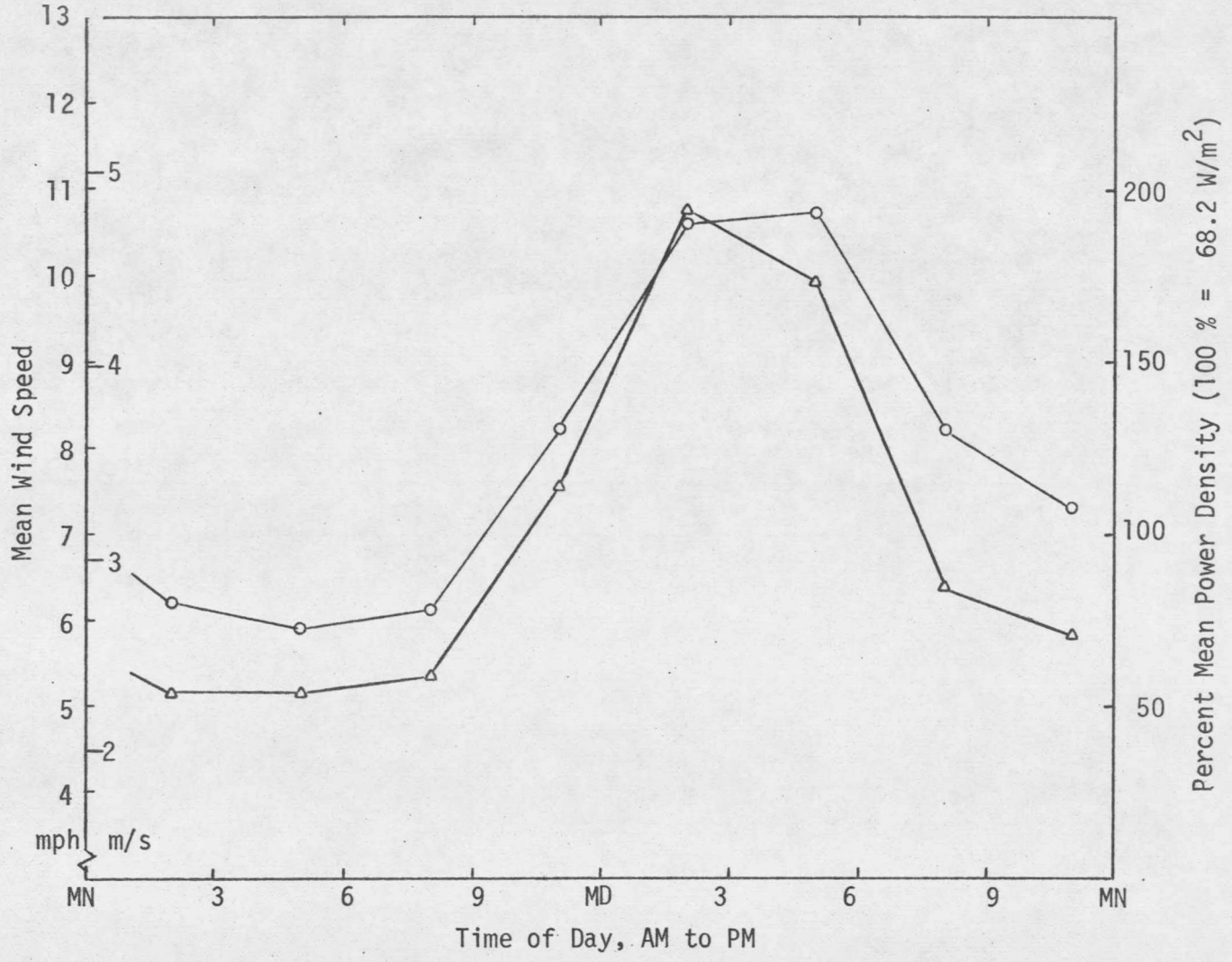


FIGURE 43 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT HELENA

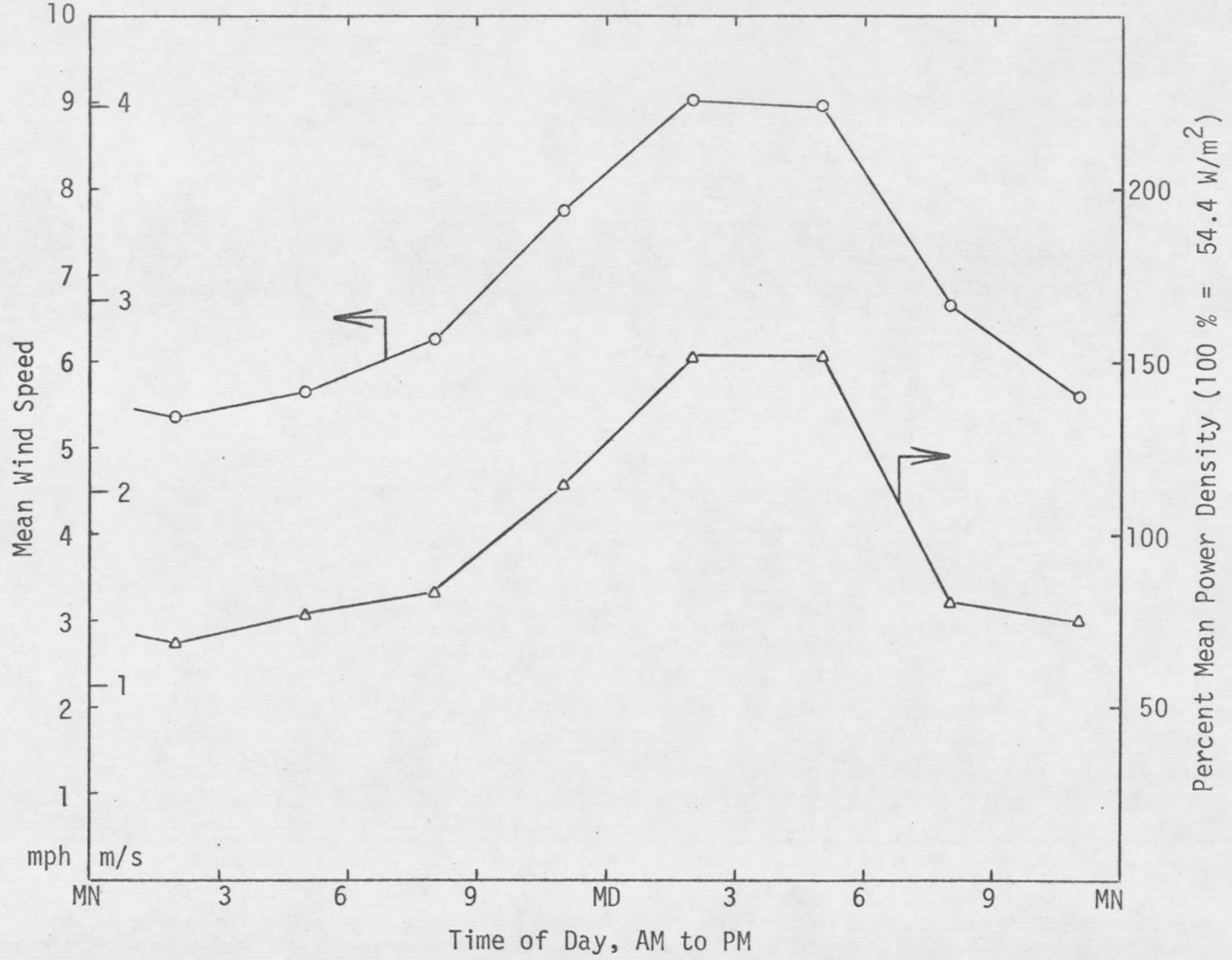


FIGURE 44 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT KALISPELL

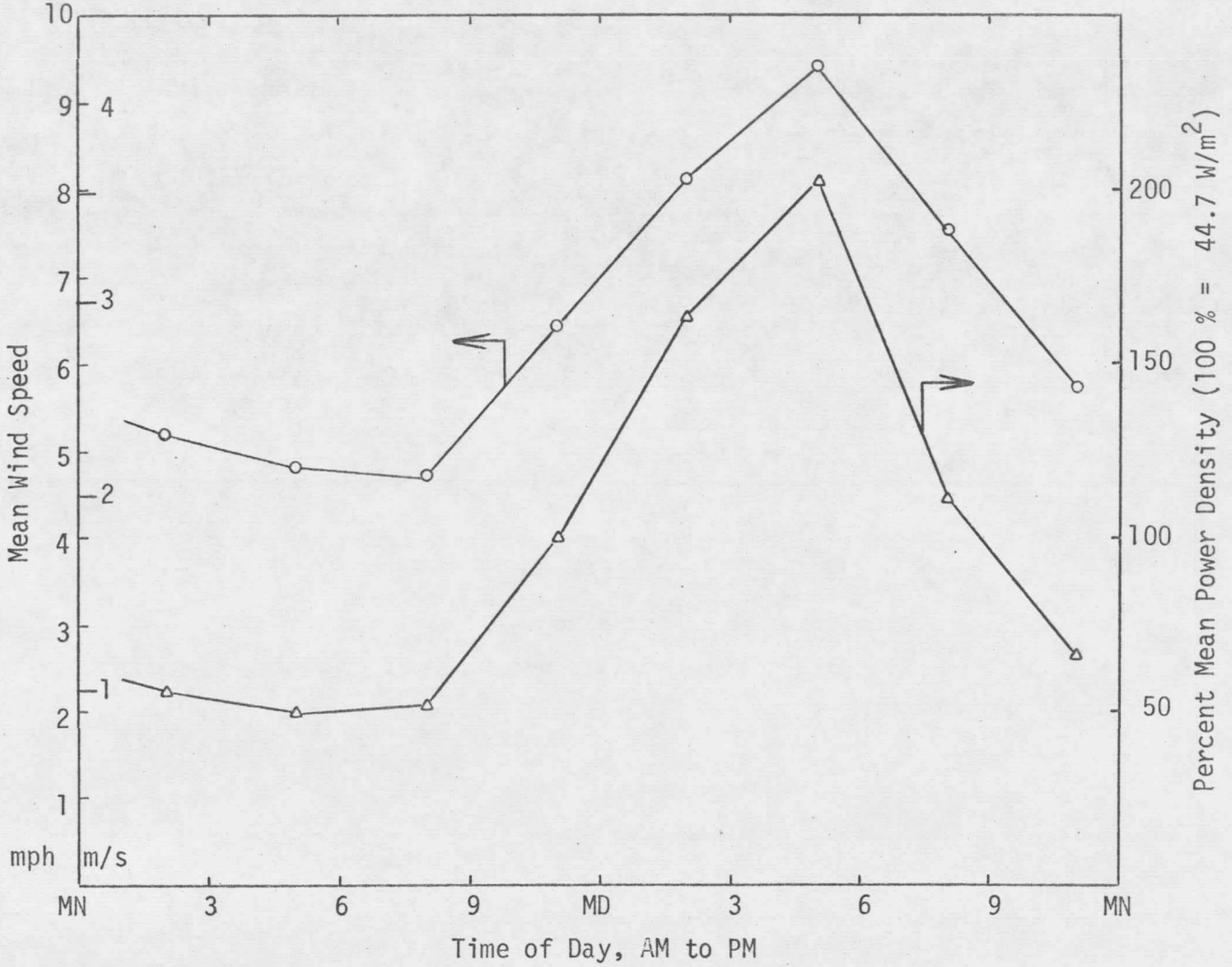


FIGURE 45 DIURNAL VARIATION IN MEAN WIND SPEED AND POWER DENSITY AT MISSOULA

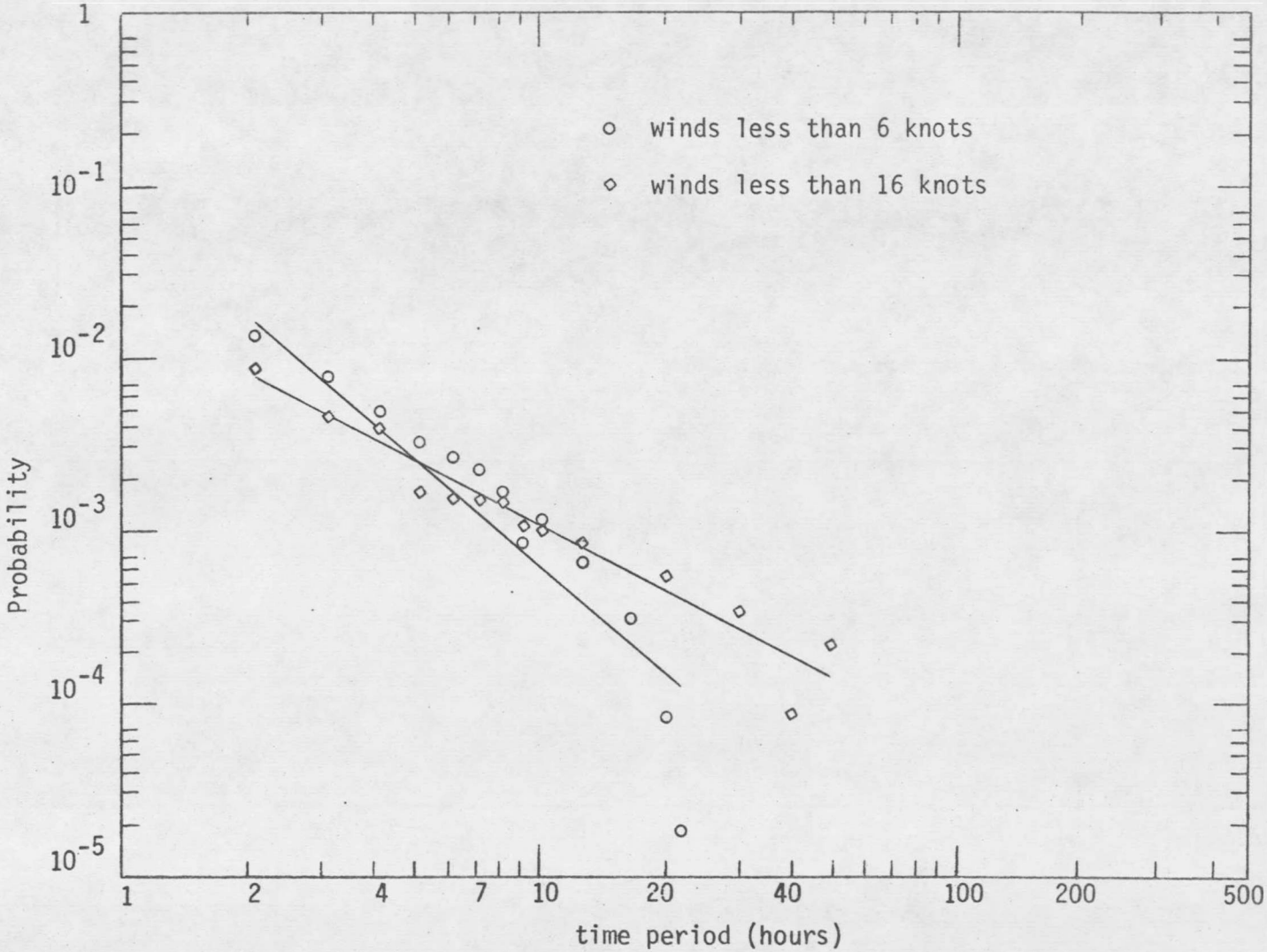


FIGURE 46. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR LIVINGSTON

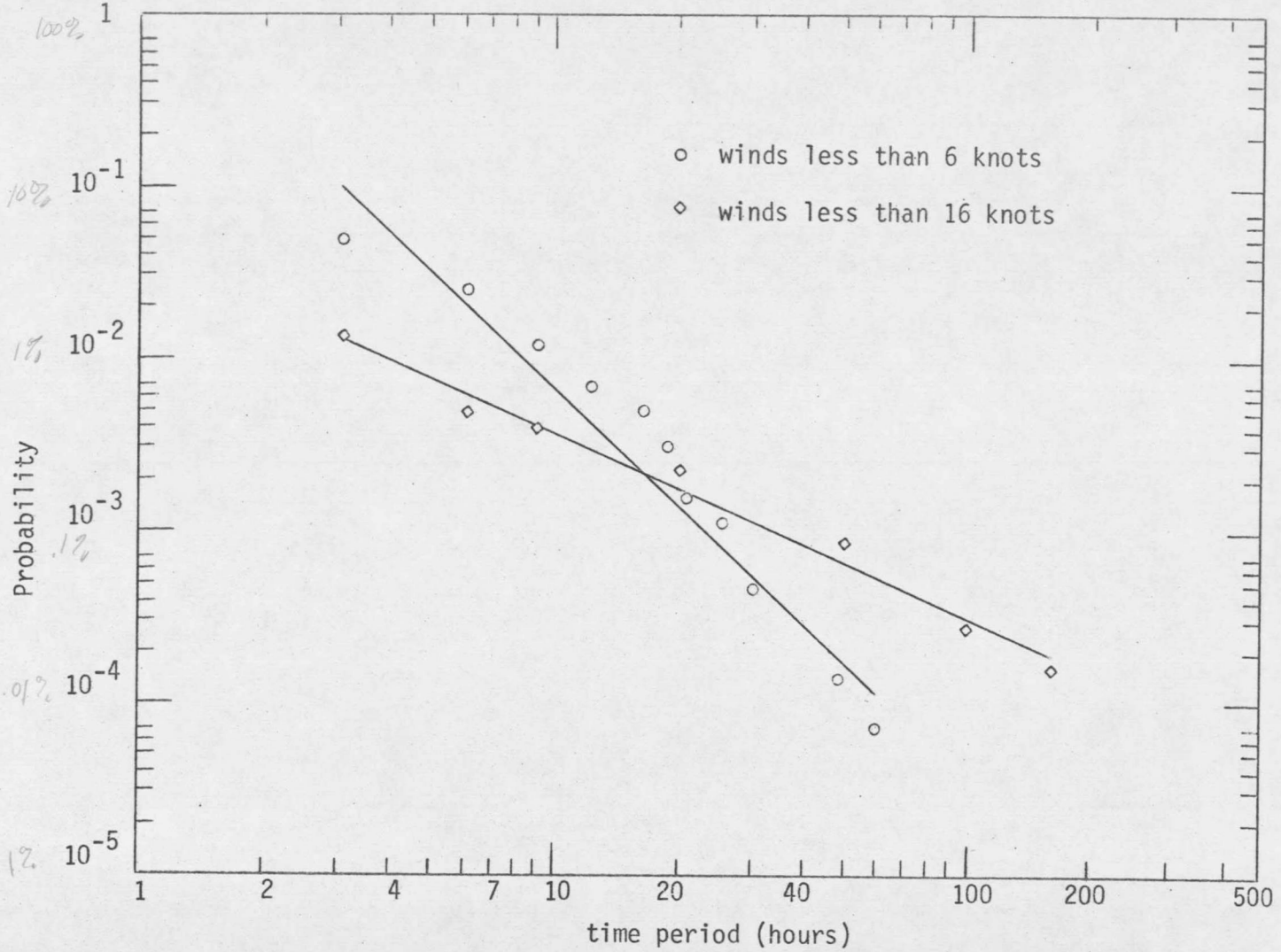


FIGURE 47. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR GREAT FALLS

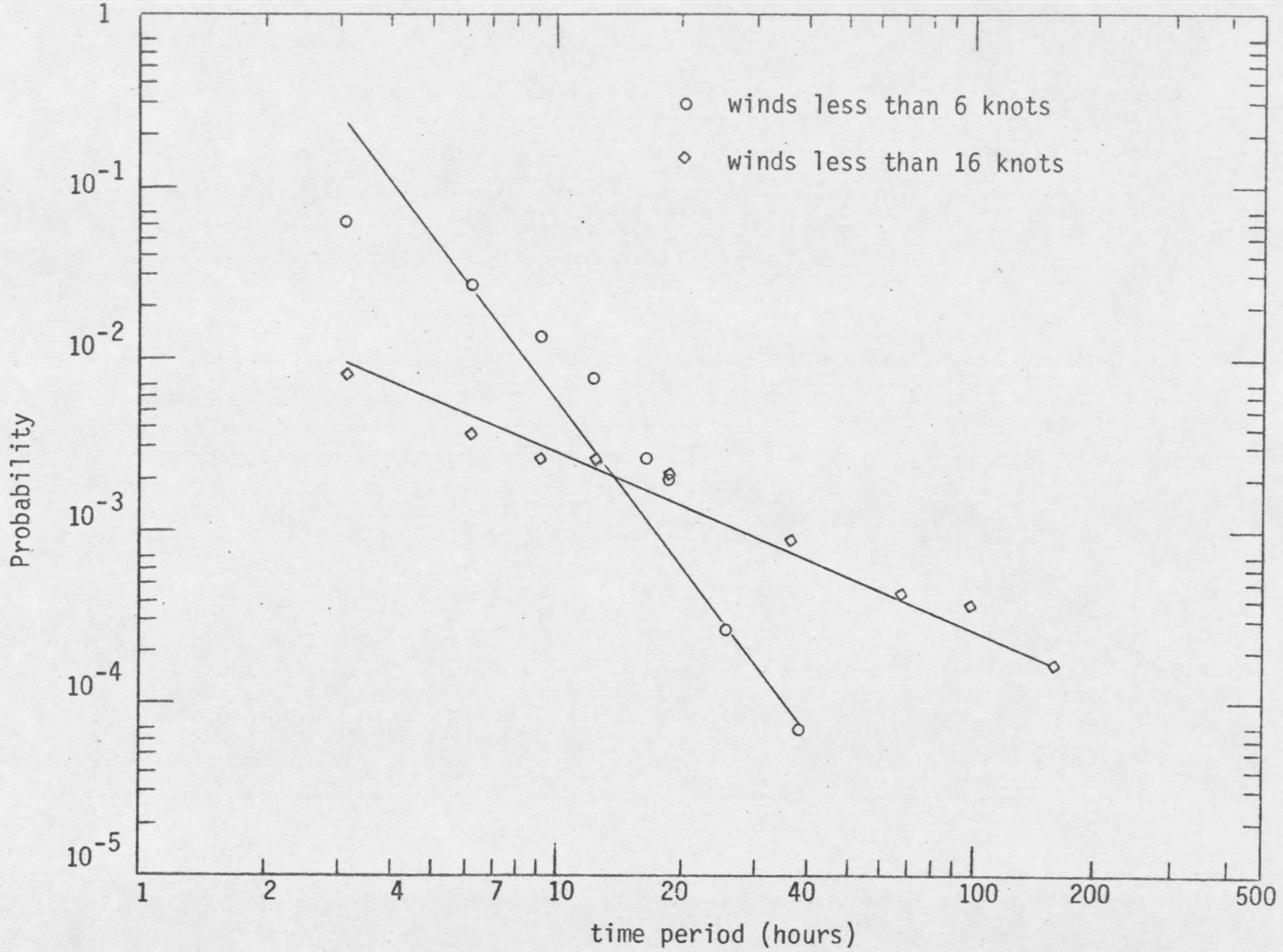


FIGURE 48. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR BILLINGS

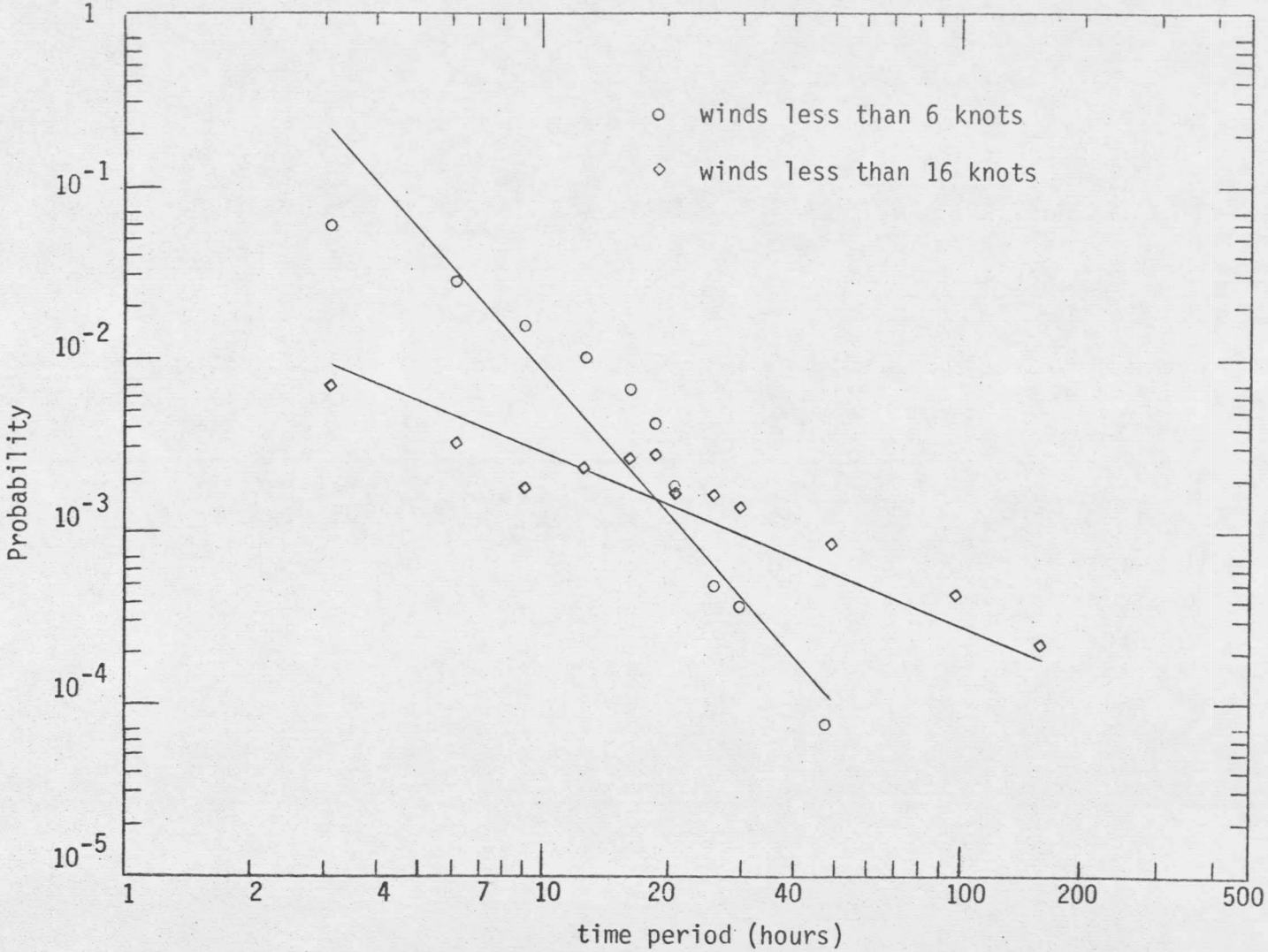


FIGURE 49. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR GLASGOW

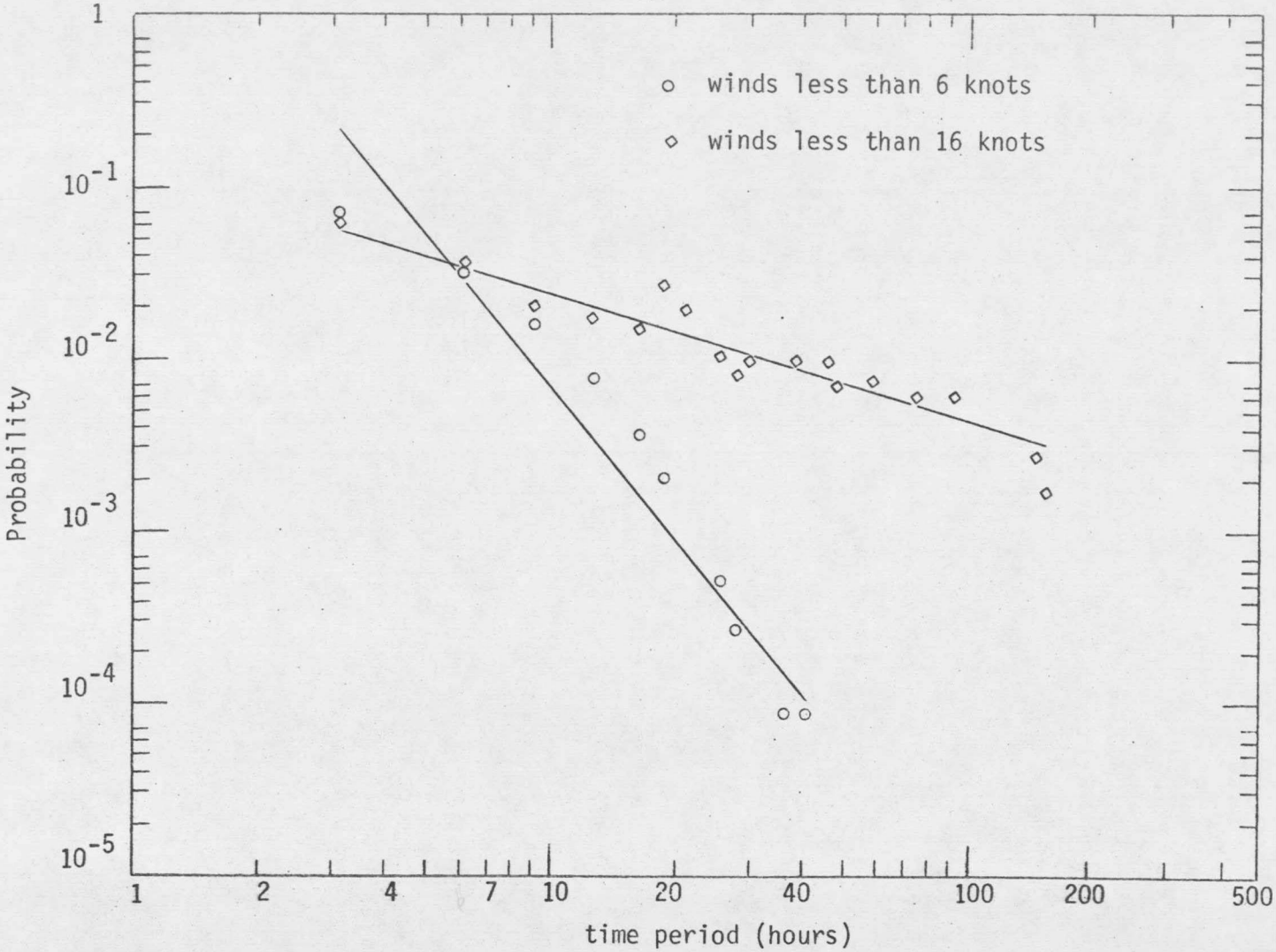


FIGURE 50. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR MILES CITY

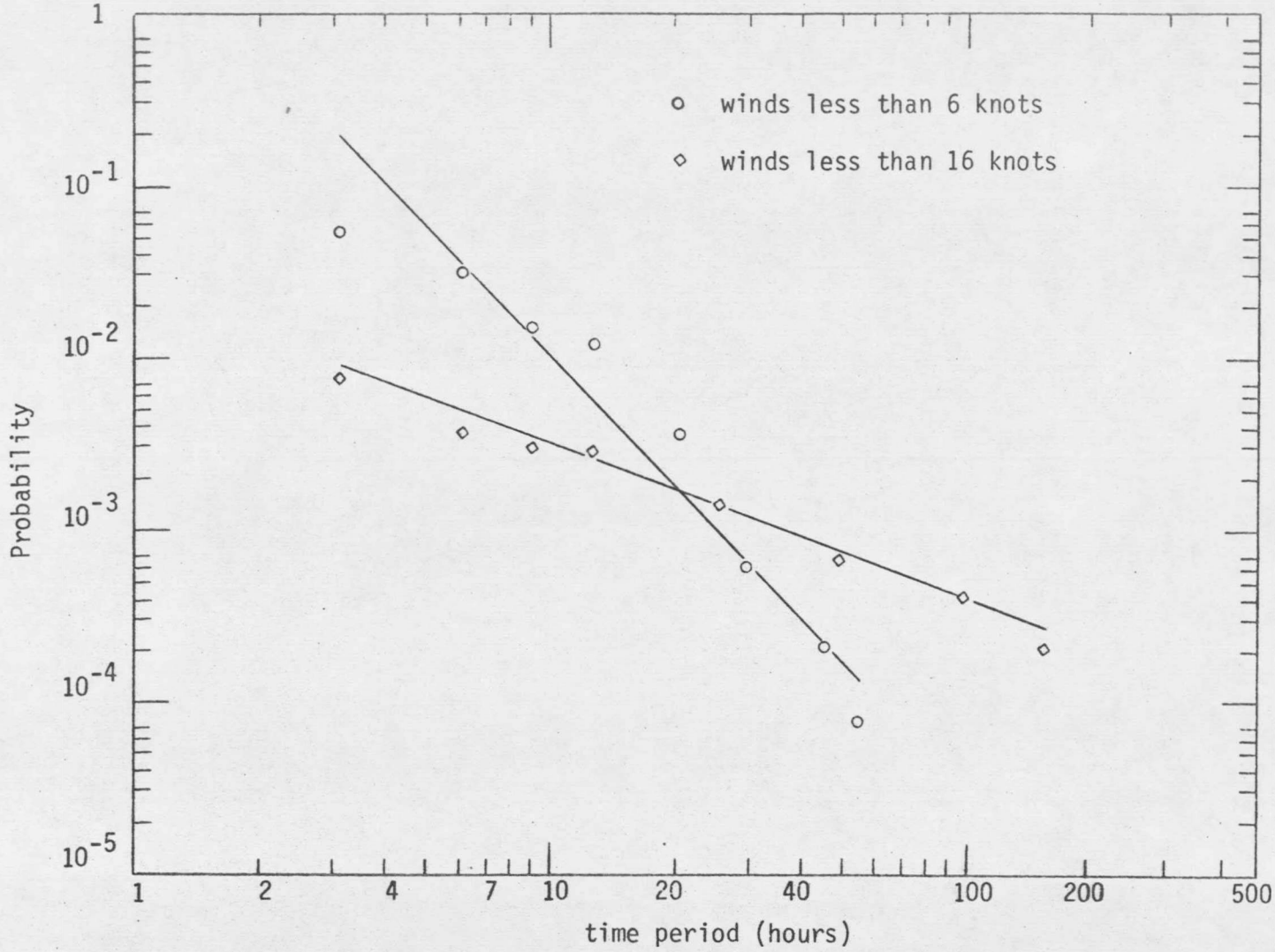


FIGURE 51. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR HAVRE

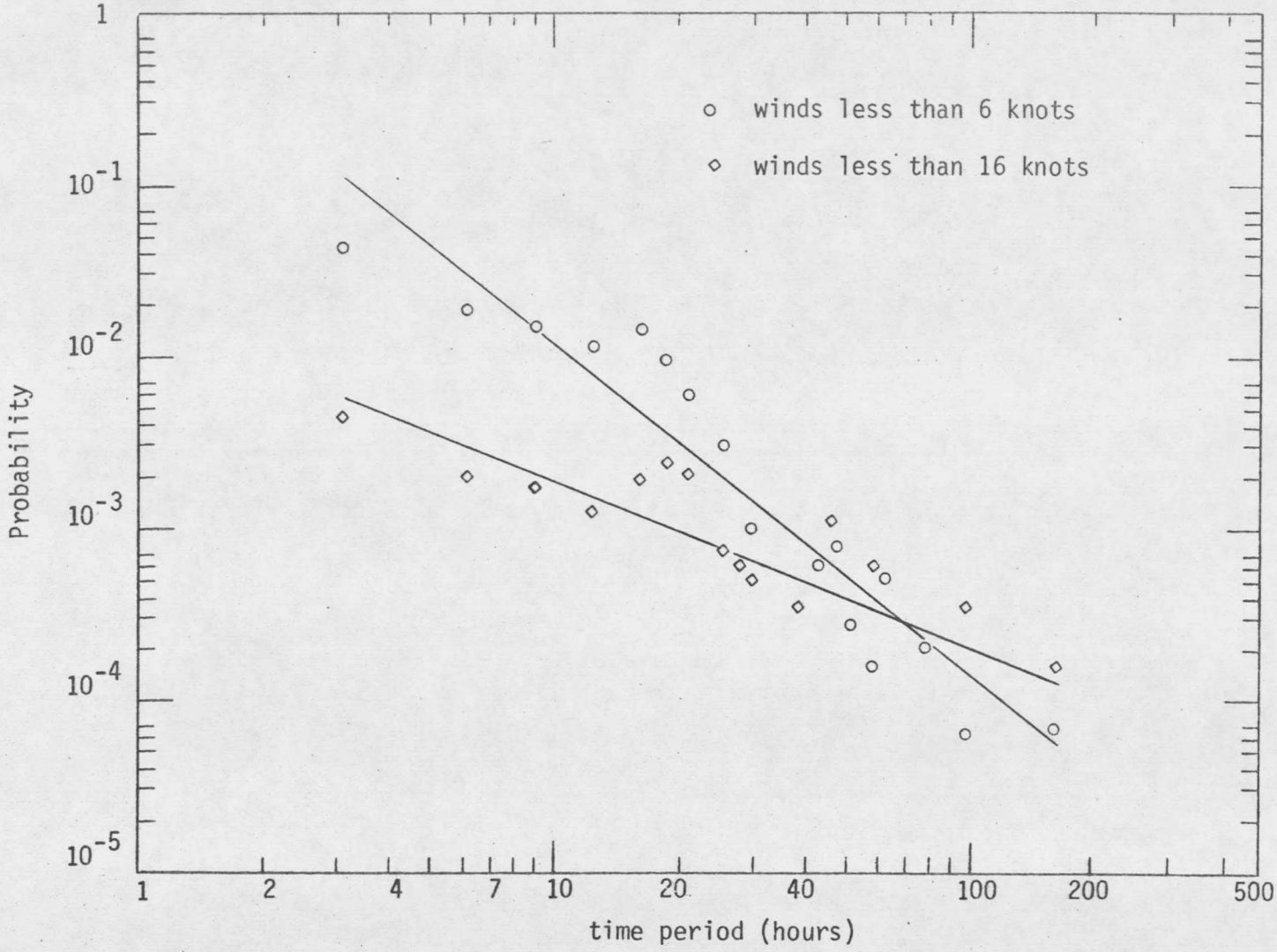


FIGURE 52. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR HELENA

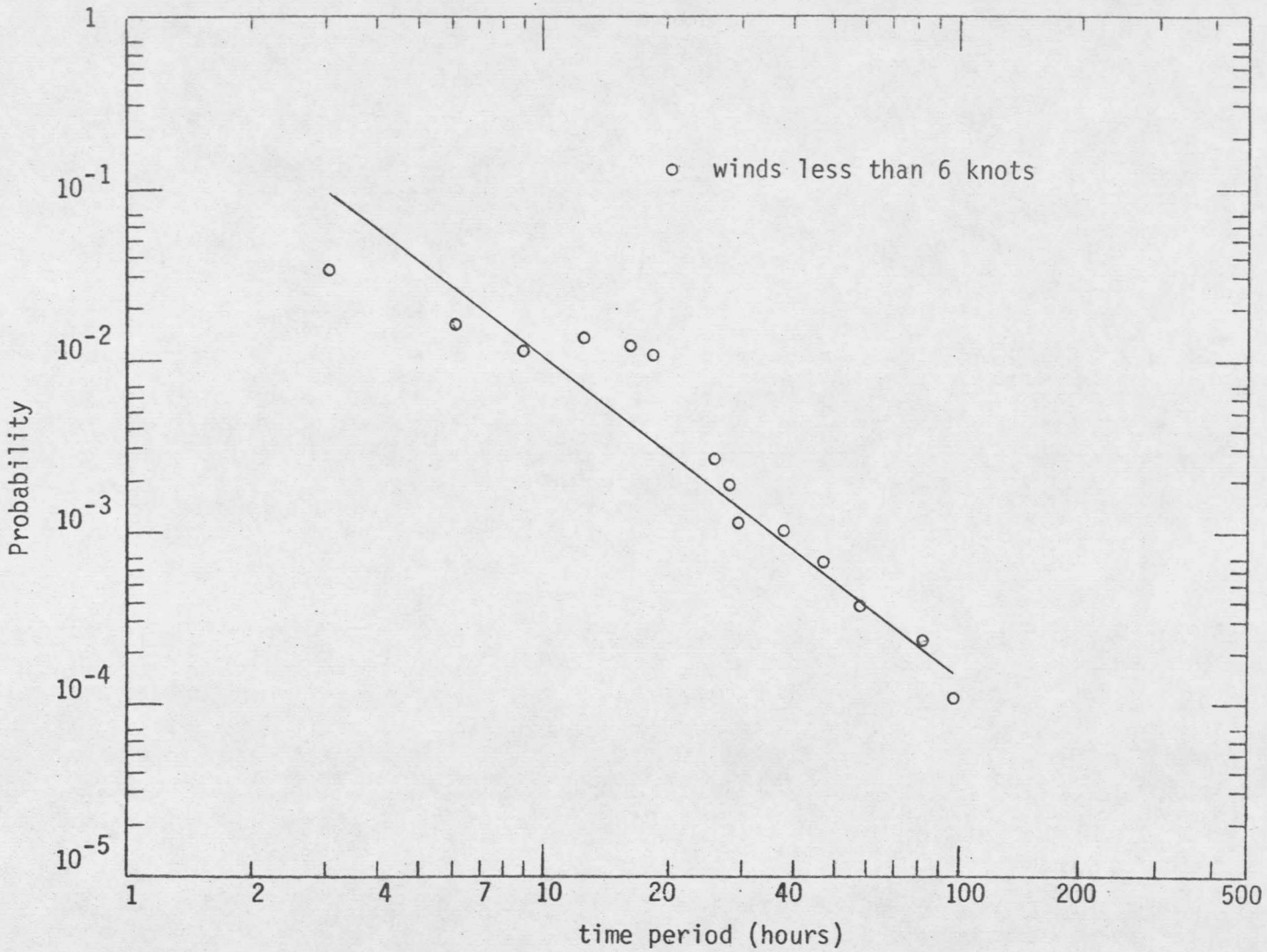


FIGURE 53. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR KALISPELL

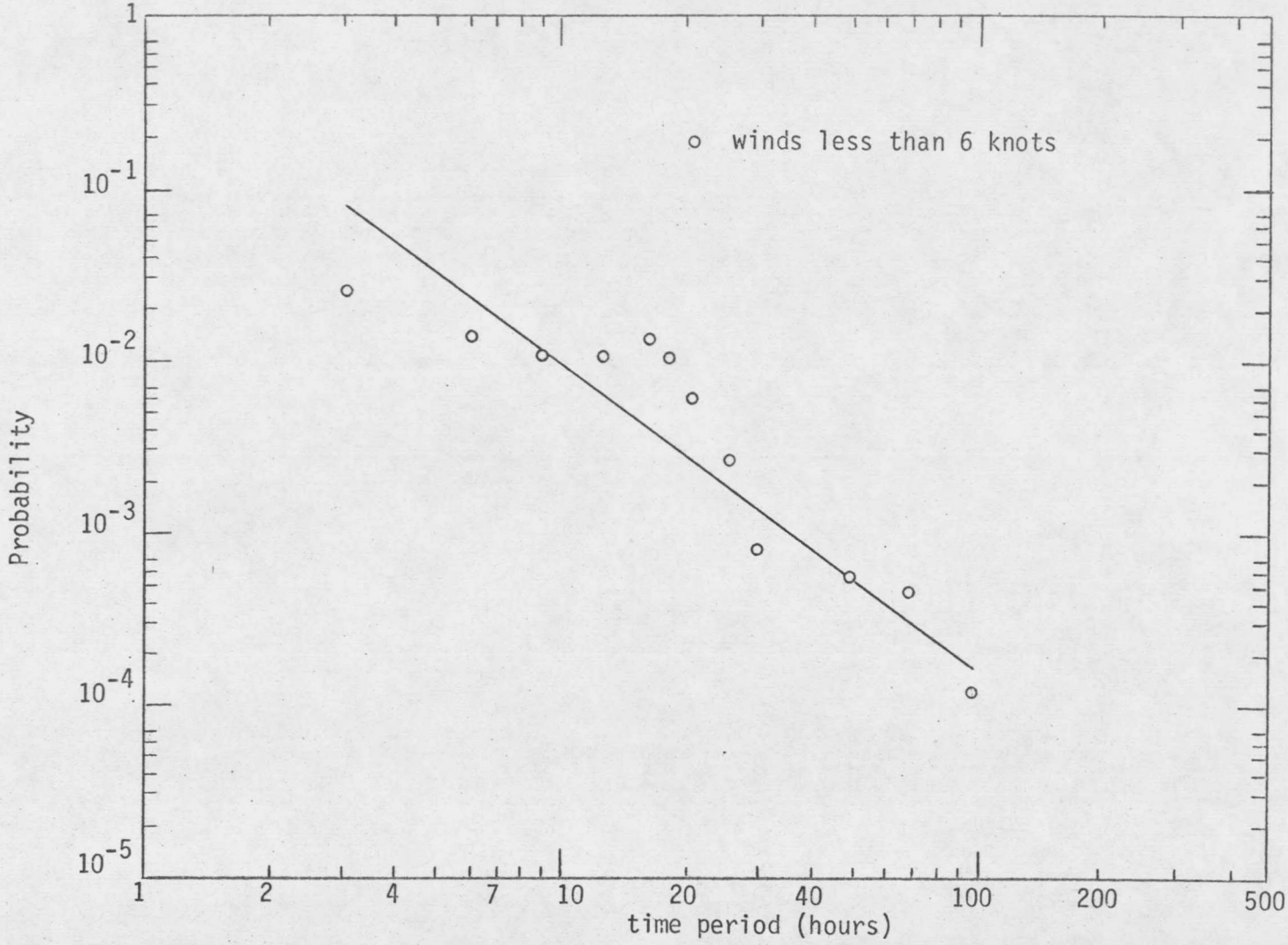


FIGURE 54. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WINDS FOR MISSOULA

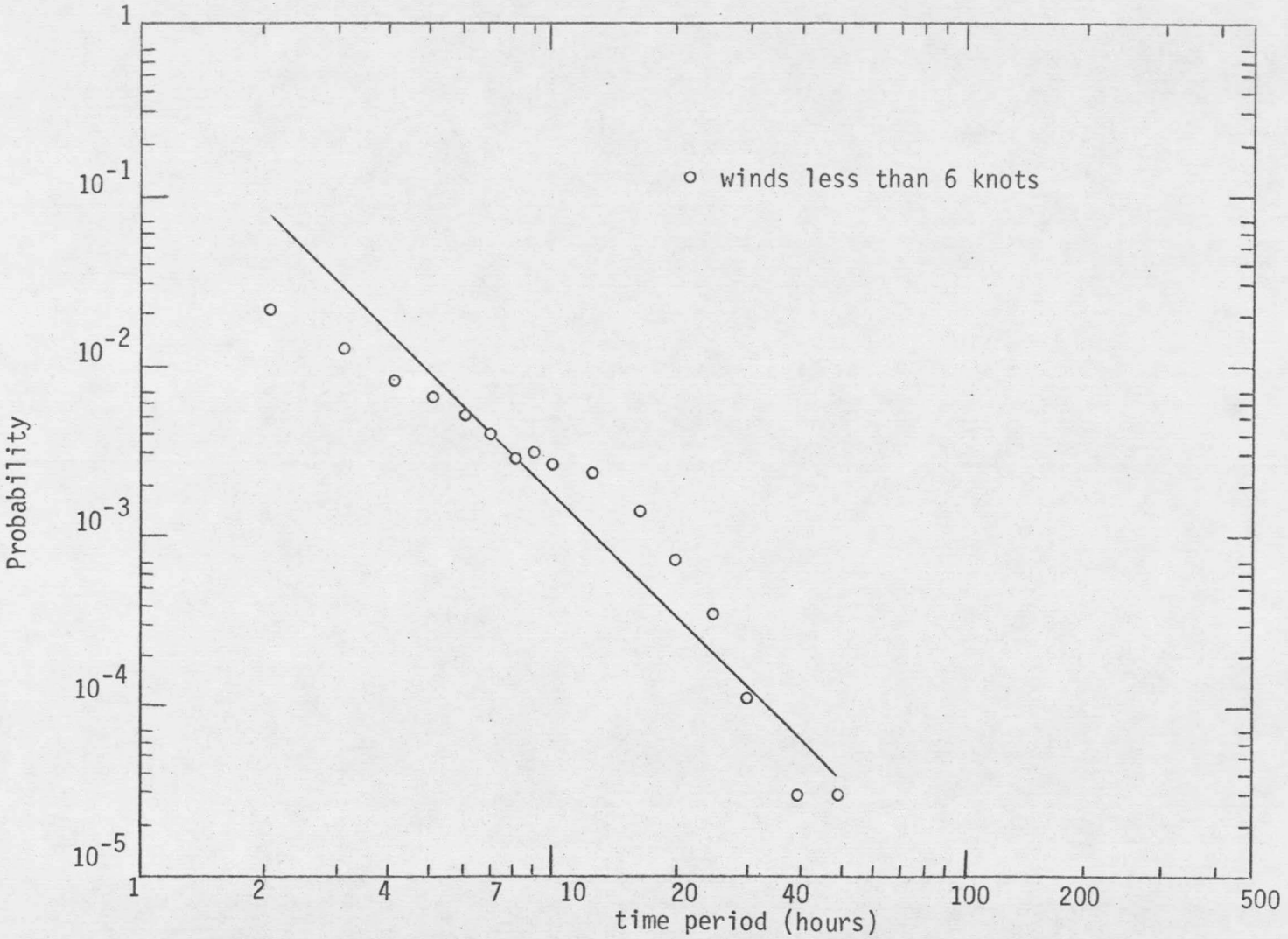


FIGURE 55. PROBABILITY OF A GIVEN TIME PERIOD WITH LOW-ENERGY-CONTENT WIND FOR BOZEMAN

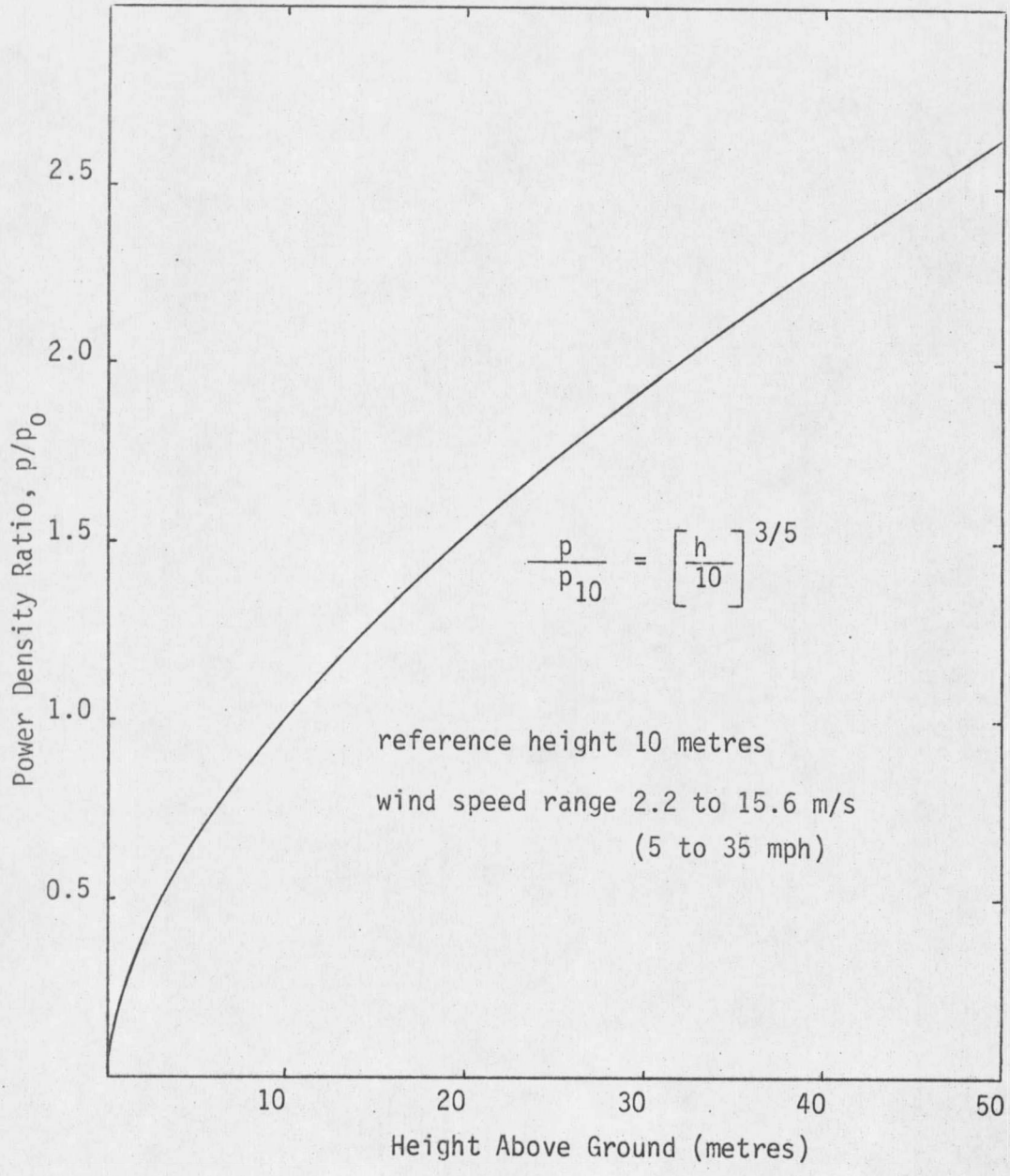


FIGURE 56. EFFECT OF HEIGHT ABOVE GROUND ON POWER DENSITY

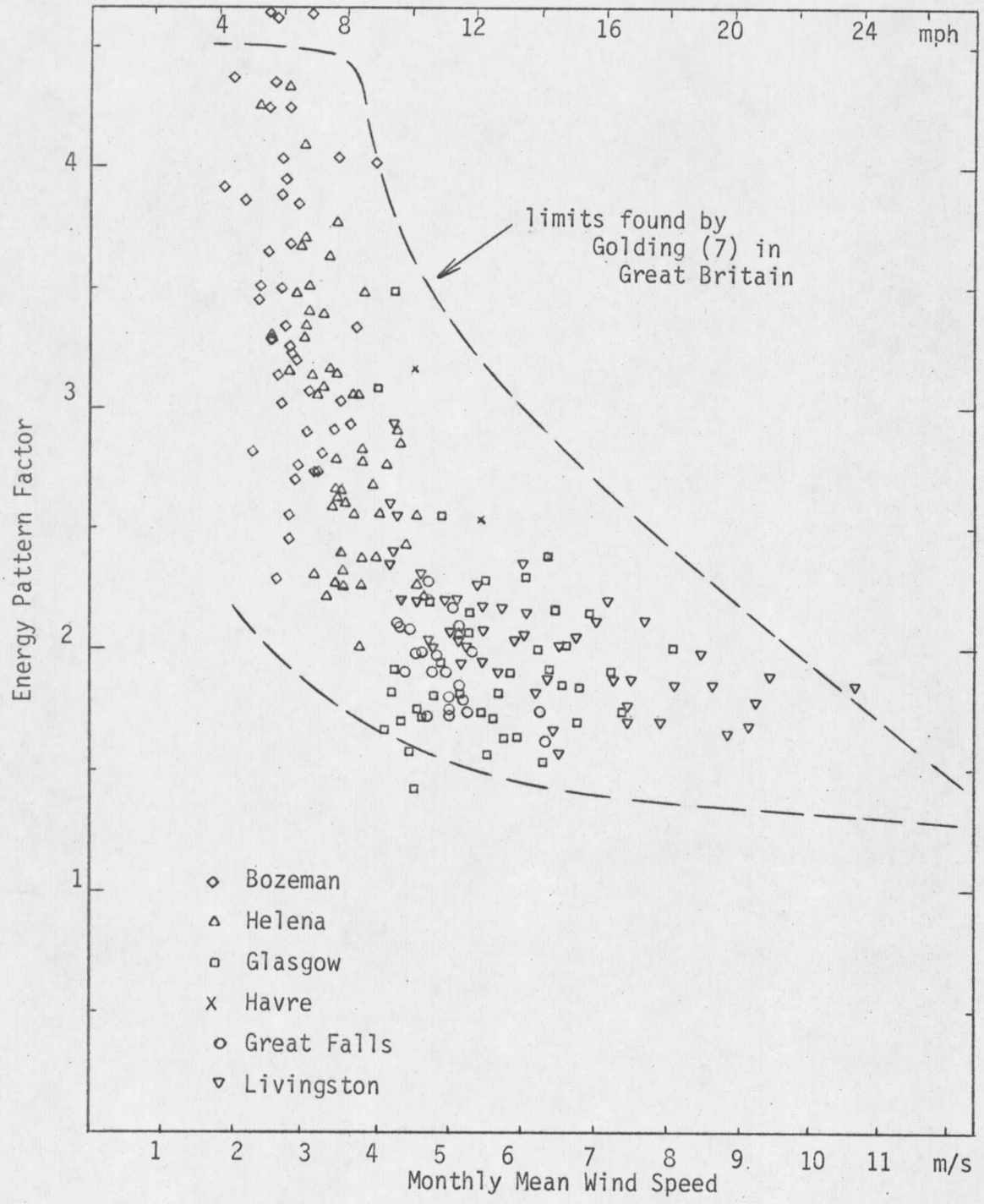


FIGURE 57. ENERGY PATTERN FACTORS

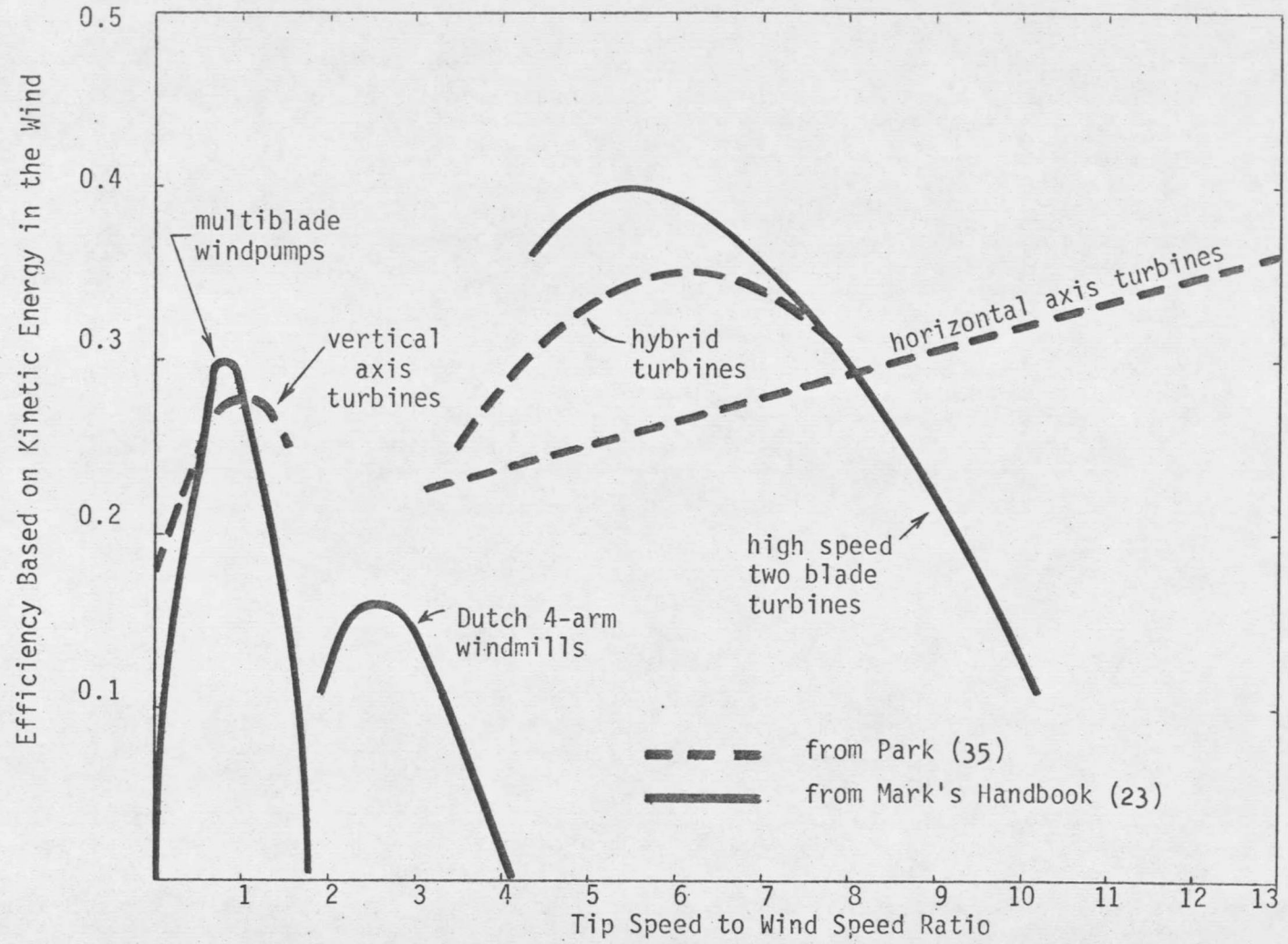


FIGURE 58. RELATIVE EFFICIENCIES OF MAJOR WIND TURBINE DESIGNS

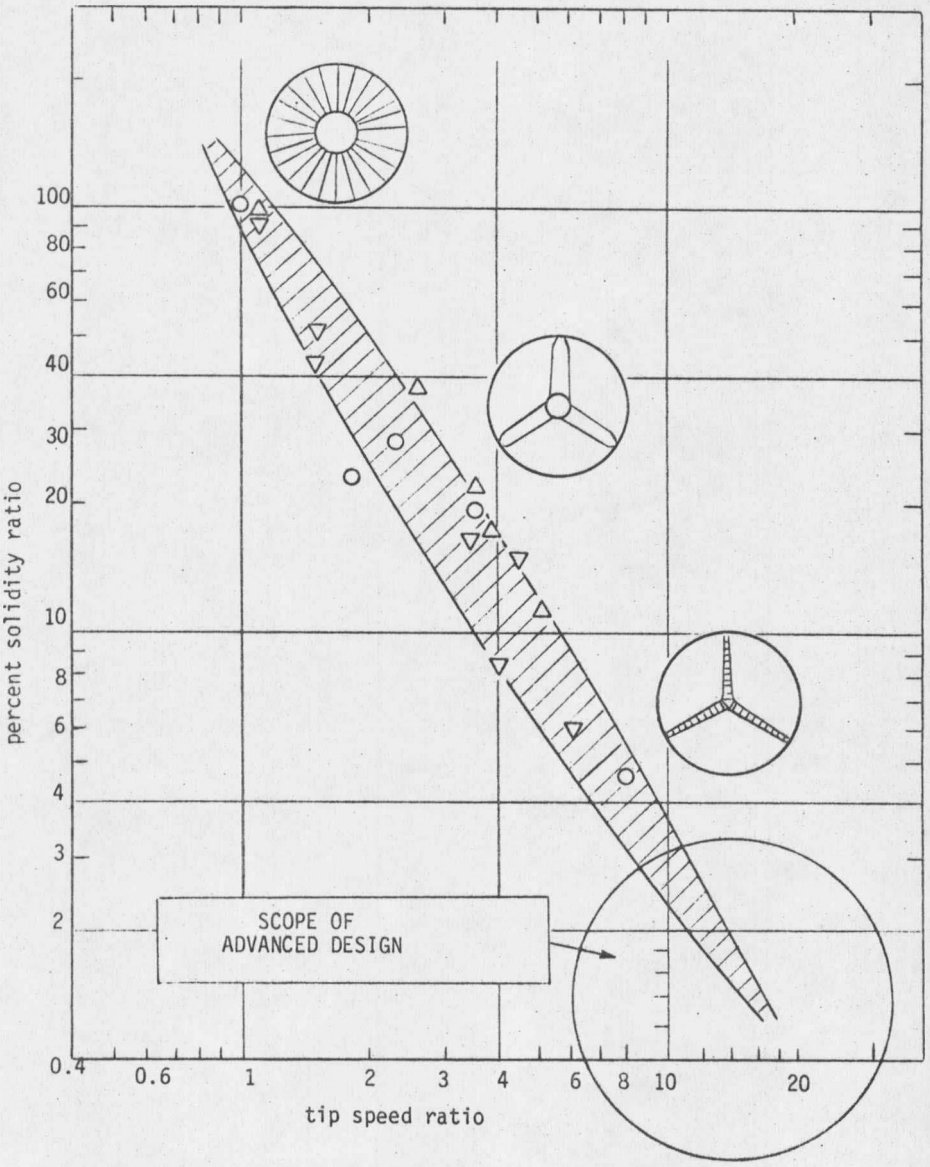


FIGURE 59. RELATION BETWEEN SOLIDITY RATIO AND TIP SPEED RATIO AS PRESENTED BY HUTTER (14)

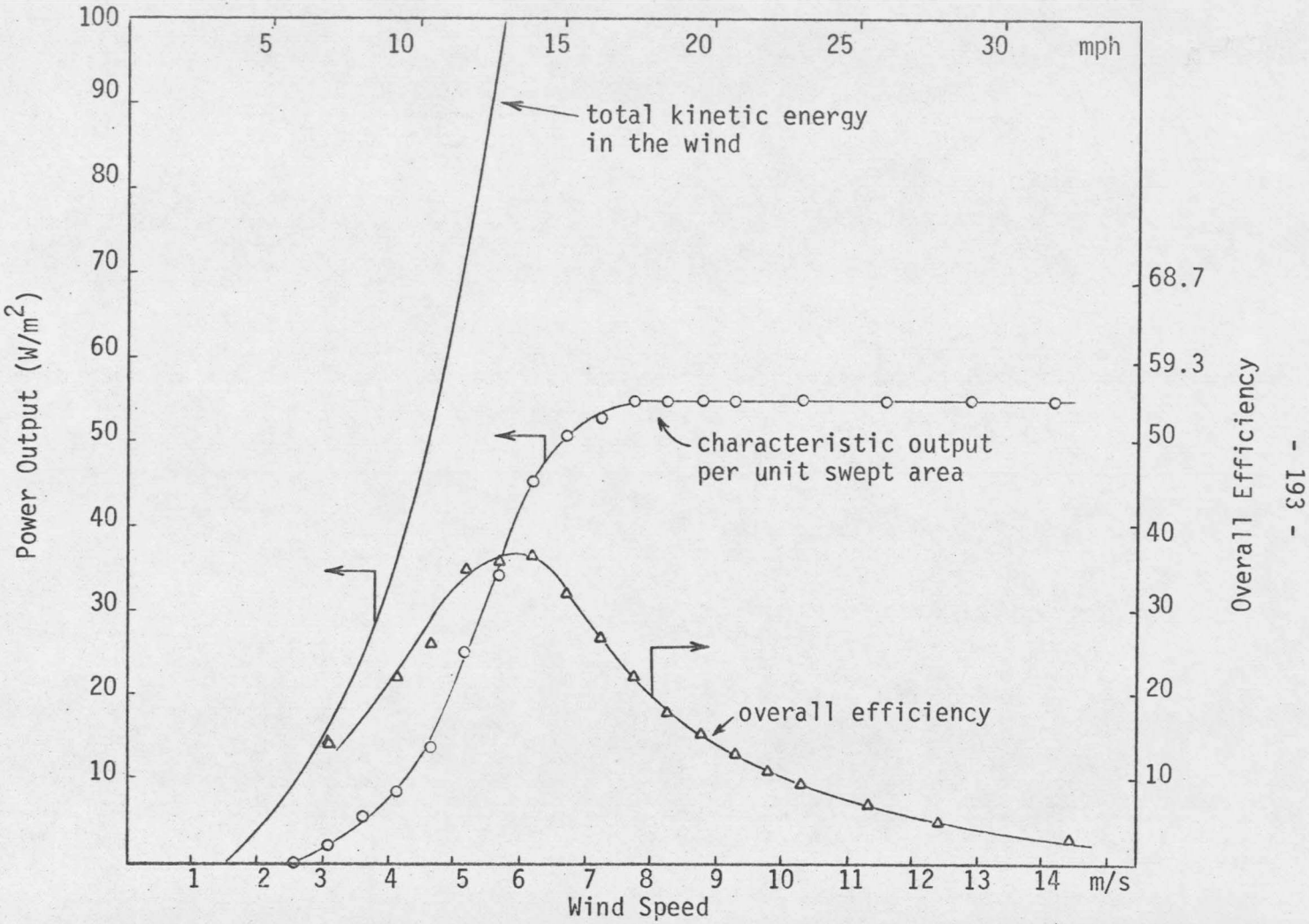


FIGURE 60. POWER CHARACTERISTIC OF AEROWATT 4100 FP7

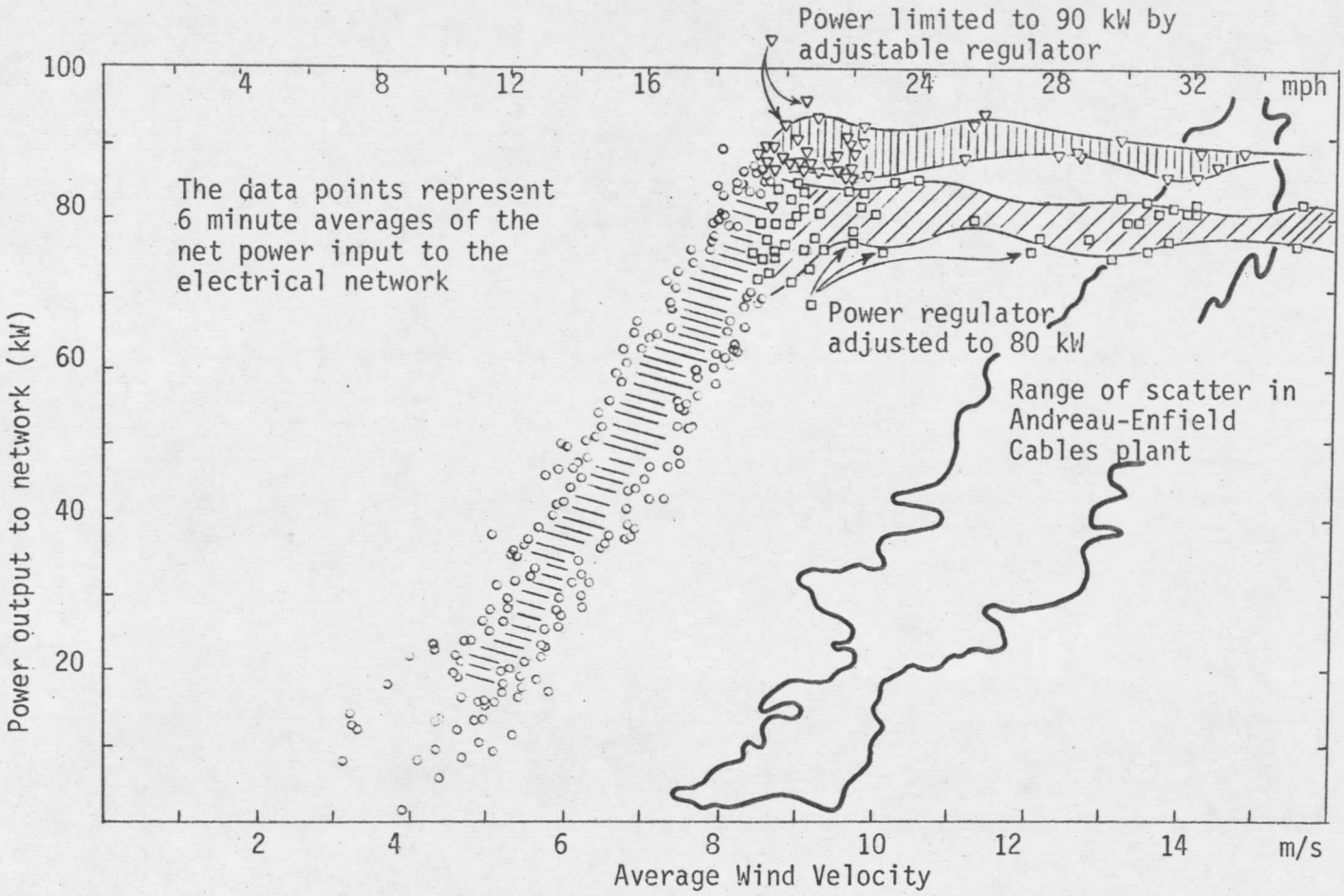


FIGURE 61. ON-SITE CHARACTERISTIC OUTPUT OF HUTTER-ALLGAIER AND ENFIELD-CABLES WIND GENERATORS AS PRESENTED BY HUTTER (27)

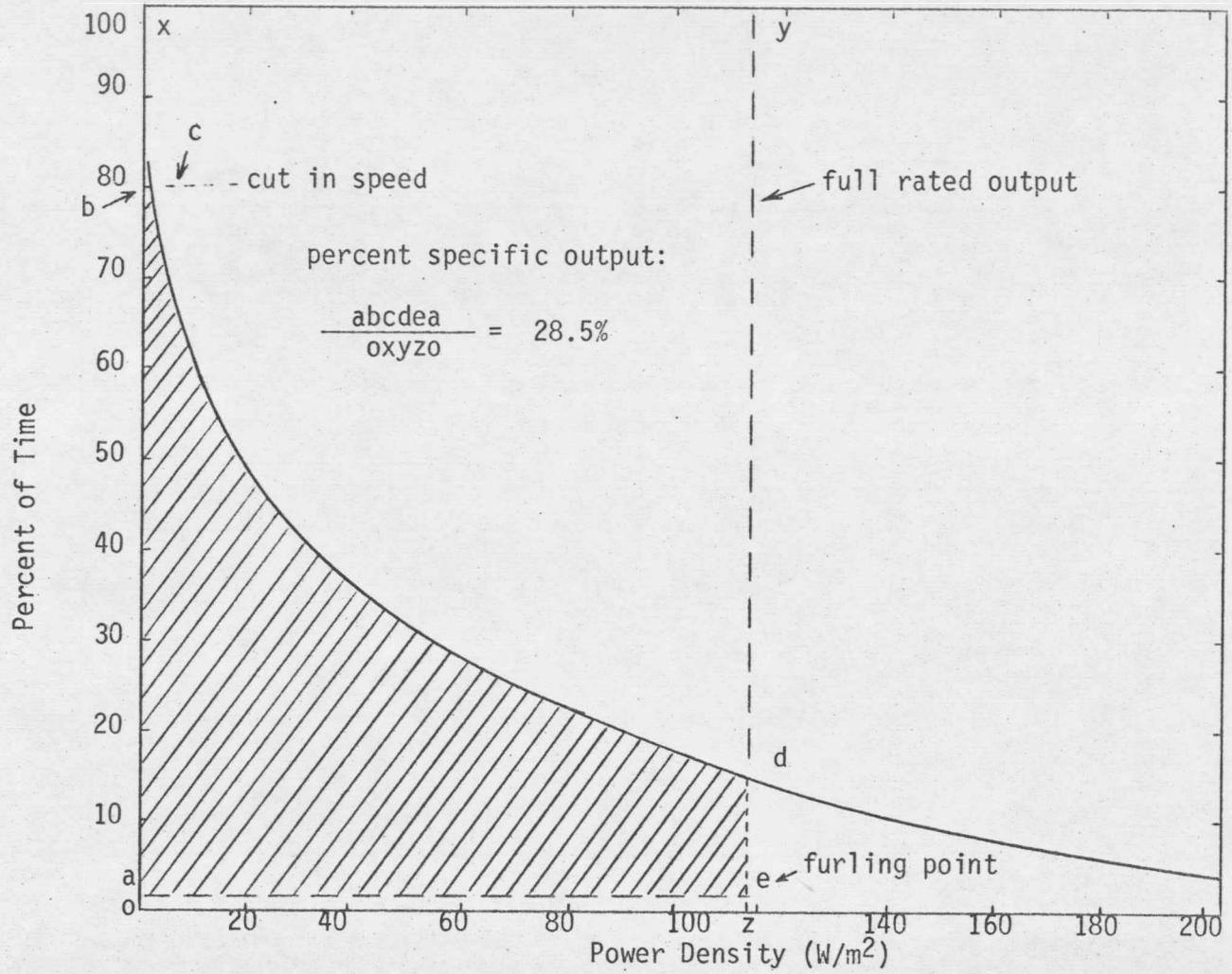


FIGURE 62. SPECIFIC OUTPUT OF THE ELEKTRO WV 35G AT LIVINGSTON

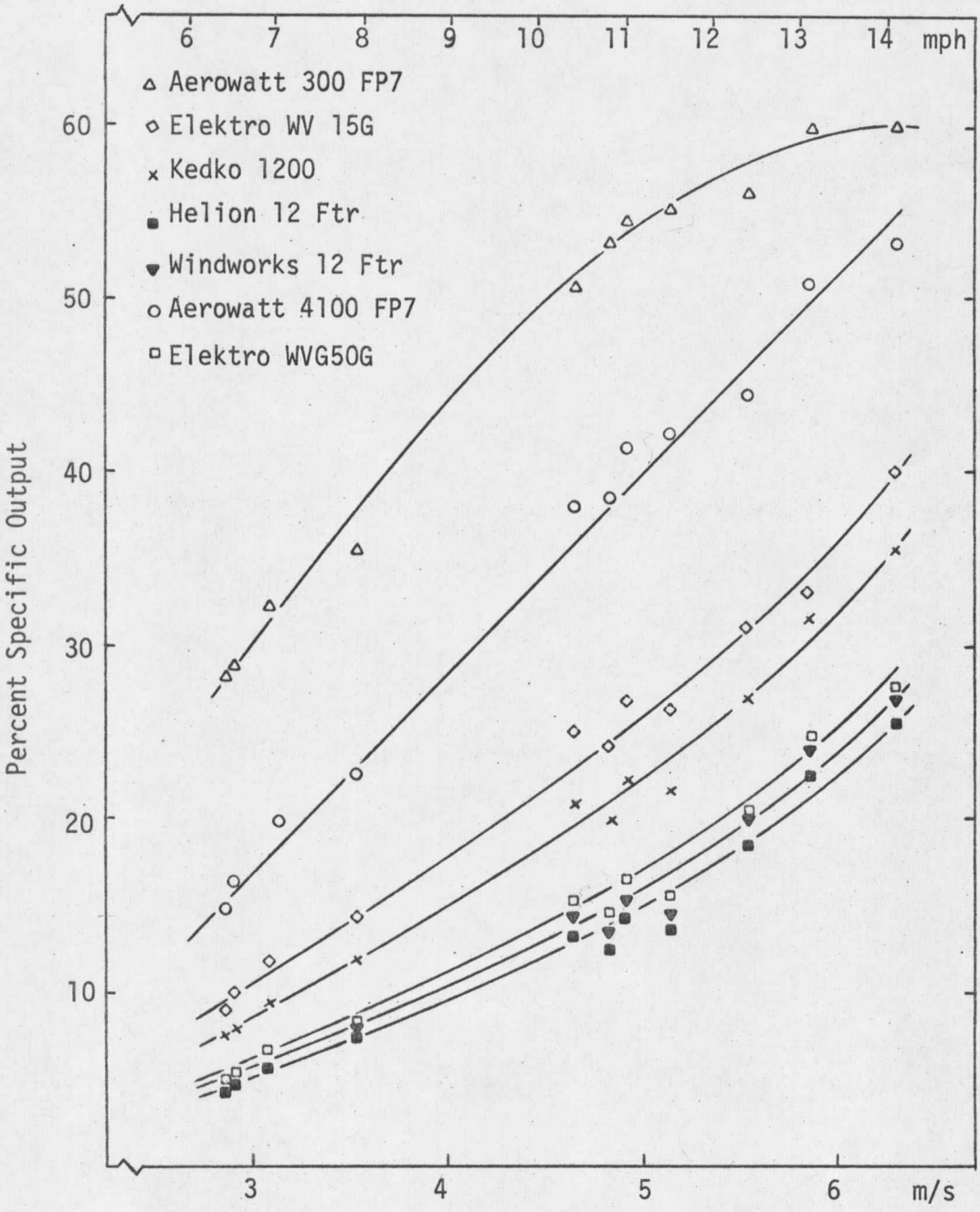


FIGURE 63. SPECIFIC OUTPUT A FUNCTION OF ANNUAL MEAN WIND SPEED

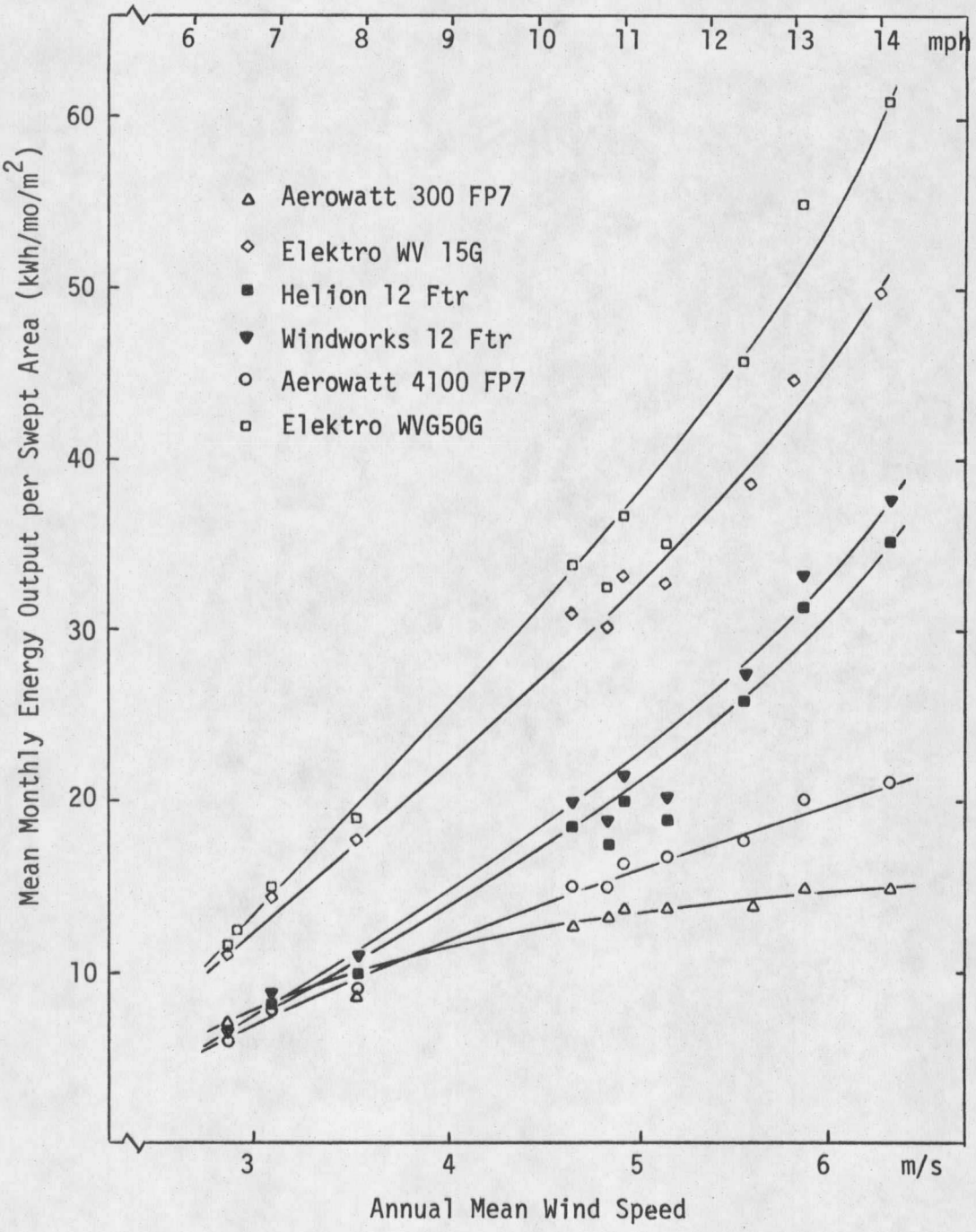


FIGURE 64. ENERGY OUTPUT PER SWEPT AREA A FUNCTION OF ANNUAL MEAN WIND SPEED

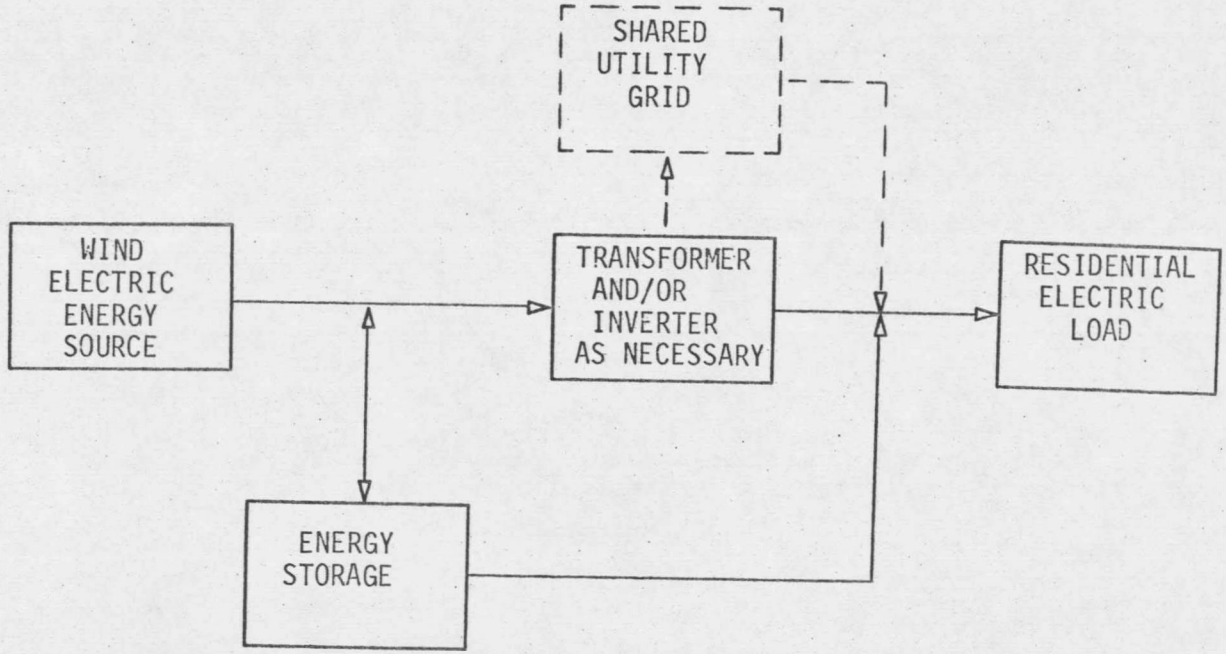


FIGURE 65. COMPLETE WIND POWER SYSTEM USING ENERGY STORAGE OR A SHARED UTILITY GRID

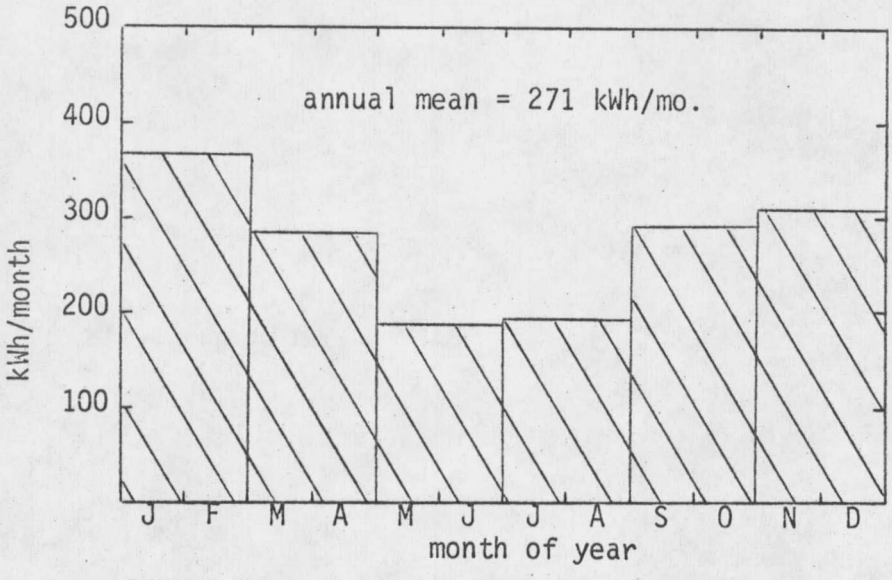


FIGURE 66. SEASONAL VARIATION IN AUTHOR'S ELECTRIC ENERGY LOAD SCHEDULE

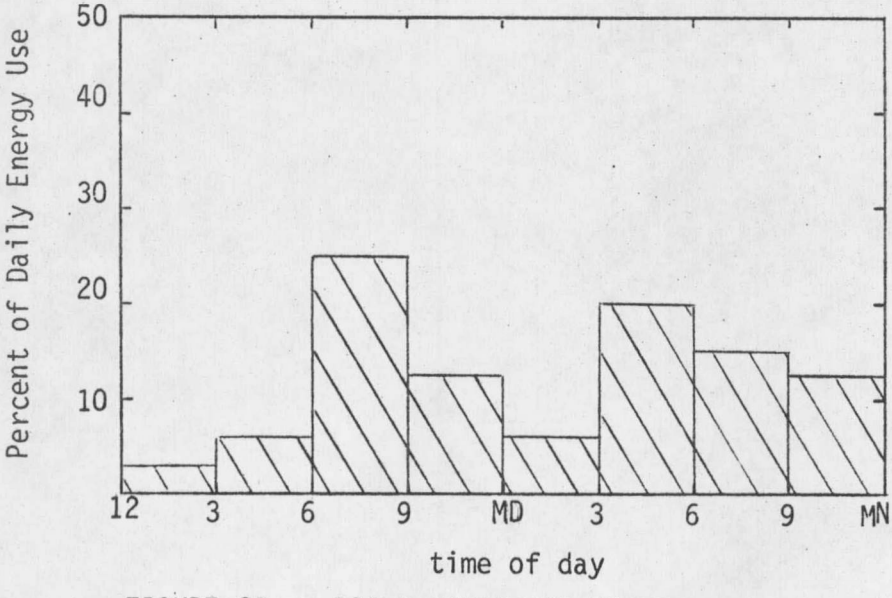


FIGURE 67. DAILY VARIATION IN ENERGY LOAD SCHEDULE

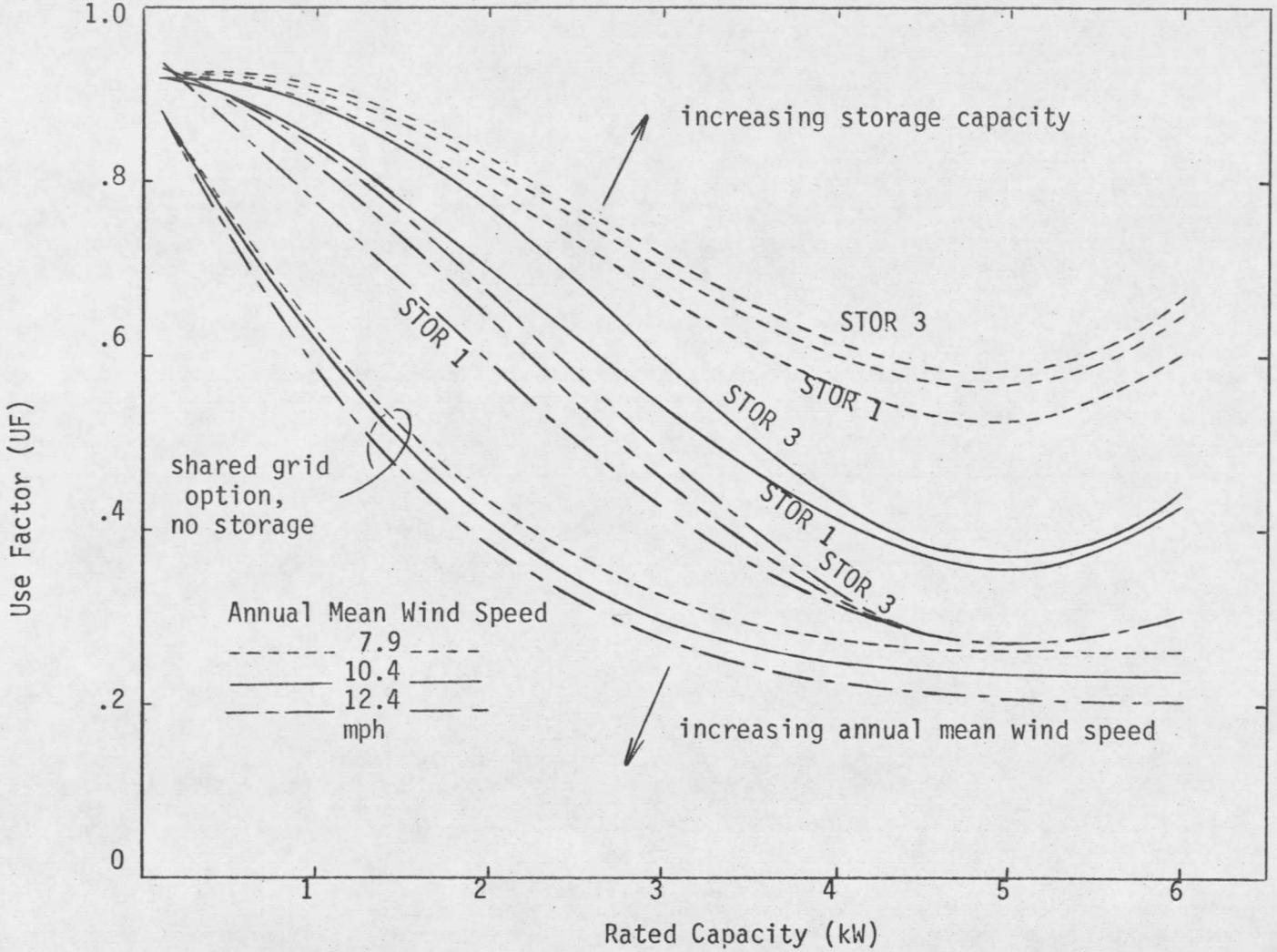


FIGURE 68. VARIATION IN USE FACTOR WITH RATED CAPACITY FOR LOAD 1

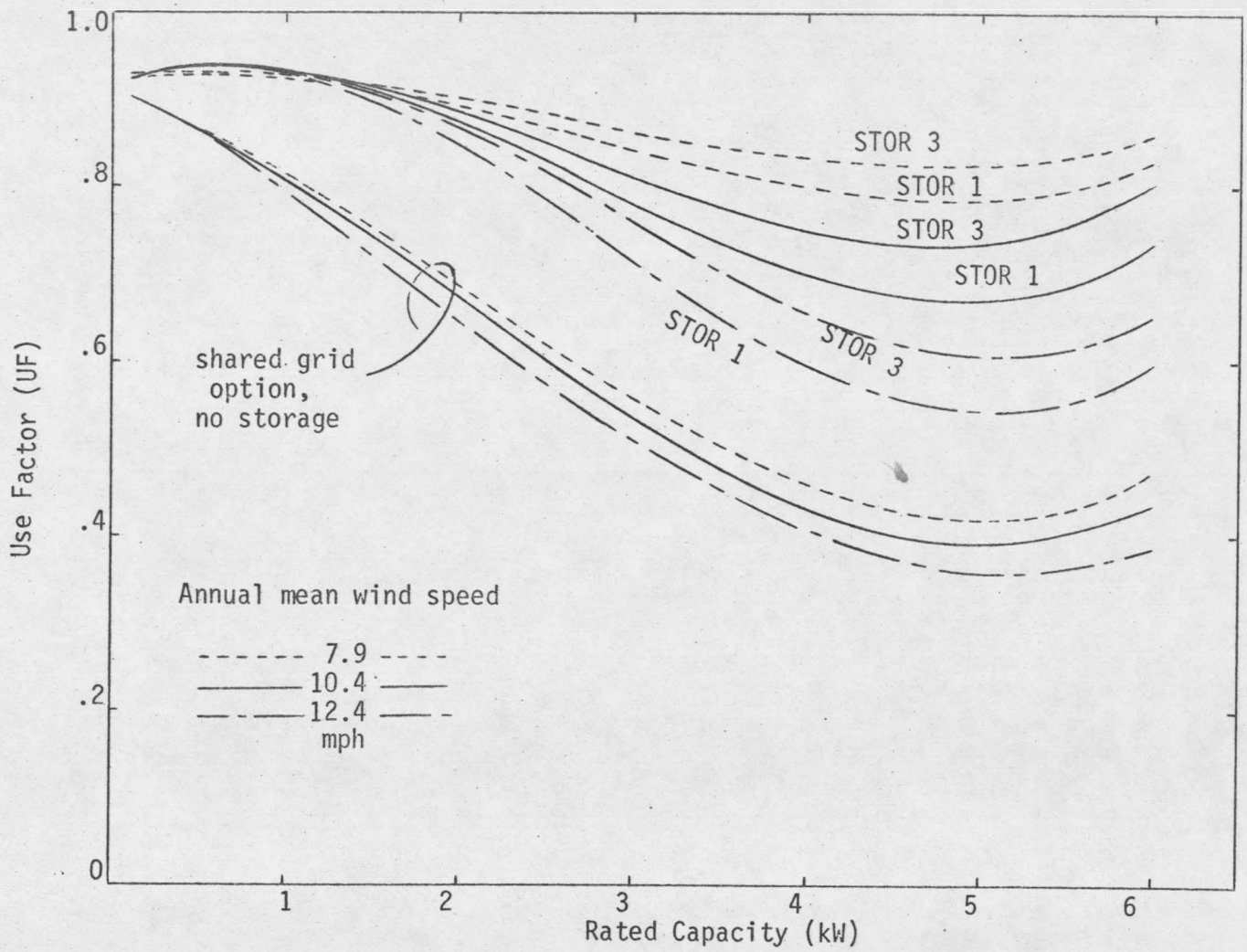


FIGURE 69. VARIATION IN USE FACTOR WITH RATED CAPACITY FOR LOAD 2

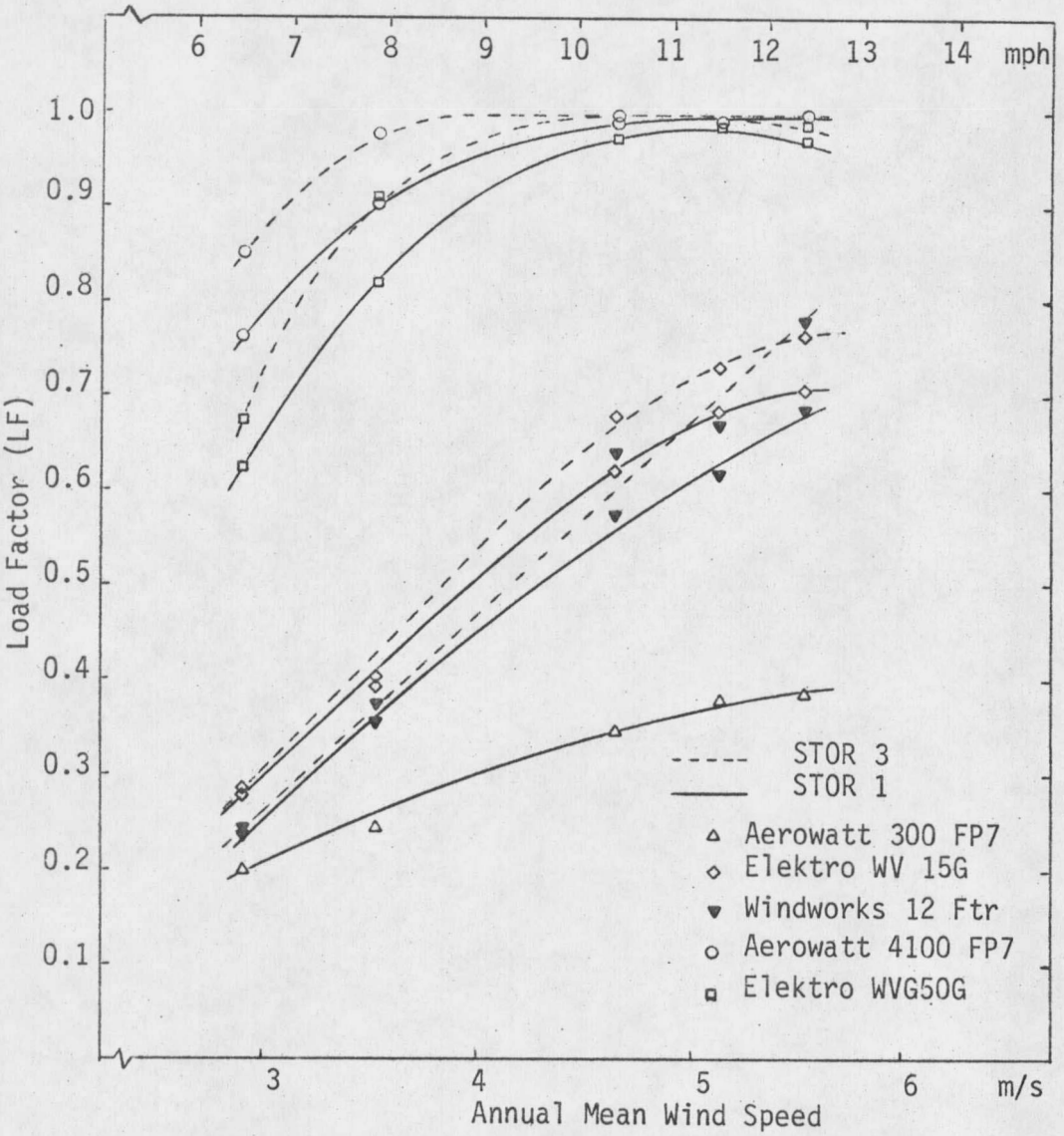


FIGURE 70. LOAD FACTORS FOR SELECTED WIND SYSTEMS, INDEPENDENT SYSTEMS OPTION, LOAD 1

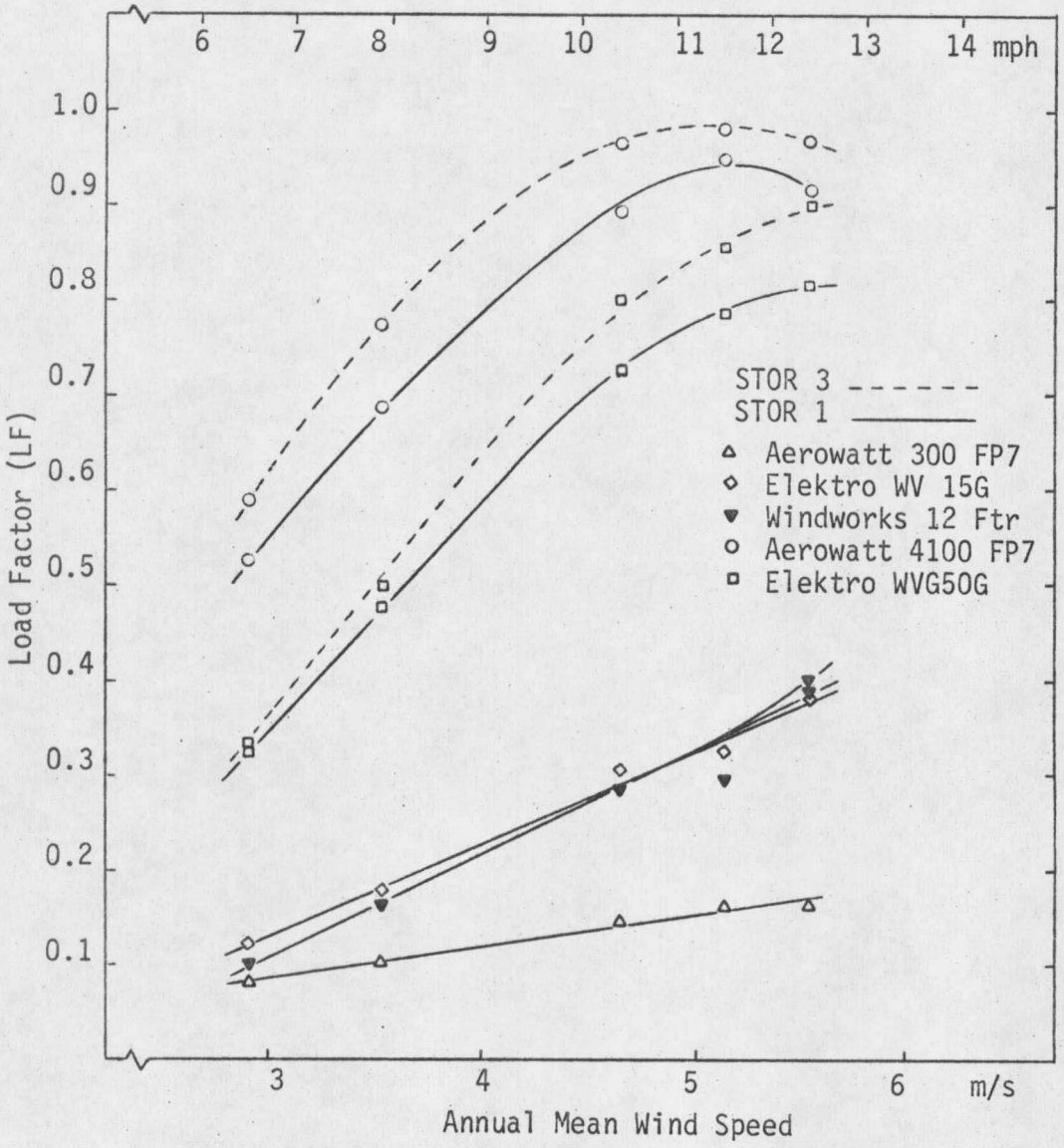


FIGURE 71. LOAD FACTORS FOR SELECTED WIND SYSTEMS, INDEPENDENT SYSTEMS OPTION, LOAD 2

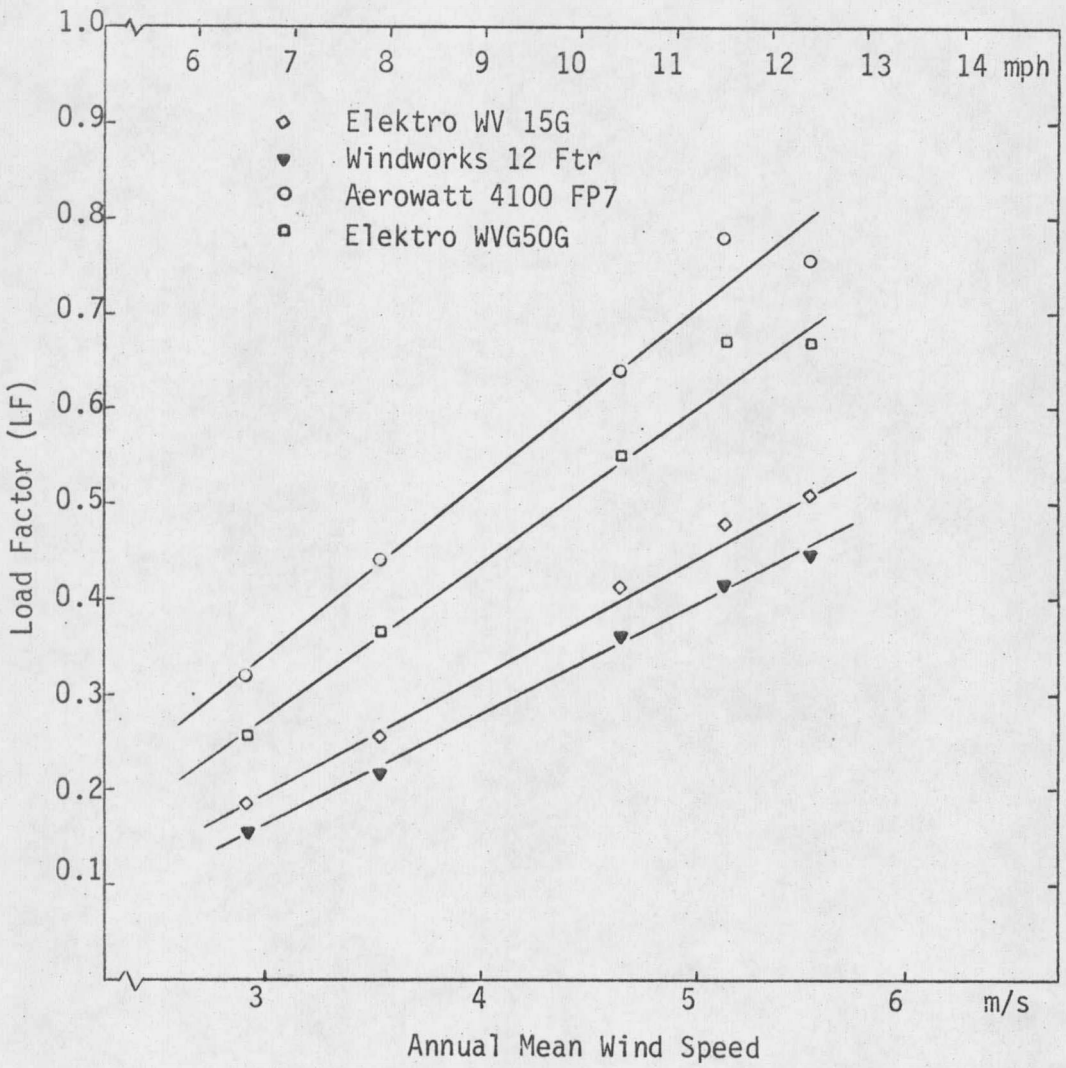


FIGURE 72. LOAD FACTORS FOR SELECTED WIND SYSTEMS, SHARED NETWORK OPTION, LOAD 1

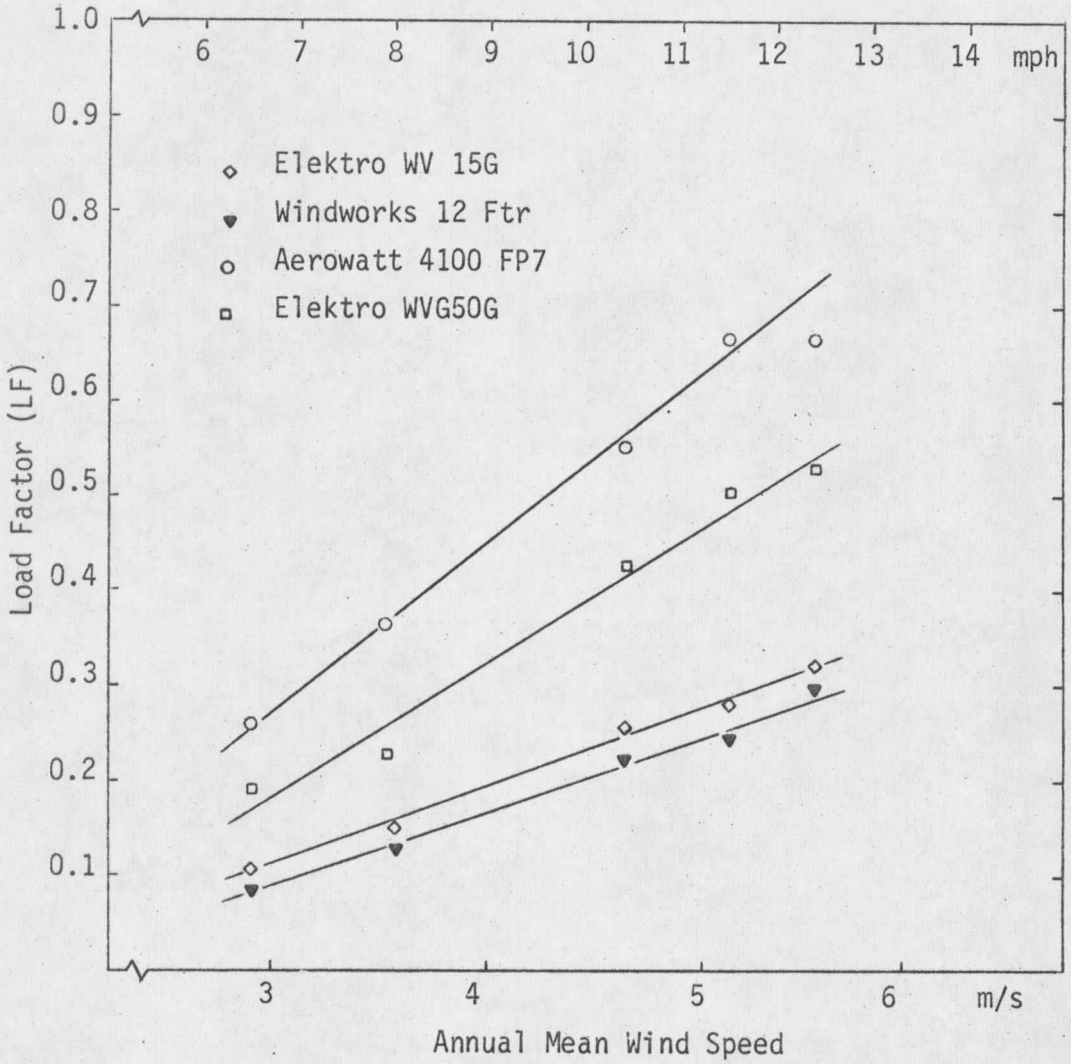


FIGURE 73. LOAD FACTORS FOR SELECTED WIND SYSTEMS, SHARED NETWORK OPTION, LOAD 2

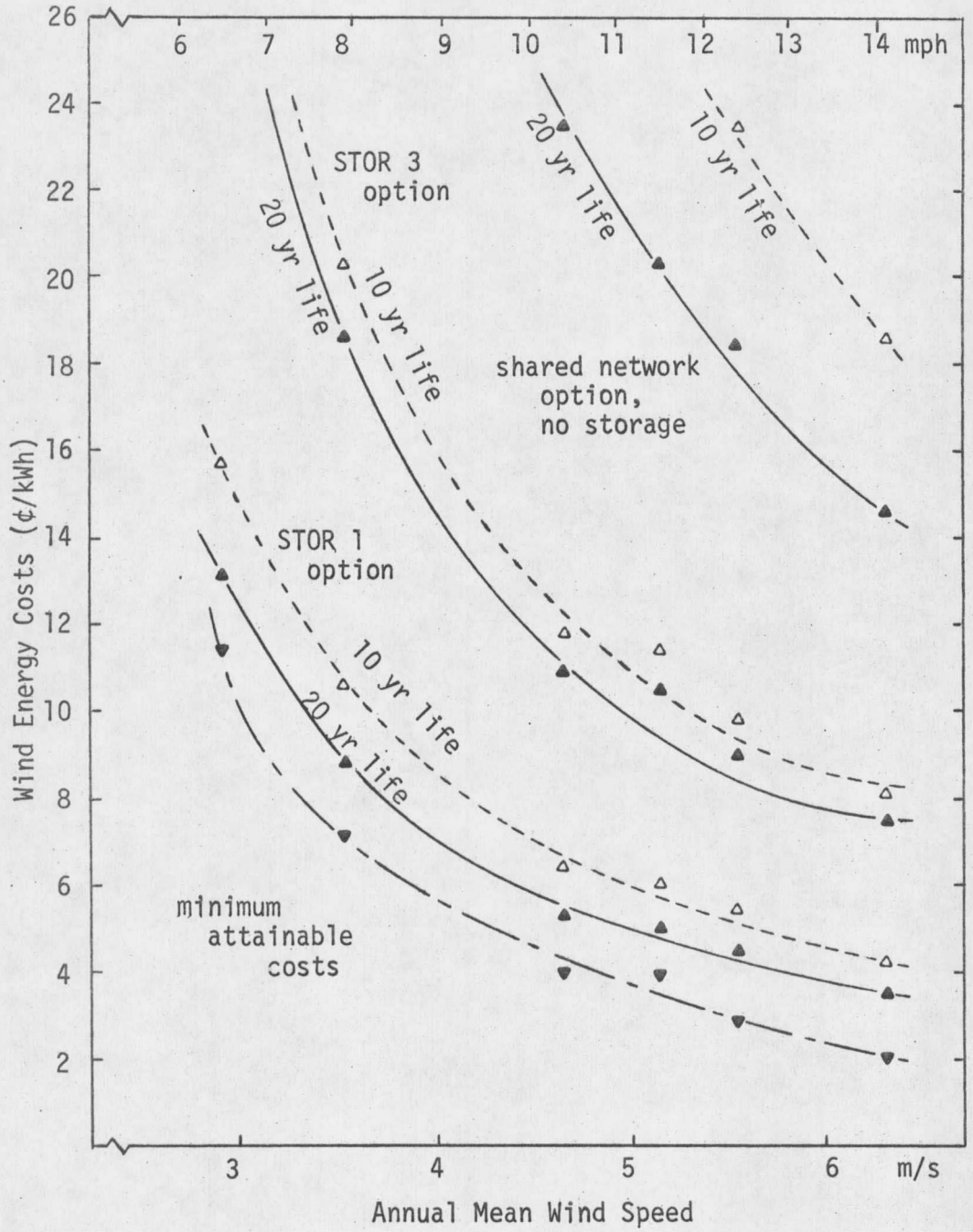


FIGURE 74. WIND ENERGY COSTS FOR THE WINDWORKS TWELVE FOOTER, LOAD 1

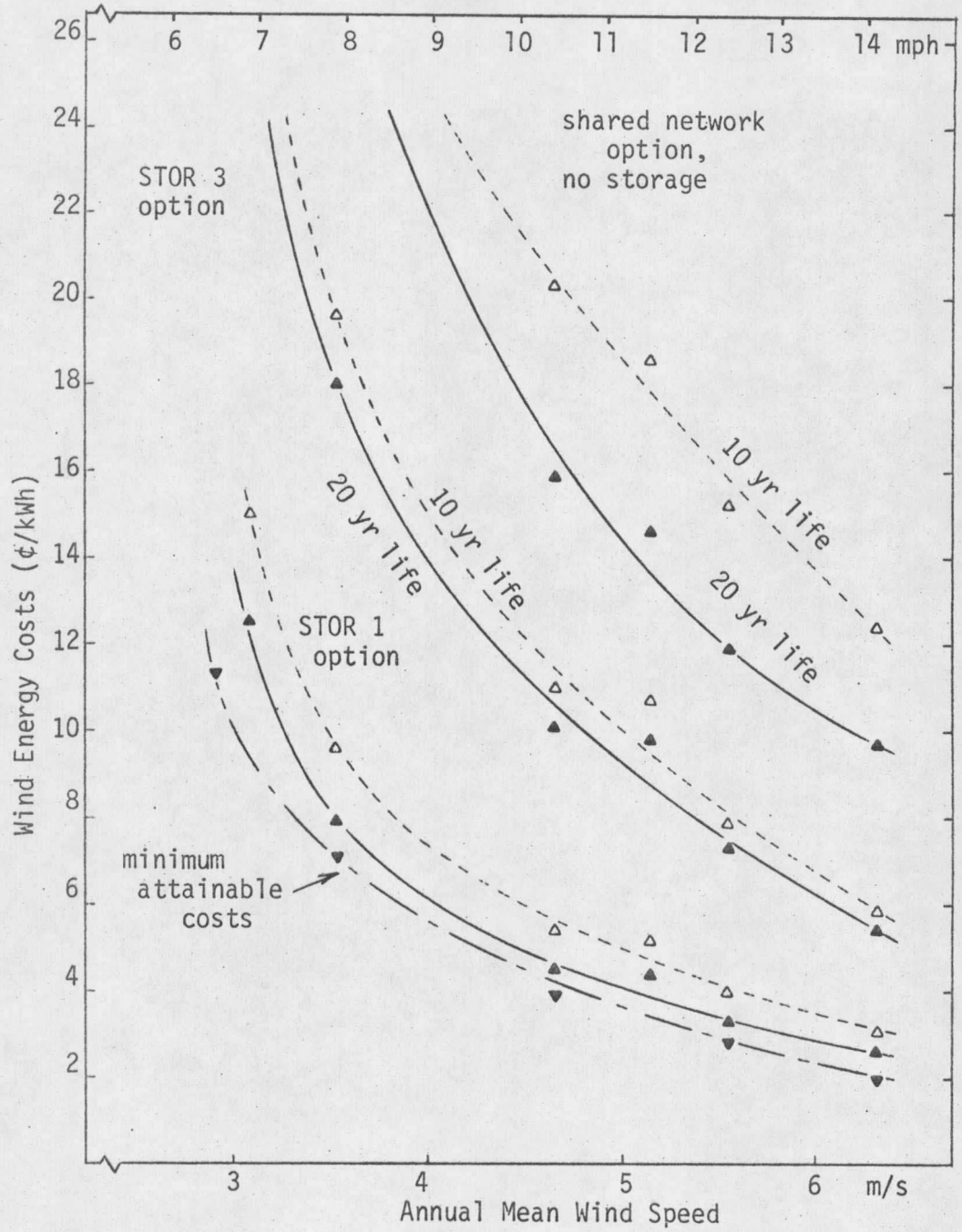


FIGURE 75. WIND ENERGY COSTS FOR THE WINDWORKS TWELVE FOOTER, LOAD 2

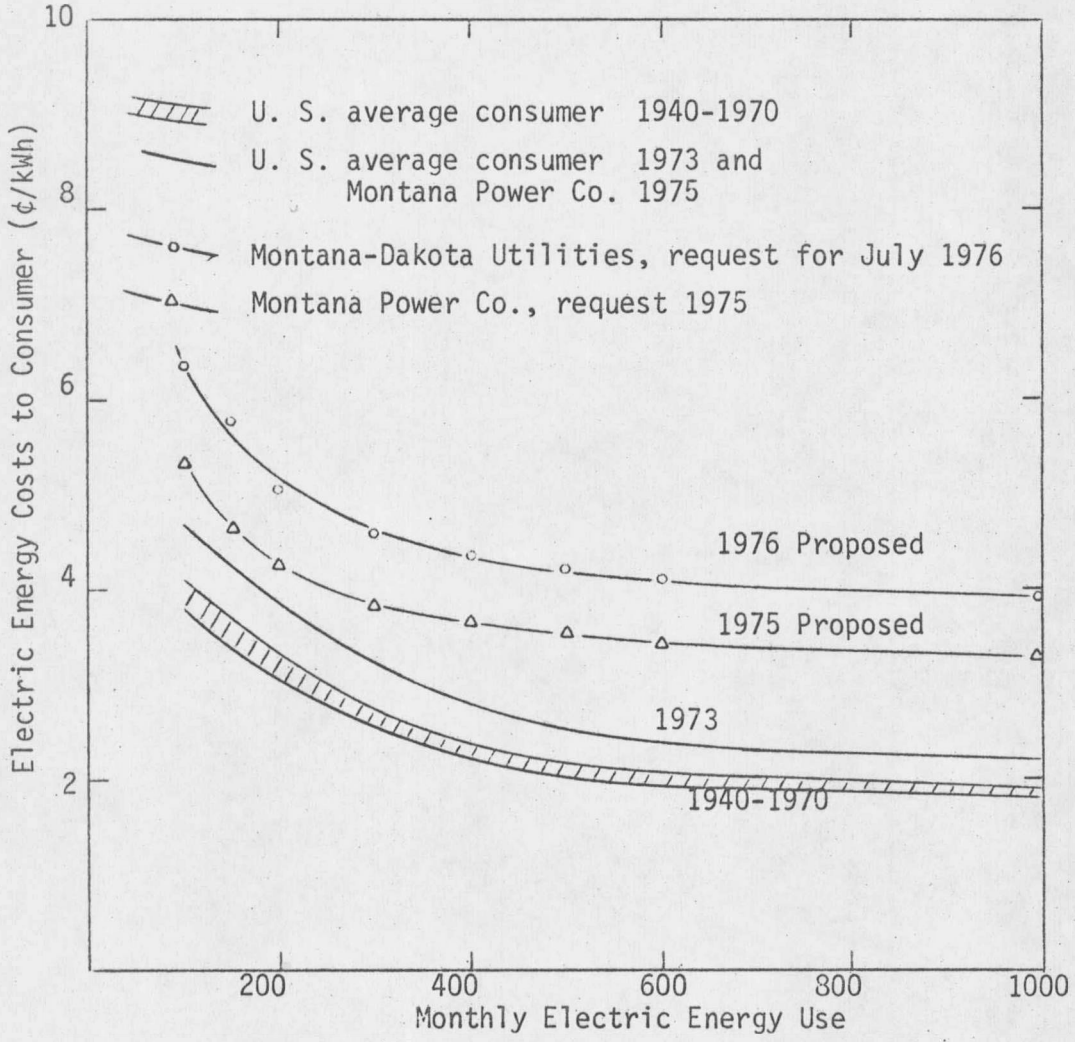


FIGURE 76. RESIDENTIAL ELECTRIC UTILITY RATES

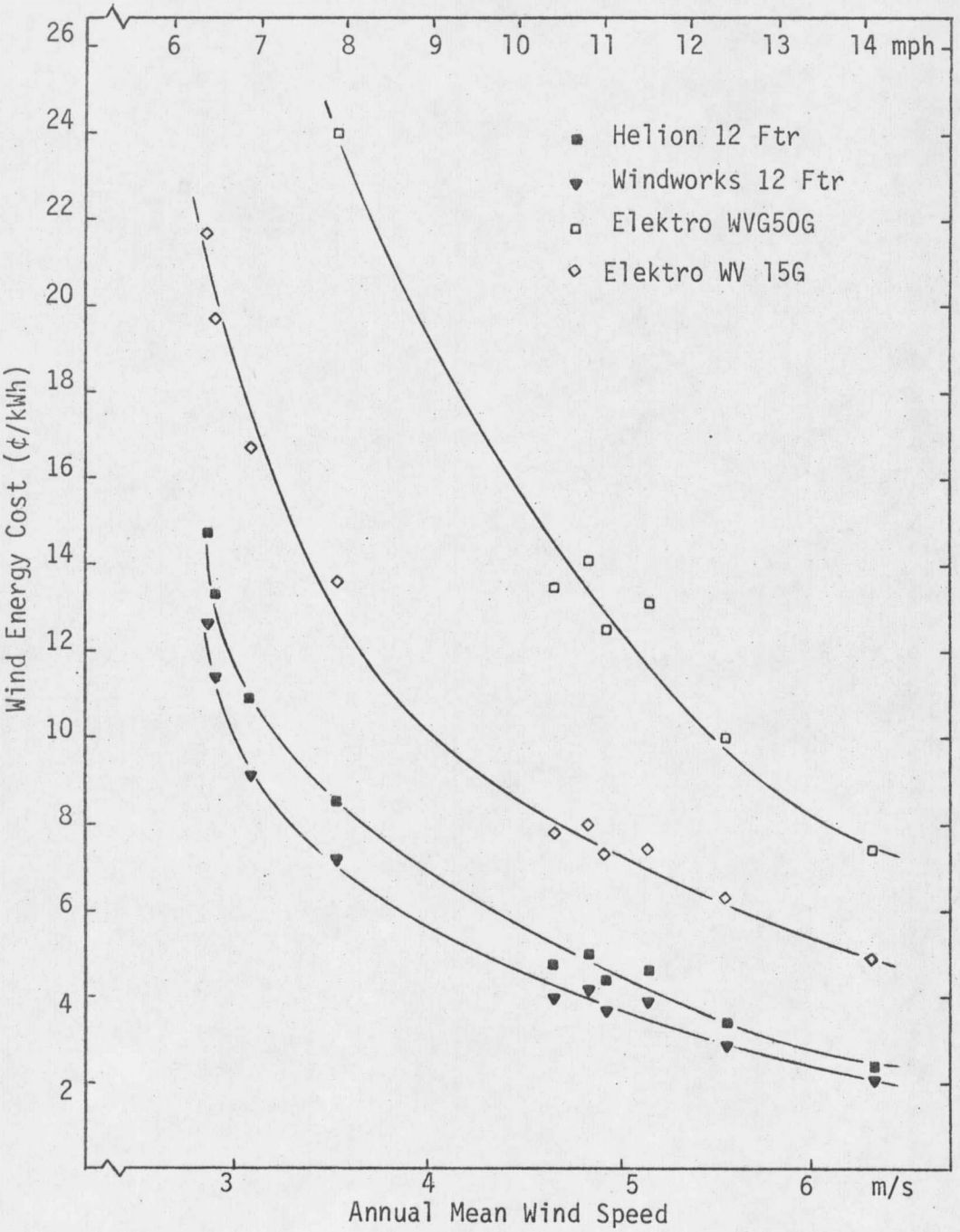


FIGURE 77. MINIMUM RESIDENTIAL WIND ENERGY COSTS FOR SELECTED WIND SYSTEMS USING THE INDEPENDENT SYSTEMS OPTION, STOR 1, 20 YEAR LIFE

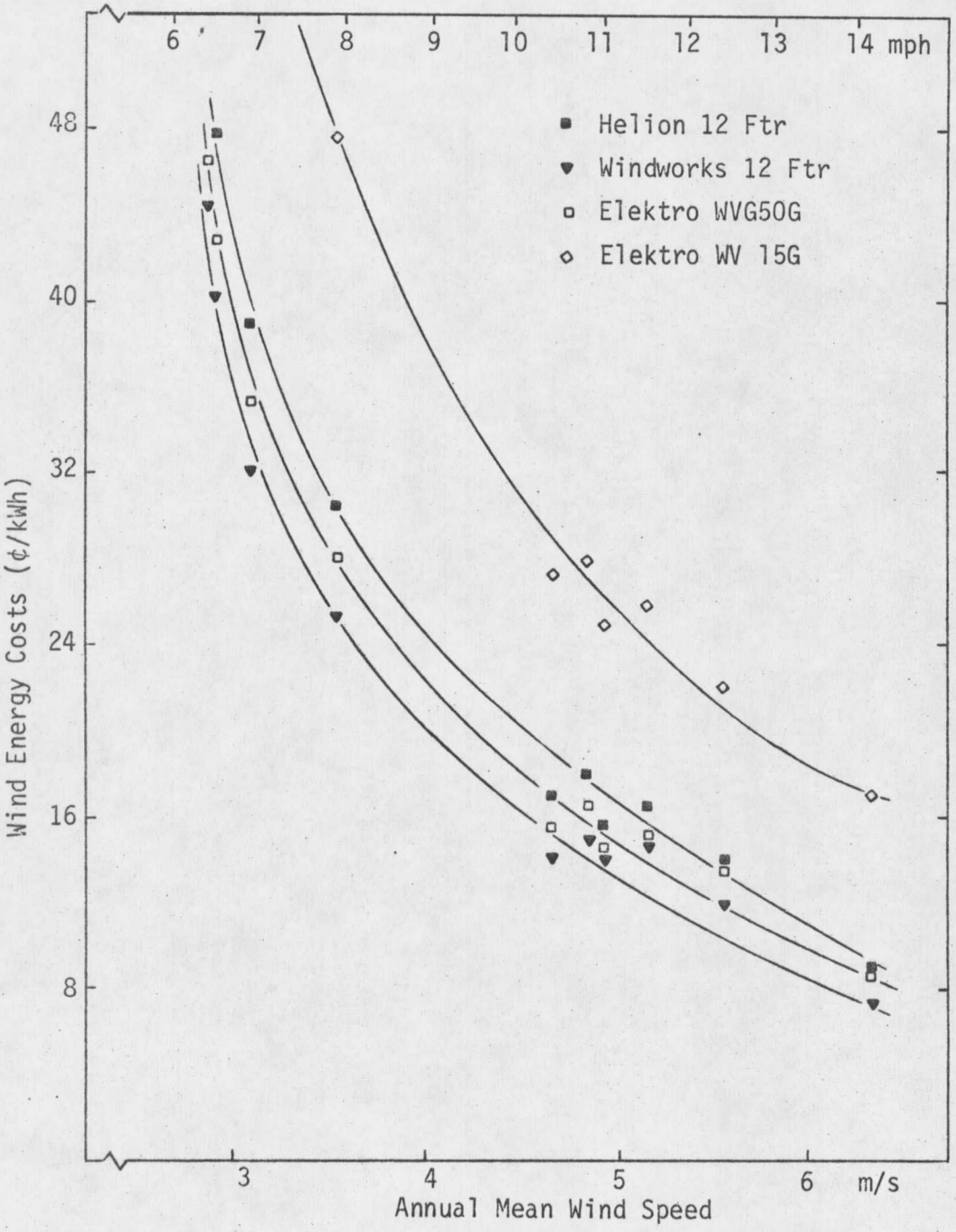


FIGURE 78. MINIMUM RESIDENTIAL WIND ENERGY COSTS FOR SELECTED WIND SYSTEMS USING THE SHARED NETWORK OPTION, 20 YEAR LIFE

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(6) For readers not familiar with the situation in Montana, this state has, effectively, been designated a "national sacrifice area." Range lands of eastern Montana and northern Wyoming are being taken out of agricultural production to strip mine the underlying coal deposits. Mine-mouth coal fired generators at Colstrip, Montana--likely to become one of the largest power complexes in the United States--will pollute Montana's clean Big Sky air with hundreds of tons of pollutants daily. The purpose of this environmental atrocity is to supply electric power to heavy population centers and industries of the Midwestern and Northwestern United States.

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* These data are available for the following eight locations: Great Falls, Billings, Glasgow, Miles City, Havre, Helena, Kalispell, and Missoula. The data used in this analysis were taken from the period 1969 to 1973.

(22) The average year has 365¼ days or 8766 hours, thus accounting for leap years.

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APPENDICES

APPENDIX A

PERCENT TIME AT WIND SPEED FOR TEN MONTANA LOCATIONS

READ 10 LOCATIONS ACROSS, 65 SPEEDS DOWN, KNOTS

	LIV	G.F.	BILL	GLAS	MIC	HAVRE	HELNA	KAL	MSLA	BCZ	
1	.00	.01	.01	.CO	.C1	.CC	.C1	.C1	.CO	.CC	1
2	.01	.58	.01	.14	.16	.C9	1.27	.50	1.65	.C9	2
3	.29	3.39	1.79	3.27	1.23	4.83	12.22	10.88	16.99	3.35	3
4	2.95	4.73	4.17	6.52	3.82	8.55	12.C7	10.93	15.52	10.46	4
5	6.27	8.C4	6.68	8.66	8.72	8.5C	11.76	10.91	12.14	14.44	5
6	5.23	7.65	9.50	8.70	9.64	8.99	8.16	7.14	8.13	11.27	6
7	5.33	8.39	9.24	8.86	11.70	8.57	7.71	5.93	5.36	8.77	7
8	6.72	8.89	12.73	8.86	12.71	8.11	6.46	6.42	4.55	8.15	8
9	2.96	6.97	6.63	7.47	6.30	5.CC	3.69	4.01	2.34	1.69	9
10	6.69	8.53	10.11	8.22	9.84	7.3C	5.52	6.93	4.01	5.46	1C
11	2.80	4.78	5.65	5.17	5.12	4.86	2.64	3.34	1.81	.74	11
12	6.12	5.43	7.11	5.96	6.37	5.16	3.14	3.34	3.C6	2.95	12
13	4.80	4.27	4.96	4.37	3.64	3.96	3.CC	2.22	2.12	1.C6	13
14	5.41	4.28	4.89	4.16	3.C6	4.18	2.33	1.81	1.96	1.60	14
15	6.03	3.66	4.62	3.63	4.37	3.16	2.19	1.61	1.76	2.17	15
16	3.3C	3.14	2.81	2.84	1.77	2.8C	1.44	.76	1.13	.47	16
17	4.59	2.60	1.86	2.1C	1.67	2.81	1.11	.75	.8C	.46	17
18	4.70	2.74	2.12	2.18	2.34	2.36	1.51	.65	.57	.84	18
19	1.47	1.29	.79	.98	.51	.87	.34	.32	.18	.C5	19
20	3.58	2.22	1.46	1.66	1.67	1.25	1.C1	.43	.42	.47	2C
21	1.20	.87	.42	.61	.34	.47	.2C	.15	.08	.C4	21
22	1.64	1.23	.51	.68	.51	.71	.37	.24	.1C	.12	22
23	1.50	.97	.37	.51	.27	.54	.26	.15	.C6	.C4	23
24	1.11	.97	.26	.40	.16	.35	.16	.13	.C3	.C6	24
25	1.35	.9C	.31	.31	.29	.18	.1C	.03	.C9	.11	25
26	.67	.58	.12	.19	.C9	.17	.03	.03	.C1	.C1	26
27	.66	.33	.08	.13	.12	.C9	.C1	.02	.02	.C1	27
28	.83	.38	.05	.09	.12	.10	.C5	.01	.C3	.C4	28
29	.26	.16	.01	.03	.03	.C2	.CC	.CC	.00	.C1	29
30	.66	.31	.08	.06	.C7	.08	.C3	.05	.C1	.03	3C
31	.36	.09	.01	.03	.C2	.C2	.CC	.CO	.OC	.CC	31
32	.3C	.13	.03	.01	.C3	.CC	.C1	.CC	.CC	.C1	32
33	.30	.10	.01	.01	.C3	.CO	.CC	.02	.CC	.CC	33
34	.19	.07	.00	.01	.00	.C1	.00	.OC	.CC	.CC	34
35	.26	.07	.01	.00	.02	.C1	.00	.01	.OC	.01	35
36	.18	.02	.00	.C1	.00	.C1	.C1	.OC	.00	.CC	36
37	.12	.01	.00	.00	.C1	.00	.OC	.00	.00	.CC	37
38	.16	.01	.00	.00	.C1	.C1	.00	.CC	.CC	.00	38
39	.06	.C1	.00	.CO	.00	.01	.00	.OC	.CC	.00	39
40	.07	.OC	.01	.CO	.C1	.C1	.00	.OC	.CC	.00	40
41	.04	.OC	.00	.00	.CO	.CO	.00	.OC	.CC	.CO	41
42	.05	.C1	.00	.CO	.CO	.C1	.00	.CC	.CC	.CO	42
43	.C3	.C1	.01	.00	.00	.00	.00	.OC	.CC	.00	43
44	.03	.02	.00	.00	.01	.CO	.00	.01	.00	.OC	44
45	.01	.00	.00	.00	.CO	.00	.00	.OC	.CO	.00	45
46	.02	.00	.00	.00	.00	.CO	.00	.OC	.CC	.00	46
47	.02	.OC	.00	.CO	.00	.00	.00	.OC	.00	.CO	47
48	.01	.00	.00	.00	.CO	.00	.00	.00	.CC	.00	48
49	.00	.00	.00	.00	.OC	.00	.00	.OC	.CC	.00	49
50	.01	.00	.00	.00	.00	.00	.00	.OC	.CC	.CO	5C
51	.01	.00	.00	.00	.00	.CO	.00	.CC	.CC	.00	51
52	.00	.OC	.00	.00	.00	.00	.00	.OC	.CC	.OC	52
53	.CO	.00	.00	.00	.00	.00	.00	.CC	.CC	.CC	53
54	.00	.00	.00	.00	.00	.CO	.OC	.OC	.CC	.OC	54
55	.00	.00	.00	.00	.CO	.00	.00	.00	.CO	.CO	55
56	.00	.00	.00	.00	.00	.00	.00	.CC	.CO	.00	56
57	.00	.00	.00	.00	.00	.00	.CO	.CC	.CC	.00	57
58	.00	.00	.00	.00	.00	.CO	.00	.OC	.OC	.00	58
59	.00	.00	.00	.00	.00	.00	.00	.OC	.CC	.00	59
60	.00	.00	.00	.00	.00	.00	.00	.OC	.CC	.CC	6C
61	.00	.00	.00	.00	.00	.CO	.00	.OC	.CC	.CC	61
62	.CO	.00	.00	.00	.00	.CO	.00	.OC	.CC	.OC	62
63	.00	.00	.00	.00	.00	.OC	.00	.OC	.CC	.CO	63
64	.CO	.00	.00	.CC	.00	.CO	.00	.OC	.CC	.OC	64
65	.00	.CO	.00	.00	.00	.CO	.CO	.OC	.CC	.00	65

APPENDIX B

POWER CHARACTERISTIC DATA FOR THIRTY WIND GENERATORS

Performance is listed up to 30 knots wind speed. Wind system numbers correspond to those of Table 27, page 90.

CHARACTERISTIC PERFORMANCE OF SYSTEMS 1-11

WIND SPEED IN KNOTS, OUTPUT IN KW

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	
1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	2
3	.000	.000	.000	.000	.027	.000	.000	.000	.000	.000	.000	3
4	.002	.007	.000	.000	.046	.000	.000	.000	.000	.000	.000	4
5	.003	.014	.000	.000	.066	.000	.000	.000	.000	.000	.000	5
6	.005	.027	.000	.000	.086	.036	.045	.036	.039	.000	.000	6
7	.007	.035	.015	.018	.110	.057	.113	.063	.062	.020	.000	7
8	.008	.049	.034	.026	.128	.085	.169	.113	.093	.089	.010	8
9	.010	.059	.054	.034	.148	.121	.281	.175	.133	.133	.080	9
10	.011	.065	.075	.043	.166	.167	.518	.250	.182	.182	.173	10
11	.013	.080	.100	.050	.183	.222	.709	.330	.242	.242	.296	11
12	.014	.085	.121	.057	.205	.288	.934	.430	.315	.315	.438	12
13	.015	.093	.138	.065	.228	.366	1.046	.550	.400	.400	.591	13
14	.016	.100	.150	.072	.244	.457	1.091	.670	.500	.500	.714	14
15	.017	.103	.162	.080	.258	.562	1.125	.800	.614	.614	.730	15
16	.017	.105	.172	.086	.267	.683	1.125	.940	.746	.746	.985	16
17	.017	.107	.183	.094	.274	.750	1.125	1.080	.895	.895	1.133	17
18	.017	.107	.192	.100	.275	.750	1.125	1.170	1.062	1.062	1.281	18
19	.017	.107	.202	.108	.275	.750	1.125	1.200	1.224	1.249	1.428	19
20	.017	.107	.210	.115	.275	.750	1.125	1.200	1.224	1.457	1.658	20
21	.017	.107	.210	.123	.275	.750	1.125	1.200	1.224	1.686	1.847	21
22	.017	.107	.210	.130	.275	.750	1.125	1.200	1.224	1.939	2.000	22
23	.017	.107	.210	.137	.275	.750	1.125	1.200	1.224	2.000	2.000	23
24	.017	.107	.210	.144	.275	.750	1.125	1.200	1.224	2.000	2.000	24
25	.017	.107	.210	.153	.275	.750	1.125	1.200	1.224	2.000	2.000	25
26	.017	.107	.210	.160	.275	.750	1.125	1.200	1.224	2.000	2.000	26
27	.017	.107	.210	.168	.275	.750	1.125	1.200	1.224	2.000	2.000	27
28	.017	.107	.210	.177	.275	.750	1.125	1.200	1.224	2.000	2.000	28
29	.017	.107	.210	.186	.275	.750	1.125	1.200	1.224	2.000	2.000	29
30	.017	.107	.210	.193	.275	.750	1.125	1.200	1.224	2.000	2.000	30

CHARACTERISTIC PERFORMANCE OF SYSTEMS 12-22

WIND SPEED IN KNOTS, OUTPUT IN KW

	# 12	# 13	# 14	# 15	# 16	# 17	# 18	# 19	# 20	# 21	# 22	
1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	2
3	.000	.000	.000	.000	.000	.000	.011	.000	.000	.000	.000	3
4	.000	.000	.000	.000	.000	.000	.027	.000	.000	.000	.000	4
5	.000	.000	.000	.000	.000	.000	.052	.000	.000	.000	.000	5
6	.000	.000	.000	.000	.000	.164	.090	.000	.000	.250	.000	6
7	.000	.100	.000	.197	.020	.410	.143	.120	.220	.300	.000	7
8	.100	.200	.148	.337	.166	.615	.214	.220	.350	.450	.000	8
9	.200	.300	.211	.475	.236	1.025	.304	.350	.475	.875	.000	9
10	.250	.400	.289	.651	.324	1.886	.417	.500	.650	1.000	.000	10
11	.250	.600	.385	.867	.431	2.583	.555	.670	.850	1.375	.976	11
12	.300	.750	.500	1.125	.559	3.403	.721	.800	1.100	1.975	2.196	12
13	.400	1.000	.635	1.431	.711	3.813	.917	1.000	1.400	2.575	3.659	13
14	.500	1.200	.794	1.787	.888	3.977	1.145	1.250	1.750	3.130	4.879	14
15	.550	1.600	.976	2.198	1.092	4.100	1.408	1.550	2.150	4.025	5.855	15
16	.750	2.000	1.185	2.510	1.326	4.100	1.709	1.850	2.600	4.585	6.587	16
17	1.000	2.400	1.422	3.000	1.590	4.100	2.050	2.250	3.100	5.500	7.074	17
18	1.200	2.800	1.687	3.000	1.888	4.100	2.434	2.700	3.650	5.800	7.806	18
19	1.500	3.400	1.985	3.000	2.220	4.100	2.862	3.200	4.300	5.950	8.294	19
20	1.750	4.000	2.315	3.000	2.589	4.100	3.338	3.700	4.850	6.000	8.782	20
21	1.900	4.000	2.680	3.000	2.998	4.100	3.864	4.000	5.300	6.000	9.270	21
22	2.000	5.200	3.081	3.000	3.447	4.100	4.453	4.250	5.500	6.000	9.758	22
23	2.000	5.200	3.081	3.000	3.447	4.100	4.500	4.400	5.700	6.000	10.002	23
24	2.000	6.400	3.081	3.000	3.447	4.100	4.500	4.500	5.800	6.000	10.246	24
25	2.000	6.400	3.081	3.000	3.447	4.100	4.500	4.500	5.900	6.000	10.490	25
26	2.000	7.700	3.081	3.000	3.447	4.100	4.500	4.500	5.950	6.000	10.734	26
27	2.000	7.700	3.081	3.000	3.447	4.100	4.500	4.500	6.000	6.000	10.978	27
28	2.000	9.300	3.081	3.000	3.447	4.100	4.500	4.500	6.000	6.000	11.124	28
29	2.000	10.500	3.081	3.000	3.447	4.100	4.500	4.500	6.000	6.000	11.222	29
30	2.000	10.500	3.081	3.000	3.447	4.100	4.500	4.500	6.000	6.000	11.319	30

CHARACTERISTIC PERFORMANCE OF SYSTEMS 23-32

WIND SPEED IN KNOTS, OUTPUT IN KW

	# 23	# 24	# 25	# 26	# 27	# 28	# 29	# 30	# 31	# 32	
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2
3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	3
4	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	4
5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	5
6	.0	.0	.0	5.0	.0	.0	.0	.0	1.0	.0	6
7	.0	.0	3.0	16.0	.0	.0	.0	.0	7.0	.0	7
8	.0	4.0	8.0	22.0	.0	.0	.0	1.0	17.0	.0	8
9	1.2	8.0	13.0	23.0	.0	.0	4.0	4.0	30.0	.0	9
10	1.5	12.0	20.0	30.0	.0	.0	11.4	11.0	44.0	.0	10
11	1.7	19.0	30.0	40.0	.0	.0	18.7	22.0	59.0	.0	11
12	2.0	30.0	39.0	50.0	.0	.0	26.5	40.0	73.5	.0	12
13	2.6	68.0	49.0	60.0	2.0	.0	35.6	70.0	88.5	.0	13
14	3.7	45.0	59.0	67.0	10.0	2.0	45.8	80.0	100.0	.0	14
15	4.8	55.0	67.0	76.0	17.5	4.0	56.0	98.0	100.0	.0	15
16	6.0	64.0	76.0	87.0	26.0	8.0	66.1	100.0	100.0	45.7	16
17	7.0	76.0	85.0	92.0	34.0	10.0	76.3	100.0	100.0	99.7	17
18	9.0	85.0	90.0	95.0	42.0	15.0	86.5	100.0	100.0	165.6	18
19	11.2	85.0	90.0	92.0	50.0	20.0	96.7	100.0	100.0	250.4	19
20	13.0	85.0	90.0	92.0	58.0	25.0	106.8	100.0	100.0	340.8	20
21	15.0	19.0	90.0	92.0	66.0	31.0	117.0	100.0	100.0	450.8	21
22	17.7	30.0	90.0	92.0	74.0	38.0	127.2	100.0	100.0	561.5	22
23	20.5	38.0	90.0	92.0	82.0	45.0	137.4	100.0	100.0	678.7	23
24	23.5	45.0	90.0	92.0	90.0	52.0	147.5	100.0	100.0	813.2	24
25	25.0	55.0	90.0	92.0	96.0	60.0	157.7	100.0	100.0	942.9	25
26	25.0	64.0	90.0	92.0	100.0	68.0	167.9	100.0	100.0	1069.5	26
27	25.0	76.0	90.0	92.0	100.0	77.0	178.1	100.0	100.0	1187.7	27
28	25.0	85.0	90.0	92.0	100.0	87.0	188.2	100.0	100.0	1291.3	28
29	25.0	85.0	90.0	92.0	100.0	100.0	198.4	100.0	100.0	1385.1	29
30	25.0	85.0	90.0	92.0	100.0	100.0	200.0	100.0	100.0	1500.0	30

APPENDIX C

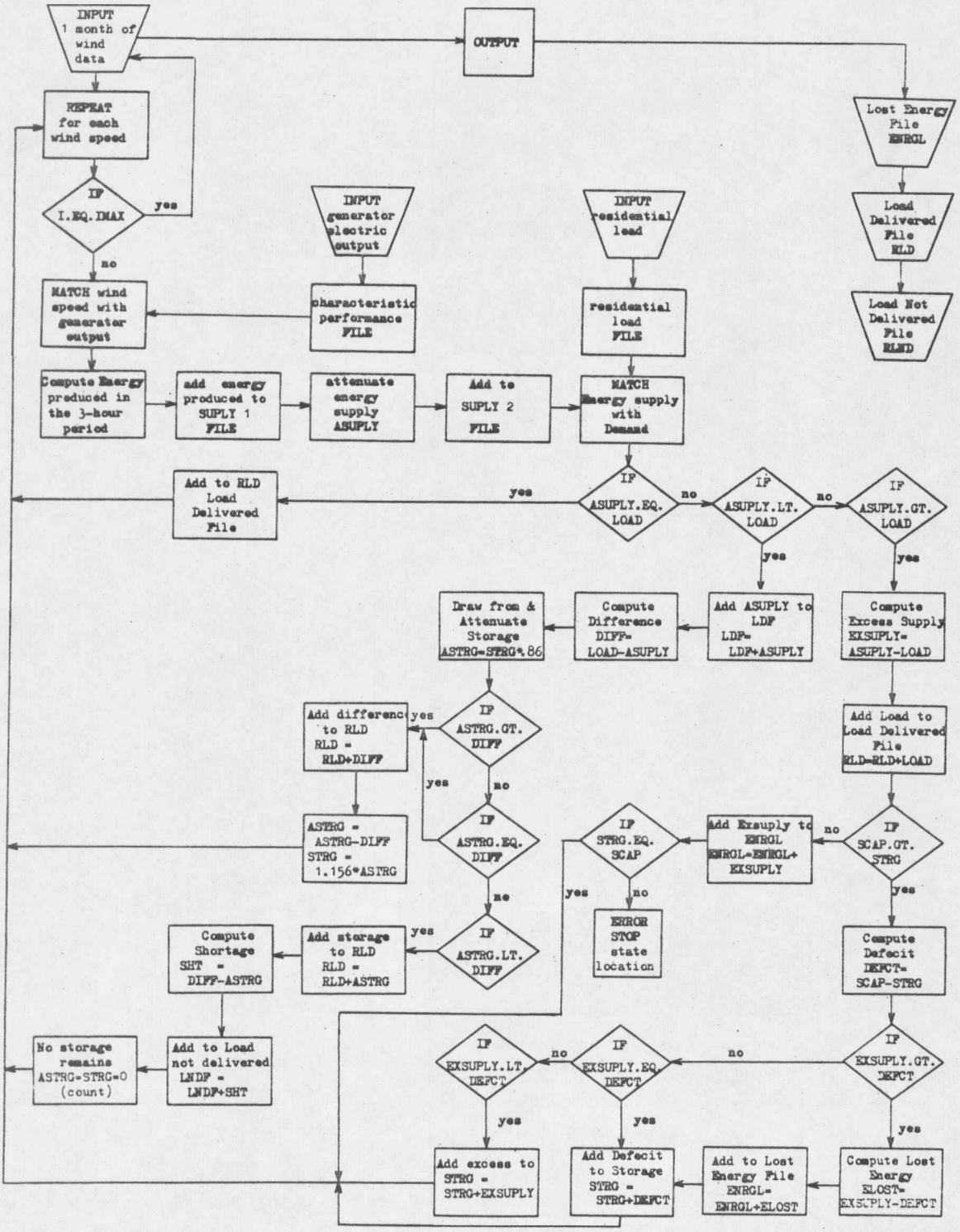
BATTERY STORAGE CAPACITIES USED IN COMPUTER MODEL OF WIND SYSTEM PEFORMANCE

BATTERY STORAGE CAPACITIES USED IN COMPUTER MODEL OF WIND SYSTEM PERFORMANCE
(kWh)

WIND SYSTEM #	"STOR 1"	"STOR 2"	"STOR 3"
2	2.64	5.28	7.92
3	2.64	5.28	7.92
5	5.28	10.56	15.84
6	2.64	5.28	7.92
7	13.80	27.60	41.40
8	7.92	15.84	23.76
9	7.92	15.84	23.76
10	10.62	21.24	31.86
11	13.80	27.60	41.40
12	10.62	21.24	31.86
15	29.90	59.80	98.70
17	51.75	103.50	155.25
19	29.90	59.80	59.80
20	51.75	103.50	155.25

APPENDIX D

LOGIC FLOW DIAGRAM FOR COMPUTER ANALYSIS OF BATTERY STORAGE


INPUT 1 month of wind data
OUTPUT
Lost Energy File ENRGL
REPEAT for each wind speed
Load Delivered File RLD
IF I.EQ.IMAX
yes
no
INPUT generator electric output
INPUT residential load
Load Not Delivered File RLND
MATCH wind speed with generator output
characteristic performance FILE
residential load FILE
Compute Energy produced in the 3-hour period
add energy produced to SUPLY 1 FILE
attenuate energy supply ASUPLY
Add to SUPLY 2 FILE
MATCH Energy supply with Demand
Add to RLD Load Delivered File
IF ASUPLY.EQ. LOAD
IF ASUPLY.LT. LOAD
IF ASUPLY.GT. LOAD
Draw from & Attenuate Storage ASTRG=STRG*.86
Compute Difference DIFF= LOAD-ASUPLY
Add ASUPLY to LDF LDF= LDF+ASUPLY
Compute Excess Supply EXSUPLY= ASUPLY-LOAD
Add difference to RLD RLD = RLD+DIFF
IF ASTRG.GT. DIFF
Add Load to Load Delivered File RLD=RLD+LOAD
ASTRG = ASTRG-DIFF STRG = 1.156*ASTRG
IF ASTRG.EQ. DIFF
IF STRG.EQ. SCAP
Add Exsuply to ENRGL ENRGL=ENRGL+ EXSUPLY
IF SCAP.GT. STRG
ERROR STOP state location
Compute Shortage SHT = DIFF-ASTRG
Add storage to RLD RLD = RLD+ASTRG
IF ASTRG.LT. DIFF
Compute Defecit DEFCT= SCAP-STRG
No storage remains ASTRG=STRG=0 (count)
Add to Load not delivered LNDF = LNDF+SHT
IF EXSUPLY.LT. DEFCT
IF EXSUPLY.EQ. DEFCT
IF EXSUPLY.GT. DEFCT
Add excess to STRG = STRG+EXSUPLY
Add Defecit to Storage STRG = STRG+DEFCT
Add to Lost Energy File ENRGL= ENRGL+ELOST
Compute Lost Energy ELOST= EXSUPLY-DEFCT

APPENDIX E

WIND SYSTEM COSTS AND EQUIPMENT SELECTION

#2. AEROWATT 150 FP7 2.0 m Dia. 0.1 kW

Factory Produced, Distributed by Pennwalt (53)

Tower: as supplied by Pennwalt

Battery: 220 AH, 12V, Surrette Series 400, (2.64 kWh)

Inverter: dc controllers as supplied by Pennwalt

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	3105	31050	3105	2794.50	1863.00	1397.25
tower	460	4600	460	414.00	276.00	207.00
inverter	972	9720	972	874.80	874.80	874.80
battery (1)	150	1500	0	150.00	150.00	150.00
battery (2)	290	2900	0	290.00	290.00	290.00
battery (3)	430	4300	0	430.00	430.00	430.00
interest	7 % add-on					
maintenance	1%					
			(1)	4571.64	3416.90	2839.37
Annual Costs per kW			(2)	4722.84	3568.10	2990.57
			(3)	4874.04	3719.30	3141.77

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	3105	31050	10%			
tower	460	4600	10%			
inverter	1275	12750	10%			
total	4840	48400	4840	4356.00	2904.00	2178.00
interest	7% add-on			3388.00	3388.00	3388.00
maintenance	1%			484.00	484.00	484.00
Annual Cost per kW				8228.00	6776.00	6050.00

#3. WINDCHARGER 1.8m Dia 0.20 kW

Windcharger, Factory produced by Dyna-Technology (40)

Tower: system includes battery recharger and tower as per H. Clews(40)
Battery: 220 AH, 12 V, Surrette Series 400 (2.64 kWh)
Inverter: as per H. Clews catalog (40)

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	650	3250	325	292.50	195.00	146.25
tower						
inverter						
battery (1)	150	750	0	75.00	75.00	75.00
battery (2)	290	1450	0	145.00	145.00	145.00
battery (3)	430	2150	0	215.00	215.00	215.00
interest	7 % add-on					
maintenance	5%					
Annual Costs per kW			(1)	402.60	293.40	238.80
			(2)	472.60	363.40	308.80
			(3)	542.60	433.40	378.80

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	675					
tower						
inverter	1275					
total	1950	9750	0	975.00	650.00	487.50
interest	7% add-on			682.50	682.50	682.50
maintenance	5%			487.50	487.50	487.50
Annual Cost per kW				2145.00	1820.00	1657.50

#5. AEROWATT 300 FP7 2.0 m Dia 0.30 kW

Factory produced, distributed by Pennwalt (53)

Tower: Rohn guyed tower, 30 ft., from Solar Wind (40)

Battery: 440 Ah, 12 V, Surrette Series 400, (5.28 kWh)

Inverter: 12 v dc to 115 v ac, 60 cyc., 300 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	5250	17500	1750	1575.00	1050.00	787.50
tower	500	1667	167	150.00	100.00	75.00
inverter	125	417	42	37.50	37.50	37.50
battery (1)	290	967	0	96.69	96.69	96.69
battery (2)	575	1917	0	191.67	191.67	191.67
battery (3)	860	2867	0	286.67	296.67	296.67
interest	7 % add-on					
maintenance	1 %					
Annual Costs per kW			(1)	2007.90	1386.90	1076.40
			(2)	2110.50	1489.50	1179.00
			(3)	2213.10	1592.10	1281.60

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	5250		10%			
tower	500		10%			
inverter	1275		10%			
total	7025	23417	2342	2107.50	1405.00	1053.75
interest	7% add-on			1639.17	1639.17	1639.17
maintenance	1 %			234.17	234.17	234.17
Annual Cost per kW				3980.84	3278.34	2927.09

#6. SENCENBAUGH 8 ft. Dia. 0.750 kW

Owner assembled from kit form

Tower: Octahedron Module, 30 ft., Owner assembled

Battery: 440 AH, 12 V, Surrette Series 400 (5.28 kWh)

Inverter: 12 V dc to 115 V ac, 60 cyc., Terado

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	1400	1867	187	168.00	112.00	84.00
tower	100	133	13	12.00	8.00	6.00
inverter	125	167	17	15.00	15.00	15.00
battery (1)	290	287	0	38.67	38.67	38.67
battery (2)	575	767	0	76.67	76.67	76.67
battery (3)	860	1147	0	114.67	114.67	114.67
interest	7 % add-on					
maintenance	3 %					
			(1)	257.04	191.04	158.04
Annual Costs per kW			(2)	298.83	232.83	199.83
			(3)	340.63	274.63	241.63

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	1400		10%			
tower	100		10%			
inverter	1275		10%			
total	2775	3700	370	333.00	220.00	166.50
interest	7% add-on			259.00	259.00	259.00
maintenance	3%			111.00	111.00	111.00
Annual Cost per kW				703.00	529.00	536.50

#7. AEROWATT 1100 FP7 5 m Dia 1.1 kW

Factory produced, distributed by Penwalt (53)

Tower: Rohn guyed, 40 ft.

Battery: 120 AH, 115 V, Surrette Series 400, (13.8 kW)

Inverter: 115 V dc to 115 V ac, NOVA, 1500 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	9630	8755	875	787.91	525.27	393.95
tower	660	600	60	54.00	36.00	27.00
inverter	2290	2082	208	187.36	187.36	187.36
battery (1)	850	773	0	77.27	77.27	77.27
battery (2)	1700	1545	0	154.55	154.55	154.55
battery (3)	2550	2318	0	231.82	231.82	231.82
interest	7 % add-on					
maintenance	1 %					
			(1)	1195.07	891.97	740.43
Annual Costs per kW			(2)	1278.52	975.43	823.88
			(3)	1361.98	1058.88	907.34

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	9630		10%			
tower	660		10%			
inverter	1275		10%			
total	11565	10514	1051	946.23	630.82	473.11
interest	7% add-on			753.95	753.95	753.95
maintenance	1%			105.14	105.14	105.14
Annual Cost per kW				1787.32	1471.91	1314.20

#8. ELEKTRO WV 15G 3 m Dia. 1.2 kW

Factory import from Switzerland (40)

Tower: Rohn guyed, 30 ft.

Battery: 660 AH, 12 V Serrette (7.92 kWh)

Inverter: 12 V dc to 115 V ac, 500 W, Terado

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	2450	2042	204	183.75	122.50	91.88
tower	500	417	42	37.50	25.00	18.75
inverter	150	125	13	11.25	11.25	11.25
battery (1)	435	363	0	36.25	362.5	36.25
battery (2)	865	721	0	72.08	72.08	72.08
battery (3)	1295	1079	0	107.92	107.92	107.92
interest	7 % add-on					
maintenance	1 %					
			(1)	290.25	210.60	170.78
Annual Costs per kW			(2)	328.95	249.30	209.48
			(3)	367.65	288.00	248.18

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	2450		10%			
tower	500		10%			
inverter	1275		10%			
total	4225	3521	352	316.88	211.25	158.44
interest	7% add-on			246.46	246.46	246.46
maintenance	1%			35.21	35.21	35.21
Annual Cost per kW				598.54	492.92	440.11

#9. KEDKO 1200 12 ft Dia. 1.2 kW

Factory Produced (35)

Tower: Octahedron Module, 30', Owner Assembled

Battery: 660 AH, 12 V, Surrette (7.92 kWh)

Inverter: 12 V dc to 115 V ac, 500 W, Terado

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	1695	1413	141	127.13	84.75	63.56
tower	100	83	8	7.50	5.00	3.75
inverter	150	125	13	11.25	11.25	11.25
battery (1)	435	363	0	36.25	36.25	36.25
battery (2)	865	721	0	72.08	72.08	72.08
battery (3)	1295	1079	0	107.92	107.92	107.92
interest	7 % add-on					
maintenance	3%					
Annual Costs per kW			(1)	200.34	150.98	126.29
			(2)	239.76	190.39	165.71
			(3)	279.18	229.81	205.12

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	1695		10%			
tower	100		10%			
inverter	1275		10%			
total	3070	2558	256	230.25	153.20	115.13
interest	7% add-on			179.08	179.08	179.08
maintenance	3%			76.75	76.75	76.75
Annual Cost per kW				486.08	409.33	370.96

#10. HELION TWELVE FOOTER 12 ft Dia., 2.0 kW

Owner built from plans by Jack Park

Tower: Octahedron Module, 30 ft., Owner built from plans
Battery: 885 AH, 12 V, 4-12 V units, Surrette (10.62 kWh)
Inverter: 12 V dc to 115 V ac, 500 W., Terado

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	500	250	25	22.50	15.00	11.25
tower	100	50	5	4.50	3.00	2.25
inverter	150	75	8	6.75	6.75	6.75
battery (1)	575	288	0	28.75	28.75	28.75
battery (2)	1140	570	0	57.00	57.00	57.00
battery (3)	1705	852	0	85.25	85.25	85.25
interest	7 % add-on					
maintenance	5 %					
			(1)	70.00	59.92	54.88
Annual Costs per kW			(2)	101.64	91.56	86.52
			(3)	133.28	123.20	118.16

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	500		10%			
tower	100		10%			
inverter	1275		10%			
total	1875	938	94	84.38	56.25	42.19
interest	7% add-on			65.63	65.63	65.63
maintenance	5%			46.88	46.88	46.88
Annual Cost per kW				196.88	168.75	154.69

#11. DUNLITE 2000 3.66 m Dia 2.0 kW

Factory built, Australian import (40)

Tower: Self supporting 40 ft, 3-leg, with tower top

Battery: 120 AH, 115 V, Mule with straps and indicators (13.8 kw)

Inverter: dc to ac at 115V, surplus rotary 300 W, 65% efficient

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	3725	1863	186	167.63	111.75	83.81
tower	910	455	46	40.95	27.30	20.48
inverter	250	125	0	12.50	12.50	12.50
battery (1)	850	425	0	42.50	42.50	42.50
battery (2)	1700	850	0	85.00	85.00	85.00
battery (3)	2550	1275	0	127.50	127.50	127.50
interest	7 % add-on					
maintenance	1 %					
			(1)	284.67	209.57	172.03
Annual Costs per kW			(2)	330.57	255.47	217.93
			(3)	376.47	301.37	263.83

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	3725		10%			
tower	910		10%			
inverter	1275		10%			
total	5910	2955	296	265.95	177.30	132.98
interest	7% add-on			206.85	206.85	206.85
maintenance	1%			29.55	29.55	29.55
Annual Cost per kW				502.35	413.70	369.38

#12. WINDWORKS TWELVE FOOTER 12 ft. Dia. 2.0 kW

Home-built from plans

Tower: Octahedron Module, 30 ft.

Battery: 885 AH, 12 V, Surrette (10.6 kWh)

Inverter: 12 V dc to 115 V ac, 500 W Terado

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	300	150	15	13.50	9.00	6.75
tower	100	50	5	4.50	3.00	2.25
inverter	150	75	8	6.75	6.75	6.75
battery (1)	575	288	0	28.75	28.75	28.75
battery (2)	1140	570	0	57.00	57.00	57.00
battery (3)	1705	852	0	85.25	85.25	57.00
interest	7 % add-on					
maintenance	5 %					
			(1)	59.92	53.20	49.84
Annual Costs per kW			(2)	91.56	84.84	81.48
			(3)	123.20	116.48	113.12

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	300		10%			
tower	100		10%			
inverter	1275		10%			
total	1675	838	84	75.38	50.25	37.69
interest	7% add-on			58.63	58.63	58.63
maintenance	5%			41.88	41.88	41.88
Annual Cost per kW				175.88	150.75	138.19

#15. JACOBS WIND ELECTRIC 3000 16 ft. Dia 3.0 kW

Minneapolis Factory Closed 1957

Tower: Octahedron Module, 72 ft.

Battery: 260 AH, 115 V, Surrette (29.9 kWh)

Inverter: dc to ac 115 V, Nova, 1500 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	2425	808	81	72.75	48.50	36.38
tower	900	300	30	27.00	18.00	13.50
inverter	2290	763	77	68.70	68.70	68.70
battery (1)	1990	663	0	66.33	66.33	66.33
battery (2)	3325	1108	0	110.83	110.83	110.83
battery (3)	4660	1553	0	155.33	155.33	155.33
interest	7 % add-on					
maintenance	1 %					
Annual Costs per kW			(1)	253.56	217.65	199.70
			(2)	301.62	265.71	247.76
			(3)	349.68	313.77	295.82

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	3050		10%			
tower	900		10%			
inverter	1275		10%			
total	5225	1742	175	156.75	104.50	78.38
interest	7% add-on			121.92	121.92	121.91
maintenance	1%			17.42	17.42	17.42
Annual Cost per kW				289.15	236.90	210.77

#17. AEROWATT 4100 FP7 9.8 m Dia. 4.1 kW

Factory produced, Distributed by Penwalt (53)

Tower: Rohn guyed, 80 ft

Battery: 450 AH, 115 V, Surrette Series 400 (51.75 kWh)

Inverter: dc to ac at 115V, Soleq, 3000 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	21690	5290	529	476.12	317.41	238.06
tower	1200	293	29	26.34	17.56	13.17
inverter	4500	1098	110	98.78	98.78	98.78
battery (1)	3325	811	0	81.10	81.10	81.10
battery (2)	6650	1622	0	162.20	162.20	162.20
battery (3)	9975	2433	0	243.29	243.29	243.29
interest	7 % add-on					
maintenance	1 %					
Annual Costs per kW			(1)	736.92	556.04	465.60
			(2)	824.51	643.62	553.18
			(3)	912.10	731.21	640.77

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost 10 yr	15 yr	20 yr
system	21690		10%			
tower	1200		10%			
inverter	1275		10%			
total	24165	5894	589	530.45	353.63	265.23
interest	7% add-on			412.57	412.57	412.57
maintenance	1 %			58.94	58.94	58.94
Annual Cost per kW				1001.96	825.15	736.74

#19. ELECTRO WV 35G 4.39 m Dia 4.5 kW

Factory import from Switzerland (40)

Tower: Rohn guyed, 40 ft.

Battery: 260 AH, 115 V, Surrette Series 400 (29.9 kWh)

Inverter: dc to ac 115 V, Nova, 1500 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	4900	1089	109	98.00	65.33	49.00
tower	660	147	15	13.20	8.80	6.60
inverter	2290	509	51	45.80	45.80	45.80
battery (1)	1990	442	0	44.22	44.22	44.22
battery (2)	3325	739	0	73.89	73.89	73.89
battery (3)	4660	1036	0	103.56	103.56	103.56
interest	7 % add-on					
maintenance	1 %					
			(1)	217.32	177.28	157.27
Annual Costs per kW			(2)	249.36	209.33	189.31
			(3)	281.40	241.37	221.36

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	4900		10%			
tower	660		10%			
inverter	1275		10%			
total	6835	1519	152	136.70	91.13	68.35
interest	7% add-on			106.32	106.32	106.32
maintenance	1 %			15.19	15.19	15.19
Annual Cost per kW				258.21	212.64	189.86

#20. ELEKTRO WVG50G 5 m Dia 6.0 kW

Factory import from Switzerland (40)

Tower: Rohn guyed, 50 ft.

Battery: 450 AH, 115 V, Surrette Series 400, (51.75)

Inverter: dc to ac at 115 V, Soleq, 3000 W

Autonomous Systems Option

	first costs	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	5335	889	89	80.03	53.35	40.01
tower	775	129	13	11.63	7.75	5.81
inverter	4500	750	75	67.50	67.50	67.50
battery (1)	3225	535	0	53.50	53.50	53.50
battery (2)	5695	949	0	94.92	94.92	94.92
battery (3)	8165	1361	0	136.08	136.08	136.08
interest	7 % add-on					
maintenance	1 %					
			(1)	229.67	196.67	180.17
Annual Costs per kW			(2)	274.40	241.40	224.90
			(3)	318.86	285.86	269.36

Shared Grid Option

	first cost	costs per installed kW				
		cost	salvage	annual cost		
				10 yr	15 yr	20 yr
system	5335		10%			
tower	775		10%			
inverter	1275		10%			
total	7385	1231	123	110.78	73.85	55.39
interest	7% add-on			86.16	86.16	86.16
maintenance	1%			12.31	12.31	12.31
Annual Cost per kW				209.24	172.32	153.85

APPENDIX F

FORTRAN IV COMPUTER PROGRAM LISTING

The following is a short description and a listing of the computer programs used in this analysis.

ANNSUM: Lists annual average frequency distributions and power duration for a specified location. Also outputs NAMETM, listing percent time at speed.

ANSUM: Lists twelve frequency distributions and power duration curves, one for each average month, for a specified location.

DIVAR: Lists diurnal variation in mean wind speed and mean power density, by average month and average year, for a specified location.

LOWIND: Computes the number of occurrences of consecutive data points below a specified wind speed. Lists number of data points, hours, number of occurrences, and probability of occurrence.

MLIST: Output is one page table listing twelve average monthly values of mean wind speed, power density, energy density. Annual averages listed in thirteenth row.

MOLIST: Lists monthly mean wind speed, power density and energy density, consecutively by month, for a specified location.

OBER: Analysises wind system performance with residential electric load under the shared grid option.

STORAGE: Analysises wind system performance with residential electric load under the independent systems option.

ARRAY: Lists complete performance and economic evaluation of thiry wind systems at ten locations. Requires five input files containing information on percent time at speed by location, wind turbine output as a function of wind speed, wind system size information, use factor file, and economic cost information.

```
! 769,OBERMEIER,1.                ANNSUM
!LIMIT (TIME,1),(CORE,19),(LO,10),(UO,10)
!ASSIGN F:203,(FILE,LOCATION),(IN),(SAVE)
!ASSIGN F:12,(FILE,MISTM),(OUT),(SAVE)
!FORTRAN GO,LS
      DIMENSIØN N(248,12,4),IFRQ(0:50),IMAX(12,4),FR(0:50)
      DIMENSIØN C(0:50),ØBS(0:50),PWR(0:50),PTM(0:50),PØWR(0:50)
      DIMENSIØN CPTM(0:50)
      LM=4
      DEN=1.142
      DØ 11 J=1,248
      DØ 11 K=1,12
      DØ 11 L=1,LM
      N(J,K,L)=0
11    CØNTINUE
      KNTR=TØT=TPWR=TENRG=0
      DØ 12 JK=1,51
      JJ=JK-1
      C(JJ)=ØBS(JJ)=PTM(JJ)=CPTM(JJ)=PØWR(JJ)=FR(JJ)=IFRQ(JJ)=0
12    CØNTINUE
      DØ 13 L=1,LM
      DØ 13 K=1,12
      READ(105,14),IMØ,IYR,ICY,IMAX(K,L)
 14   FØRMAT(3I2,I3)
      READ(105,15) (N(J,K,L),J=1,IMAX(K,L)
15    FØRMAT(40I2)
13    CØNTINUE
      DØ 40 L=1,LM
      DØ 40 K=1,12
      DØ 40 J=1,IMAX(K,L)
      KNTR=KNTR+1
      M=N(J,K,L)
      IFRQ(M)=IFRQ(M)+1
40    CØNTINUE
      GØ TØ(1,2,3,4,5,6,7,8,9,10)ICY
 1    WRITE(108,21)
21    FØRMAT(15X,'GREAT FALLS FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
 2    WRITE(108,22)
22    FØRMAT(15X,'MISSØULA TWØ YEAR SUMMARY, 1969,1973',//)
      GØ TØ 16
 3    WRITE(108,23)
23    FØRMAT(15X,'KALISPELL TWØ YEAR SUMMARY, 1972-73',//)
      GØ TØ 16
 4    WRITE(108,24)
```

```
 24   FØRMAT(15X,'GLASGØW FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
  5   WRITE(108,25)
 25   FØRMAT(15X,'BILLINGS FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
  6   WRITE(108,26)
 26   FØRMAT(15X,'MILES CITY FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
  7   WRITE(108,27)
 27   FØRMAT(15X,'HAVRE FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
  8   WRITE(108,28)
 28   FØRMAT(15X,'HELENA FØUR YEAR SUMMARY, 1970-73',//)
      GØ TØ 16
  9   WRITE(108,29)
 29   FØRMAT(15X,'BØZEMAN FØUR YEAR SUMMARY, 1973-73',//)
      GØ TØ 16
 10   WRITE(108,30)
 30   FØRMAT(15X,'LIVINGSTØN FØUR YEAR SUMMARY, 1970-73',//)
 16   CØNTINUE
      WRITE(108,17)
 17   FØRMAT(//,'   WIND SPEED IN:                TØTAL       .593    PERC
     CENT     PØWER                    CUM %',//,'     KNØTS    MPH      M/
     CSEC      ØBS       PWR      TIME     WATT/M2     KW-HR/M2     TIME
     C',/)
      DØ 18 M=1,51
      I=M-1
      AI=I
      WSP=AI*1.1508
      WSPD=WSP*0.44704
      C(I)=IFRQ(I)
      B=KNTR
      FR(I)=C(I)/B
      PTM(I)=FR(I)*100.
      PWR(I)=(16./27.)*0.5*DEN*WSPD**3
      PØWR(I)=PWR(I)*FR(I)
      TPWR=TPWR+PØWR(I)
      TØT=TØT+PTM(I)
      CPTM(I)=100.00-TØT
      WRITE(108,31)I,WSP,WSPD,IFRQ(I),PWR(I),PTM(I),PØWR(I),CPTM(I)
 31   FØRMAT(5X12,5XF4.1,5XF6.1,6XI4,3XF7.0,5XF5.2,5XF5.2,19XF5.2)
      WRITE(16,41)  PTM(I)
 41   FØRMAT(F5.2)
 18   CØNTINUE
      TENRG=TPWR*8.766
      WRITE(108,32)KNTR,TØT,TPWR,TENRG
 32   FØRMAT(5X,'TØTALS',21X15,14XF6.2,3XF7.2,5XF7.0)
      END
--EØF HIT AFTER    88.
```

```
!JOB 769,OBERMEIER,1.        ANSUM
!LIMIT (TIME,2),(CORE,45),(LO,75),(UO,75)
!ASSIGN F:203,(FILE,LOCATION),(IN),(SAVE)
!FORTRAN GO,LS
      DIMENSIØN N(850,12,4),IFRQ(0:61),IMAX(12,4),FR(0:61)
      DIMENSIØN C(0:61),ØBS(0:61),PWR(0:61),PTM(0:61),PØWR(0:61)
      DIMENSIØN CPTM(0:61)
      LM=4
      DEN=1.041
      DØ 11 J=1,850
      DØ 11 K=1,12
      DØ 11 L=1,LM
      N(J,K,L)=0
11    CØNTINUE
      DØ 13 L=1,LM
      DØ 13 K=1,12
      READ(203,14)IMØ,IYR,ICY,IMAX(K,L)
 14   FØRMAT(3I2,I3)
      READ(203,15) (N(J,K,L),J=1,IMAX(K,L))
15    FØRMAT(40I2)
13    CØNTINUE
      DØ 33 K=1,12
      KNTR=TØT=TPWR=TENRG=0
      DØ 12 JK=1,61
      JJ=JK-1
      C(JJ)=ØBS(JJ)=PTM(JJ)=CPTM(JJ)=PØWR(JJ)=0
      PWR(JJ)=FR(JJ)=IFRQ(JJ)=0
 12   CØNTINUE
      DØ 40 L=1,LM
      DØ 40 J=1,IMAX(K,L)
      KNTR=KNTR+1
      M=N(J,K,L)
      IFRQ(M)=IFRQ(M)+1
40    CØNTINUE
      WRITE(108,21)K
 21   FØRMAT('1',15X,'LIVINGSTØN  MØNTHLY LIST FØR MØNTH ',I2)
      WRITE(108,17)
17    FØRMAT(//,'   WIND SPEED IN:                TØTAL      .593    PERC
     CENT      PØWER                    CUM %',/,'      KNØTS    MPH      M/
     CSEC       ØBS       PWR       TIME     WATT/M2     KW-HR/M2     TIME
     C',/)
      DØ 18 M=1,61
      I=M-1
      AI=I
```

```
      WSP=AI*1.1508
      WSPD=WSP*0.44704
      C(I)=IFRQ(I)
      B=KNTR
      FR(I)=C(I)/B
      PTM(I)=FR(I)*100.
      PWR(I)=(16./27.)*0.5*DEN*WSPD**3
      P0WR(I)=PWR(I)*FR(I)
      TPWR=TPWR+P0WR(I)
      T0T=T0T+PTM(I)
      CPTM(I)=100.00-T0T
      WRITE(108,31)I,WSP,WSPD,IFRQ(I),PWR(I),PTM(I),P0WR(I),
     CCPTM(I)
   31 F0RMAT(5X12,5XF4.1,5XF6.1,6X14,3XF7.0,5XF5.2,5XF5.2,
     C19XF5.2)
   18 C0NTINUE
      TENRG=TPWR*8.766
      WRITE(108,32)KNTR,T0T,TPWR,TENRG
   32 F0RMAT(5X,'T0TALS',21X15,14XF6.2,3XF7.2,5XF7.0)
   33 C0NTINUE
      END
--E0F HIT AFTER    61.


!JOB 769,OBERMEIER,1.          DIURNAL  VARIATION
!LIMIT (TIME,1),(CORE,39),(LO,25),(UO,25)
!ASSIGN F:203,(FILE,LOCATION),(IN),(SAVE)
!FORTRAN GO,LS
```

```
      DIMENSIØN N(8,31,12,5),IMAX(12),JMAX(12),XBAR(8,12)
      DIMENSIØN XIS(8,12),KNTR(8,12),XI2(8,12),IFR(8,12,0:50)
      DIMENSIØN AXIS(8),AKTR(8),AXI2(8),RMWS(8),IPWR(8,12)
      DIMENSIØN FRCT(8,12,0:50),PØWR(8,12,0:50),PWR(8,12),TPWR(8)
      DIMENSIØN RFR(8,12,0:50),RKNTR(8,12),IATP(8)
      DEN=1.103
      LM=5
      DØ 10 L=1,LM
      DØ 10 K=1,12
      DØ 10 J=1,31
      DØ 10 I=1,8
      N(I,J,K,L)=0
   10 CØNTINUE
      DØ 3 L=1,LM
      DØ 3 K=1,12
      READ(203,1)IMØ,IYR,ICY,IMAX(K)
    1  FØRMAT(3I2,I3)
      JMAX(K)=IMAX(K)/8
      READ(203,2)((N(I,J,K,L),I=1,8),J=1,JMAX(K))
    2 FØRMAT(40I2)
    3 CØNTINUE
      DØ 21 K=1,12
      DØ 21 I=1,8
      XIS(I,K)=XI2(I,K)=KNTR(I,K)=XBAR(I,K)=RKNTR(I,K)=0
   21 CØNTINUE
      DØ 22 MI=1,51
       M=MI-1
      DØ 22 K=1,12
      DØ 22 I=1,8
      IFR(I,K,M)=RFR(I,K,M)=0
   22 CØNTINUE
      DØ 4 L=1,LM
      DØ 4 K=1,12
      DØ 4 J=1,JMAX(K)
      DØ 4 I=1,8
      RN=N(I,J,K,L)
      XIS(I,K)=XIS(I,K)+RN
      KNTR(I,K)=KNTR(I,K)+1
      RKNTR(I,K)=KNTR(I,K)
      XBAR(I,K)=(XIS(I,K)/RKNTR(I,K))*1.1508
      XI2(I,K)=XI2(I,K)+RN**2
      M=N(I,J,K,L)
      IFR(I,K,M)=IFR(I,K,M)+1
    4 CØNTINUE
      DØ 23 I=1,8
      AXIS(I)=AKTR(I)=AXI2(I)=TPWR(I)=0.
      IATP(I)=0
   23 CØNTINUE
      DØ 5 K=1,12
      DØ 5 I=1,8
```

```
      AXIS(I)=XIS(I,K)+AXIS(I)
      AKTR(I)=KNTR(I,K)+AKTR(I)
      AXI2(I)=XI2(I,K)+AXI2(I)
    5 CONTINUE
      DO 6 I=1,8
      RMWS(I)=(AXIS(I)/AKTR(I))*1.1508
    6 CONTINUE
      WRITE(108,11)
   11 FORMAT(10/,42X,'BILLINGS        MONTANA',///,
     C33X,'DIURNAL VARIATION IN MEAN SPEED, BY MONTH',//,
     C36X,'TIME OF DAY AM TO PM,  SPEED IN MPH',///,
     C20X,'MONTH    1-3      4-6      7-9     10-12     1-3      4-6      7-9
     C  10-12',//)
      DO 7 K=1,12
      WRITE(108,8)K,(XBAR(I,K),I=1,8)
    8 FORMAT(22X12,8(4XF4.1))
    7 CONTINUE
      WRITE(108,12)(RMWS(I),I=1,8)
   12 FORMAT(/,21X,'MEAN',3XF4.1,7(4XF4.1))
      DO 24 I=1,8
      DO 24 K=1,12
      PWR(I,K)=0
   24 CONTINUE
      DO 15 K=1,12
      DO 15 I=1,8
      DO 15 MI=1,51
      M=MI-1
      WSP=M*0.5144536
      RFR(I,K,M)=IFR(I,K,M)
      RKNTR(I,K)=KNTR(I,K)
      FRCT(I,K,M)=RFR(I,K,M)/RKNTR(I,K)
      POWR(I,K,M)=(0.5*DEN*WSP**3)*FRCT(I,K,M)
       PWR(I,K)=PWR(I,K)+POWR(I,K,M)
      IPWR(I,K)=PWR(I,K)
   15 CONTINUE
      DO 16 K=1,12
      DO 16 I=1,8
      TPWR(I)=TPWR(I)+PWR(I,K)
      IATP(I)=TPWR(I)/12.
   16 CONTINUE
      WRITE(108,17)
   17 FORMAT('1',10/,42X,'BILLINGS       MONTANA',///,
     C29X,'DIURNAL VARIATION IN MEAN POWER DENSITY, BY MONTH',//,
     C31X,'TIME OF DAY AM TO PM, POWER IN WATTS/METER SQ',///,
     C21X,'MONTH     1-3      4-6      7-9     10-12     1-3      4-6      7-9
     C    10-12',//)
      DO 18 K=1,12
      WRITE(108,9)K,(IPWR(I,K),I=1,8)
    9 FORMAT(23X12,8(4X14))
   18 CONTINUE
```

```
      WRITE(108,14)(IATP(I),I=1,8)
   14 FØRMAT(/,22X,'MEAN',3XI4,7(4XI4))
      END
--EØF HIT AFTER  103.
```

```
!JØB 769,ØBERMEIER,1.    LØWIND
!LIMIT (TIME,1),(CØRE,38),(LØ,25),(UØ,25)
!ASSIGN F:203,(FILE,BILDATA),(IN),(SAVE)
!FØRTRAN GØ,LS
      DIMENSIØN N(248,60),IMAX(60),LSN(0:50),RPRØ(0:50)
      DIMENSIØN RLSN(0:50)
C.....MØNTH LIMIT..........
      ML=60
      DØ 3 K=1,ML
      READ(203,1)IMØ,IYR,ICY,IMAX(K)
    3 READ(203,2)(N(J,K),J=1,IMAX(K))
    1 FØRMAT(3I2,I3)
    2 FØRMAT(40I2)
      TKNTR=LKNTR=LSEC=HKNTR=RLPTM=HPTM=0
      DØ 10 J=1,51
      JK=J-1
   10 LSN(JK)=0
      DØ 6 K=1,ML
      DØ 6 J=1,IMAX(K)
      TKNTR=TKNTR+1
      I=N(J,K)
      IF(I.LE.16) GØ TØ 4
      GØ TØ 5
    4 LKNTR=LKNTR+1
      LSEC=LSEC+1
      GØ TØ 6
    5 LSN(LSEC)=LSN(LSEC)+1
      LSEC=0
      HKNTR=HKNTR+1
    6 CØNTINUE
      RLKNTR=LKNTR
       RLPTM=(RLKNTR/TKNTR)*100.
      HPTM=(HKNTR/TKNTR)*100.
      DØ 7 L=1,51
```

```
      LL=L-1
      L3=LL*3
      RLSN(LL)=LSN(LL)
      RPRØ(LL)=RLSN(LL)/TKNTR
  7   WRITE(108,8)LL,L3,LSN(LL),RPRØ(LL)
  8   FØRMAT(15X12,5X13,5X16,5XE10.3)
      WRITE(108,9)RLKNTR,HKNTR,TKNTR,RLPTM,HPTM
  9   FØRMAT(/,25XF5.0,5XF7.0,5XF8.0,/,25XF6.2,5XF6.2)
      END
!LØAD (GØ)
!RUN
!EØD
```

```
!JOB 769,OBERMEIER,1.          MLIST
!LIMIT (TIME,1),(CORE,16),(LO,10),(UO,10)
!ASSIGN F:203,(FILE,LOCATION),(IN),(SAVE)
!FORTRAN GO,LS
      DIMENSIØN N(248,12,5),IFR(0:50),RFR(0:50),FRCT(0:50)
      DIMENSIØN PØWR(0:50),IMAX(12)
      WRITE(108,5)
  5   FØRMAT(32X,'GREAT FALLS      MØNTANA',///,
     C15X,'MØNTH     MEAN WIND SPEED                PØWER'
     C,5X,'ENERGY',/,
     C25X,'KTS       MPH       M/S        W/M2      KWH/M2',///)
      LM=5
      DEN=1.068
      TKNTR=TSUM=TPØWR=TNRG=0
      DØ 6 J=1,248
      DØ 6 K=1,12
      DØ 6 L=1,LM
      N(J,K,L)=0
  6   CØNTINUE
      DØ 7 L=1,LM
      DØ 7 K=1,12
      READ(203,1)IMØ,IYR,ICY,IMAX(K)
  1   FØRMAT(3I2,I3)
      READ(203,2)(N(J,K,L),J=1,IMAX(K))
  2   FØRMAT(4012)
  7   CØNTINUE
      DØ 33 K=1,12
      DØ 8 JK=1,51
      KK=JK-1
```

```
      IFR(KK)=RFR(KK)=FRCT(KK)=PØWR(KK)=0
    8 CØNTINUE
      SUM=TPWR=TENRG=KNTR=RNTR=0
      DØ 9 L=1,LM
      DØ 9 J=1,IMAX(K)
      IN=N(J,K,L)
      RN=N(J,K,L)
      IFR(IN)=IFR(IN)+1
      KNTR=KNTR+1
      SUM=SUM+RN
    9 CØNTINUE
      RMAX=IMAX(K)
      RNTR=KNTR
      TKNTR=TKNTR+KNTR
      TSUM=TSUM+SUM
      DØ 10 MI=1,51
      I=MI-1
      RFR(I)=IFR(I)
      RI=I
      WSPD=0.514453632*RI
      FRCT(I)=RFR(I)/RNTR
      PØWR(I)=(0.296296296*DEN*WSPD**3)*FRCT(I)
      TPWR=TPWR+PØWR(I)
      TENRG=TENRG+PØWR(I)*0.720
   10 CØNTINUE
      RMWSK=SUM/RNTR
      RMWSE=RMWSK*1.1508
      RMWSM=RMWSE*0.44704
      WRITE(108,11)K,RMWSK,RMWSE,RMWSM,TPWR,TENRG
   11 FØRMAT(18X12,3(5XF4.1),8XF5.1,5XF5.1)
      TPØWR=TPØWR+TPWR
      TNRG=TNRG+TENRG
   33 CØNTINUE
      TMWSK=TSUM/TKNTR
      TMWSE=TMWSK*1.1508
      TMWSM=TMWSE*0.44704
      TP=TPØWR/12.
      TE=TNRG/12.
      WRITE(108,12)TMWSK,TMWSE,TMWSM,TP,TE
   12 FØRMAT(/,9X,'ANNUAL MEAN',3(5XF4.1),8XF5.1,5XF5.1)
      END
--EØF HIT AFTER   66.
```

```
!JOB 769,OBERMEIER,1.        MOLIST
!LIMIT (TIME,1),(CORE,6),(LO,10),(UO,10)
!ASSIGN F:203,(FILE,LOCATION),(IN),(SAVE)
!FORTRAN GO,LS
      DIMENSIØN N(830),IFR(0:61),RFR(0:61),FRCT(0:61),PØWR(0:61)
      DIMENSIØN ENRG(0:61)
      HR=730.
      WRITE(108,5)
  5   FØRMAT(15X,'BØZEMAN MØNTANA',//,
     C15X,'MØNTH',5X,'MEAN WIND',5X,'PØWER',5X,'ENERGY',//,
     C25X,'SPEED MPH',5X,'WATT/M2',5X,'KW-HR/M2',///)
      DENS=1.032
      DØ 12 K=1,48
      READ(203,1)IMØ,IYR,ICY,IMAX
  1   FØRMAT(3I2,I3)
      READ(203,2)(N(J),J=1,IMAX)
  2   FØRMAT(40I2)
      SUM=TPWR=TENRG=0
      DØ 4 J=1,61
      JL=J-1
      IFR(JL)=RFR(JL)=FRCT(JL)=PØWR(JL)=ENRG(JL)=0
  4   CØNTINUE
      DØ 3 J=1,IMAX
      IN=N(J)
      RN=N(J)
      IFR(IN)=IFR(IN)+1
      SUM=SUM+RN
  3   CØNTINUE
      RMAX=IMAX
      DØ 14 M=1,61
      L=M-1
      RFR(L)=IFR(L)
      RL=L
      WSPD=RL*0.514453632
      FRCT(L)=RFR(L)/RMAX
      PØWR(L)=(0.296296296*DENS*WSPD**3)*FRCT(L)
      ENRG(L)=PØWR(L)*HR*0.001
      TENRG=TENRG+ENRG(L)
      TPWR=TPWR+PØWR(L)
 14   CØNTINUE
      RMWS=(SUM/RMAX)*1.1508
      WRITE(108,15)K,RMWS,TPWR,TENRG
 15   FØRMAT(16X12,8XF5.2,8XF6.1,8XF6.1)
 12   CØNTINUE
      END
--EØF HIT AFTER    41.
```

```
!JØB 769,ØBERMEIER,1.    ØBER
!LIMIT (TIME,3),(CØRE,24),(LØ,25),(UØ,25)
!ASSIGN F:300,(FILE,LØCATIØN),(IN),(SAVE)
!ASSIGN F:301,(FILE,LØAD1),(IN),(SAVE)
!ASSIGN F:302,(FILE,LØAD2),(IN),(SAVE)
!ASSIGN F:303,(FILE,WINSYS),(IN),(SAVE)
!FØRTRAN GØ,LS,ADP
      REAL LØD,LDW,LØAD(8,12)
      INTEGER WS(60,248),IMAX(60)
      DIMENSIØN CHAR(22,0:65),SUPLY(248),ATSUPLY(248)
C.....MØNTH LIMIT IS ML
C.....YEAR LIMIT IS IYL
      ML=60
      IYL=5
      WRITE(108,7)
C.....ZERØ WIND SPEED AND ØTHER ARRAYS.........
      DØ 100 KI=1,ML
      DØ 100 K=1,248
 100  WS(KI,K)=0
      DØ 108 K=1,248
 108  SUPLY(K)=ATSUPLY(K)=0.
C.....INPUT ALL WIND SPEED DATA.............
      DØ 101 KI=1,ML
      READ(300,1)IMAX(KI)
 101  READ(300,2)(WS(KI,K),K=1,IMAX(KI))
C.....INPUT CHARACTERISTIC PERFØRMANCE INFØRMATIØN.....
      DØ 109 JJ=1,22
      READ(303,4)(CHAR(JJ,I),I=1,65)
 109  CHAR(JJ,0)=0.
      DØ 107 L2=1,2
      WRITE(108,5)
      IF(L2.GT.1)GØ TØ 103
      DØ 102 IM=1,12
 102  READ(301,3)(LØAD(IH,IM),IH=1,8)
      GØ TØ 105
 103  DØ 104 IM=1,12
 104  READ(302,3)(LØAD(IH,IM),IH=1,8)
C.....DØ ØNCE FØR EACH WIND SYSTEM.............
 105  DØ 107 JJ=1,22
      LØD=SUPLY1=SUPLY2=LDW=FMPC=TMPC=RATIØ=0.
      SHTG=EXSUPLY=0.
C......DØ FØR EACH WIND SPEED IN THREE HØUR STEPS......
      DØ 106 IY=1,IYL
      DØ 106 IM=1,12
      KJ=IM+(IY-1)*12
      IDA=IMAX(KJ)/8
      DØ 106 ID=1,IDA
      DØ 106 IH=1,8
      LØD=LØD+LØAD(IH,IM)
      K=(ID-1)*8+IH
```

```
      N=WS(KJ,K)
       SUPLY(K)=CHAR(JJ,N)*3.*0.9507
C.....0UTPUT IS ATTENUATED FØR ELEVATIØN AT HELENA....
       SUPLY1=SUPLY1+SUPLY(K)
       ATSUPLY(K)=0.90*SUPLY(K)
C.....ENERGY ATTENUATED 10% FØR THIS 8 KW INVERTER.....
       SUPLY2=SUPLY2+ATSUPLY(K)
       IF(ATSUPLY(K).EQ.LØAD(IH,IM))LDW=LDW+ATSUPLY(K);
      CGØ TØ 106
       IF(ATSUPLY(K).LT.LØAD(IH,IM))LDW=LDW+ATSUPLY(K);
      CSHTG=LØAD(IH,IM)-ATSUPLY(K);FMPC=FMPC+SHTG;GØ TØ 106
       LDW=LDW+LØAD(IH,IM)
       EXSUPLY=ATSUPLY(K)-LØAD(IH,IM)
       TMPC=TMPC+EXSUPLY
 106   CØNTINUE
       RYL=IYL
       ANSUPLY=SUPLY/RYL
       FR1=LDW/LØD
       FR2=FMPC/LØD
       UF=LDW/SUPLY1
       RATIØ=LDW/FMPC
       WRITE(108,6)JJ,LØD,SUPLY1,ANSUPLY,SUPLY2,LDW,
      CFMPC,TMPC,FR1,FR2,RATIØ,UF,JJ
 107   CØNTINUE
   1   FØRMAT(6XI3)
   2   FØRMAT(40I2)
   3   FØRMAT(8F6.3)
   4   FØRMAT(10F8.3)
   5   FØRMAT('1',18X,'LØD    SUPLY  ANSUPLY SUPLY2    LDW    FMPC    TMPC
      C    FR1    FR2   RATIØ    UF',//)
   6   FØRMAT(12X12,7(XF7.0),4(XF5.3),XI2)
   7   FØRMAT(///,20X,'VARIABLE DESCRIPTIØN:    ',/,
      C22X,'LØD--TØTAL RESIDENTIAL LØAD ØVER 5 YRS, IN KWH',/,
      C22X,'SUPLY--ENERGY DEVELØPED BY WIND TURBINE IN 5 YRS',/,
      C22X,'ANSUPLY--ANNUAL ENERGY BY WIND TURBINE',/,
      C22X,'SUPLY2--ATTENUATED ENERGY BY WIND TURBINE IN 5 YRS',/,
      C22X,'LDW--LØAD DELIVERED BY WIND SYSTEM',/,
      C22X,'FMPC--ENERGY FRØM MØNT PØWER CØMPANY',/,
      C22X,'TMPC--ENERGY TØ MPC NETWØRK',/,
      C22X,'FR1--FRACTIØNAL PØRTIØN ØF LØAD FRØM WIND',/,
      C22X,'FR2--FRACTIØNAL PØRTIØN ØF LØAD FRØM NETWØRK',/,
      C22X,'RATIØ--ENERGY FRØM / ENERGY TØ NETWØRK',/,
      C22X,'UF--USE FACTØR = LDW / SUPLY')
       END
!LØAD (GØ)
!RUN
!EØF
--EØF HIT AFTER    90.
```

```
!JØB 769,ØBERMEIER,1.    STØRAGE
!LIMIT (TIME,9),(CØRE,24),(LØ,25),(UØ,25)
!ASSIGN F:300,(FILE,LØCATIØN),(IN),(SAVE)
!ASSIGN F:302,(FILE,WINSYS),(IN),(SAVE)
!ASSIGN F:302,(FILE,SCAP),(IN),(SAVE)
!ASSIGN F:303,(FILE,LØAD1),(IN),(SAVE)
!ASSIGN F:304,(FILE,LØAD2),(IN),(SAVE)
!FØRTRAN GØ,LS
      REAL LØD,LØAD(8,12),LDW,LNDW
      INTEGER WS(60,248)
      DIMENSIØN CHAR(22,0:65),SUPLY(248),ASUPLY(248),IMAX(60)
      DIMENSIØN SCAP(22,3),STØR(22)
C.....MØNTH LIMIT IS ML.........
C.....YEAR LIMIT IS IYL.......
      ML=60
      IYL=5
C.....ZERØ WIND SPEED ARRAY.....
      DØ 100 KI=1,ML
      DØ 100 K=1,248
 100  WS(KI,K)=0
C.....INPUT WIND SPEED DATA.......
      DØ 101 KI=1,ML
      READ(300,1)IMAX(KI)
 101  READ(300,2)(WS(KI,K),K=1,IMAX(KI))
C.....INPUT CHARACTERISTIC PERFØRMANCE AND STØRAGE INFØ. ...
      DØ 102 JJ=1,22
      READ(301,3)(CHAR(JJ,I),I=1,65)
      CHAR(JJ,0)=0.
 102  READ(302,4)(SCAP(JJ,I),I=1,3)
      WRITE(108,5)
C.....SELECT ØPTIØN ØF STØRAGE AND LØAD.........
      DØ 300 NU=1,6
      IF(NU.GT.1) GØ TØ 202
      DØ 103 IM=1,12
 103  READ(303,6)(LØAD(IH,IM),IH=1,8)
      DØ 104 JJ=1,22
 104  STØR(JJ)=SCAP(JJ,1)
      WRITE(108,11)
      WRITE(108,7)
      GØ TØ 200
 202  IF(NU.GT.2) GØ TØ 203
      DØ 106 JJ=1,22
 106  STØR(JJ)=SCAP(JJ,2)
      WRITE(108,12)
      WRITE(108,7)
      GØ TØ 200
 203  IF(NU.GT.3) GØ TØ 204
      DØ 108 JJ=1,22
 108  STØR(JJ)=SCAP(JJ,3)
      WRITE(108,13)
```

```
      WRITE(108,7)
      GØ TØ 200
 204  IF(NU.GT.4) GØ TØ 205
      DØ 109 IM=1,12
 109  READ(304,6)(LØAD(IH,IM),IH=1,8)
      DØ 110 JJ=1,22
 110  STØR(JJ)=SCAP(JJ,1)
      WRITE(108,21)
      WRITE(108,7)
      GØ TØ 200
 205  IF(NU.GT.5) GØ TØ 206
      DØ 112 JJ=1,22
 112  STØR(JJ)=SCAP(JJ,2)
      WRITE(108,22)
      WRITE(108,7)
      GØ TØ 200
 206  DØ 114 JJ=1,22
 114  STØR(JJ)=SCAP(JJ,3)
      WRITE(108,23)
      WRITE(108,7)
C.....EXECUTE STØRAGE SYSTEM LØGIC ØNCE FØR EACH WIND SYSTEM..
 200  DØ 300 JJ=1,22
C.....SET INITIAL CØNDITIØNS TØ ZERØ.........
C.....BATTERIES ARE INITIALLY FULLY CHARGED
      STRG=STØR(JJ)
      SUPLY1=SUPLY2=LDW=EXSUPLY=DIFF=PØWR=0.
      SHTG=LNDW=DEFCT=LØD=ELØST=ENRGL=ENRG=0.
      KNTR=IDA=IC0UNT=0
C.....WØRK FØR IYL YEARS ØF 3-HØURLY WIND DATA.....
      DØ 98 IY=1,IYL
      DØ 98 IM=1,12
      KJ=IM+(IY-1)*12
      IDA=IMAX(KJ)/8
      DØ 98 ID=1,IDA
      DØ 98 IH=1,8
      IC0UNT=IC0UNT+1
      LØD=LØD+LØAD(IH,IM)
      K=(ID-1)*8+IH
      N=WS(KJ,K)
C.....ATTENUATE PØWER SUPPLIED DUE TØ DENSITY AT GREAT FALLS  0.9533
      SUPLY(K)=CHAR(JJ,N)*3.*0.9533
C.....SUPLY1 IS TØTAL AMT ØF ENERGY GENERATED AT
C.....TERMINALS ØF WIND GENERATØR.  ...............
      SUPLY1=SUPLY1+SUPLY(K)
C.....ATTENUATE SUPLY FØR HØME USE WITH INVERTER.......
      ASUPLY(K)=0.93*SUPLY(K)
C.....SUPLY2 IS TØTAL AMT ØF ATTENUATED SUPPLY AVAILABLE
C.....FRØM THIS WIND SYSTEM IN THIS LØCATIØN.  .........
      SUPLY2=SUPLY2+ASUPLY(K)
      IF(ASUPLY(K).EQ.LØAD(IH,IM))LDW=LDW+ASUPLY(K);GØ TØ 98
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```
      IF(ASUPLY(K).LT.LØAD(IH,IM))LDW=LDW+ASUPLY(K);GØ TØ 97
      IF(ASUPLY(K).GT.LØAD(IH,IM))EXSUPLY=ASUPLY(K)-LØAD(IH,IM)
     C;GØ TØ 96
  97  DIFF=LØAD(IH,IM)-ASUPLY(K)
C.....ATTENUATE STØRAGE; THIS IS ØNLY PATHWAY
C.....TØ USE ENERGY STØRED IN BATTERIES.     .........
      ASTRG=STRG *0.865
      IF(ASTRG.GT.DIFF)LDW=LDW+DIFF;ASTRG=ASTRG-DIFF;
     CSTRG=ASTRG*1.156; GØ TØ 98
      IF(ASTRG.EQ.DIFF)LDW=LDW+DIFF;ASTRG=ASTRG-DIFF;
     CSTRG=ASTRG*1.156;  GØ TØ 98
      IF(ASTRG.LT.DIFF)LDW=LDW+ASTRG;SHTG=DIFF-ASTRG;
     CLNDW=LNDW+SHTG;STRG=ASTRG=0.;KNTR=KNTR+1;GØ TØ 98
C.....KNTR CØUNTS NUMBER ØF ØCCURANCES ØF FAILURE
C.....ØF TØTAL SYSTEM TØ SUPPLY LØAD WHEN DESIRED.   .....
  96  EXSUPLY=ASUPLY(K)-LØAD(IH,IM)
      LDW=LDW+LØAD(IH,IM)
      IF(STØR(JJ).GT.STRG)DEFCT=STØR(JJ)-STRG; GØ TØ 95
      ENRGL=ENRGL+EXSUPLY
      IF(STRG.EQ.STØR(JJ)) GØ TØ 98
      WRITE(108,8)
      STØP
  95  IF(EXSUPLY.GT.DEFCT)ELØST=EXSUPLY-DEFCT;
     CENRGL=ENRGL+ELØST;STRG=STRG+DEFCT; GØ TØ 98
      IF(EXSUPLY.EQ.DEFCT)STRG=STRG+DEFCT; GØ TØ 98
      IF(EXSUPLY.LT.DEFCT)STRG=STRG+EXSUPLY; GØ TØ 98
  98  CØNTINUE
      RYL=IYL
      ANSUPL=SUPLY1/RYL
      RATIØ=LDW/LNDW
      FR1=LDW/LØD
      FR2=LNDW/LØD
      UF=LDW/SUPLY1
 300  WRITE(108,9)JJ,LØD,ANSUPL,LDW,LNDW,ENRGL,STRG,KNTR,
     CUF,FR1,FR2,RATIØ,JJ
C.....FØRMAT LISTING.....................................
    1  FØRMAT(6XI3)
    2  FØRMAT(40I2)
    3  FØRMAT(10F8.3)
    4  FØRMAT(3F6.2)
    5  FØRMAT(20X,'THIS ØUTPUT LISTS INDEPENDENT SYSTEMS INFØRMATIØN',//,
      C22X,'THERE ARE 22 DIFFERENT WIND SYSTEMS',//,
      C22X,'WITH NUMERATIØN BASED ØN LIST IN PRØGRAM ARRAY',//,
      C22X,'TWØ LØAD SCHEDULES; AUTHØRS AND ',//,
      C30X,'AVERAGE RESIDENTS USE',//,
      C22X,'LØCATIØN;  GREAT FALLS INTL AIRPØRT',///,
      C20X,'VARIABLE DESCRIPTIØN:',///,
      C22X,'LØD--TØTAL RESIDENTIAL LØAD ØVER 5 YRS',//,
      C22X,'ANSUPL--ANNUAL  ENERGY BY WIND TURBINE',//,
      C22X,'LDW--LØAD DELIVERED BY WIND SYSTEM  ',//,
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     C22X,'LNDW--LØAD NØT DELIVERED BY WIND    SYSTEM ',/,
     C22X,'ENRGL--ENERGY LØST, AVABLE FRØM GENERATØR',/,
     C30X,'BUT NØT UTILIZED WITH THIS SYSTEM & SCHEDULE',/,
     C22X,'STRG--REMAINING STØRAGE CAPACITY AFTER 5 YRS',/,
     C22X,'KNTR--NUMBER ØF ØCCURANCES ØF LØAD NØT SUPPLIED BY ',/,
     C30X,'SYSTEM;  RE: ALSØ # ØF DEEP CYCLES IN BATTERIES',/,
     C22X,'UF--USE FACTØR = LDW / SUPLY1',/,
     C22X,'FR1--FRACTIØN ØF LØAD DELIVERED BY WIND SYSTEM',/,
     C22X,'FR2--FRACTIØN ØF LØAD NØT MET BY WIND SYSTEM',/,
     C22X,'RATIØ--LDW / LNDW')
   6  FØRMAT(8F6.3)
   7  FØRMAT(11X,'LØD   ANSUPL     LDW     LNDW    ENRGL   STRG   KNTR
     C UF     FR1    FR2   RATIØ',//)
   8  FØRMAT(5X'STØP DUE TØ LØGIC ERRØR AND BATTERY ØVERLØAD')
   9  FØRMAT(5XI2,6(XF8.0),XI5,3(XF5.3),XF6.3,2XI2)
  11  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØUTPUT ØPTIØNS:   LØAD 1  STØR 1',//)
  12  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØUTPUT ØPTIØNS:   LØAD 1   STØR 2',//)
  13  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØUTPUT ØPTIØNS:   LØAD 1  STØR 3',//)
  21  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØPTIØNS:  LØAD 2  STØR 1',//)
  22  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØPTIØNS:  LØAD 2  STØR 2',//)
  23  FØRMAT('1',25X,'PERFØRMANCE ØUTPUT FØR INDEPENDENT SYSTEMS',/,
     C25X,'WITH ØPTIØNS:  LØAD 2  STØR 3',//)
      END
!LØAD (GØ)
!RUN
!EØF
--EØF HIT AFTER  173.
```

```
!JØB 769,ØBERMEIER,1.     ARRAY
!LIMIT (TIME,2),(CØRE,34),(LØ,100),(UØ,100)
!ASSIGN F:102,(DEVICE,L2)
!LDEV L2,(FØRM,2861)
!ASSIGN F:200,(FILE,PTMFILE),(IN),(SAVE)
!ASSIGN F:201,(FILE,WINSYS),(IN),(SAVE)
!ASSIGN F:202,(FILE,SYSINFØ),(IN),(SAVE)
!ASSIGN F:203,(FILE,UFILE),(IN),(SAVE)
!ASSIGN F:204,(FILE,ECØN),(IN),(SAVE)
!FØRTRAN GØ,LS,X
      DIMENSIØN PTM(11,65),CHAR(65,32),ØUT(11,32),DCF(11)
      DIMENSIØN ØUT2(11,32),ØUT3(11,32),ØUT4(11,32),ØUT5(11,32)
      DIMENSIØN SYSINFØ(32,3),ØUT6(11,32),ECØN(12,32)
      DIMENSIØN UF3(12,14,11,2),UF(12,32,11,2),ØUT7(12,32,11,2)
      DIMENSIØN ØUT8(11,32)
C     NUMBER ØF WIND SYSTEMS IS DESIGNATED        NWS
C     NUMBER ØF WIND SPEEDS IS DESIGNATED         NSP
C     NUMBER ØF LØCATIØNS IS DESIGNATED           NLØ
      NSP=65
      NWS=32
      NLØ=10
X     WRITE(108,13)
X     WRITE(108,28)
C        READ INFØRMATIØN FRØM FILES   ..........................
      DØ 10 J=1,NSP
  10  READ(200,1)NLØ,(PTM(I,J),I=1,NLØ)
X     WRITE(108,19)
X     DØ 34 J=1,NSP
X 34  WRITE(108,39)J,NLØ,(PTM(I,J),I=1,NLØ),J
      DØ 11 K=1,NWS
      READ(201,2)(CHAR(J,K),J=1,NSP)
      READ(202,3)(SYSINFØ(K,L),L=1,3)
  11  READ(204,29)(ECØN(J1,K),J1=1,12)
      DØ 44 J3=1,NLØ
      DØ 44 J4=1,2
      DØ 44 J2=1,14
  44  READ(203,47)(UF3(J1,J2,J3,J4),J1=1,12)
C.....REØRDER THE USE FACTØR ARRAY
      DØ 43 J4=1,2
      DØ 43 J3=1,11
      DØ 43 J1=1,12
      UF(J1,1,J3,J4)=UF(J1,4,J3,J4)=UF(J1,13,J3,J4)=0.
      UF(J1,14,J3,J4)=UF(J1,16,J3,J4)=UF(J1,18,J3,J4)=0.
      DØ 45 K1=21,32
  45  UF(J1,K1,J3,J4)=0.
      UF(J1,2,J3,J4)=UF3(J1,1,J3,J4)
      UF(J1,3,J3,J4)=UF3(J1,2,J3,J4)
      DØ 46 K2=3,10
      K3=K2+2
  46  UF(J1,K3,J3,J4)=UF3(J1,K2,J3,J4)
```

```
      UF(J1,15,J3,J4)=UF3(J1,11,J3,J4)
      UF(J1,17,J3,J4)=UF3(J1,12,J3,J4)
      UF(J1,19,J3,J4)=UF3(J1,13,J3,J4)
   43 UF(J1,20,J3,J4)=UF3(J1,14,J3,J4)
C.....   DENSITY CORRECTION FACTORS   .....
C.....   REFERENCE DENSITY OF ALL CHARACTERISTIC FUNCTIONS
C.....   IS ASSUMED TO BE 1057 GM/M3 WHICH CORRESPONDS TO
C.....   ROOM TEMP AT 1000 FT ELEVATION.     .............
      DCF(1)=0.9213
      DCF(2)=DCF(3)=0.9533
      DCF(4)=1.0078
      DCF(5)=0.9888
      DCF(6)=0.9965
      DCF(7)=0.9507
      DCF(8)=0.9836
      DCF(9)=0.9715
      DCF(10)=0.9326
C      .....      AT EACH LOCATION   .............
      DO 12 I=1,NLO
      DO 12 K=1,NWS
      OUT(I,K)=0.
      DO 12 J=1,NSP
   12 OUT(I,K)=OUT(I,K)+(0.01)*PTM(I,J)*CHAR(J,K)*DCF(I)
C     .....    MEAN POWER OUTPUT SECTION   .....
X     WRITE(108,5)
X     DO 14 K=1,NWS
X  14 WRITE(108,4)K,NLO,(OUT(I,K),I=1,NLO),K
C     .....   MONTHLY ENERGY OUTPUT   .......
      DO 15 K=1,NWS
      DO 15 I=1,NLO
   15 OUT2(I,K)=OUT(I,K)*730.5
X     WRITE(108,6)
X     DO 16 K=1,NWS
X  16 WRITE(108,7)K,NLO,(OUT2(I,K),I=1,NLO),K
C      .....   ANNUAL ENERGY OUTPUT   .....
      DO 17 K=1,NWS
      DO 17 I=1,NLO
   17 OUT3(I,K)=OUT(I,K)*8766.
X     WRITE(108,8)
X     DO 18 K=1,NWS
X  18 WRITE(108,7)K,NLO,(OUT3(I,K),I=1,NLO),K
C     .....   SPECIFIC ENERGY OUTPUT SECTION   .......
      DO 20 K=1,NWS
      DO 20 I=1,NLO
   20 OUT4(I,K)=OUT3(I,K)/SYSINF0(K,2)
X     WRITE(108,21)
X     DO 22 K=1,NWS
X  22 WRITE(108,23)K,NLO,(OUT4(I,K),I=1,NLO),K
C     .....   PERCENT SPECIFIC ENERGY OUTPUT   .....
      DO 24 K=1,NWS
```

```
      DØ 24 I=1,NLØ
   24 ØUT5(I,K)=(ØUT(I,K)/SYSINFØ(K,2))*100.
X     WRITE(108,25)
X     DØ 26 K=1,NWS
X  26 WRITE(108,27)K,NLØ,(ØUT5(I,K),I=1,NLØ),K
C     ......   MØNTHLY ØUTPUT PER AREA SECTIØN   .......
      DØ 30 K=1,NWS
      DØ 30 I=1,NLØ
   30 ØUT6(I,K)=ØUT2(I,K)/SYSINFØ(K,1)
X     WRITE(108,31)
X     DØ 32 K=1,NWS
X  32 WRITE(108,27)K,NLØ,(ØUT6(I,K),I=1,NLØ),K
C.....ECØNØMIC SECTIØN.....................................................
X     WRITE(108,36)
      DØ 35 K=1,NWS
      DØ 35 I=1,NLØ
      DØ 35 J4=1,2
      DØ 35 J1=1,12
   35 ØUT7(J1,K,I,J4)=ECØN(J1,K)/(ØUT4(I,K)*UF(J1,K,I,J4))
      ITBN=45
X     DØ 37 J4=1,2
X     DØ 37 J5=1,4
X     DØ 37 J6=1,3
      J7=J6+(J5-1)*3
C.....CØUNTS FRØM ØNE TØ TWELVE.............................
      J8=J7+(J4-1)*12
C.....CØUNTS FRØM ØNE TØ TWENTY-FØUR.....................................
      ITBN=ITBN+1
X     WRITE(108,38)ITBN,J8
X     DØ 49 K=2,3
X  49 WRITE(108,40)K,NLØ,(ØUT7(J7,K,I,J4),I=1,NLØ),K
X     DØ 50 K=5,12
X  50 WRITE(108,40)K,NLØ,(ØUT7(J7,K,I,J4),I=1,NLØ),K
X     DØ 51 K=15,19,2
X  51 WRITE(108,40)K,NLØ,(ØUT7(J7,K,I,J4),I=1,NLØ),K
      K=20
X  37 WRITE(108,40)K,NLØ,(ØUT7(J7,K,I,J4),I=1,NLØ),K
C.....ØPTIMUM ECØNØMIC PERFØRMANCE SECTIØN.....................
      DØ 41 K=1,NWS
      DØ 41 I=1,NLØ
   41 ØUT8(I,K)=ECØN(12,K)/ØUT4(I,K)
      WRITE(108,42)
      DØ 48 K=2,3
   48 WRITE(108,40)K,NLØ,(ØUT8(I,K),I=1,NLØ),K
      DØ 52 K=5,12
   52 WRITE(108,40)K,NLØ,(ØUT8(I,K),I=1,NLØ),K
      DØ 53 K=15,19,2
   53 WRITE(108,40)K,NLØ,(ØUT8(I,K),I=1,NLØ),K
      K=20
      WRITE(108,40)K,NLØ,(ØUT8(I,K),I=1,NLØ),K
```

```
C.....FØRMAT SPECIFICATIØNS ..........................................
   1  FØRMAT(NF5.2)
   2  FØRMAT(10F8.3)
   3  FØRMAT(F7.2,F8.2,F6.1)
   4  FØRMAT(12X12,X,N(XF7.3),2X12)
   5  FØRMAT('1',2/,43X,'MEAN PØWER ØUTPUT IN KW',///,
     C37X,'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',//,
     C35X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C20X,'LIV    G.F.    BILL    GLAS    MILC    HAVRE   HELNA    KAL
     C  MSLA     BØZ')
   6  FØRMAT('1',2/,39X,'MEAN MØNTHLY ENERGY ØUTPUT IN KWH',///,
     C37X,'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',//,
     C35X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C20X,'LIV    G.F.    BILL    GLAS     MIC   HAVRE   HELNA     KAL
     C  MSLA    BØZ')
   7  FØRMAT(11X12,2X,N(2X16),2X12)
   8  FØRMAT('1',2/,39X,'MEAN ANNUAL ENERGY ØUTPUT IN KWH',///,
     C35X,'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',//,
     C33X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C21X,'LIV    G.F.    BILL    GLAS     MIC     HAV     HEL     KAL
     C   MIS     BØZ')
  13  FØRMAT(23X,'THE TEN CØLUMNS IN THE ØUTPUT LISTINGS',//,
     C23X,'REFER TØ THE FØLLØWING LØCATIØNS:',////,
     C10X,'    LØCATIØN       ELEVATIØN   TEMP.      DENSITY   SPEED',///,
     C10X,' 1  LIVINGSTØN        4653      44.2        1066      14.1',//,
     C10X,' 2  GREAT FALLS       3662      44.9        1103      12.4',//,
     C10X,' 3  BILLINGS          3567      46.3        1103      11.5',//,
     C10X,' 4  GLASGØW           2284      41.5        1166      11.0',//,
     C10X,' 5  MILES CITY        2629      45.3        1144      10.8',//,
     C10X,' 6  HAVRE             2584      42.2        1153      10.4',//,
     C10X,' 7  HELENA            3828      43.2        1100       7.9',//,
     C10X,' 8  KALISPELL         2965      41.8        1138       6.9',//,
     C10X,' 9  MISSØULA          3190      43.7        1124       6.5',//,
     C10X,'10  BØZEMAN           4451      41.7        1079       6.4',///,
     C10X,'11  CUT BANK          3838      40.5        1101      12.6',//,
     C10X,'12  DILLØN            5218      42.5        1048       9.1',//,
     C10X,'13  LEWISTØWN         4145      41.9        1091      10.1',////,
     C23X,'DURATIØN CURVES UNAVAILABLE FØR CUT BANK, DILLØN,',//,
     C23X,'AND LEWISTØWN.  UNITS ARE:  FT, DEGREES F,',//,
     C23X,'GRAMS PER METER CUBED, MILES PER HØUR.')
  19  FØRMAT('1',42X,'PERCENT TIME AT SPEED',//,
     C32X,'READ 10 LØCATIØNS ACRØSS, 65 SPEEDS DØWN, KNØTS',///,
     C19X,'LIV     G.F.    BILL    GLAS    MIC     HAVRE   HELNA   KAL
     C   MSLA    BØZ')
  21  FØRMAT('1',2/,35X,'SPECIFIC ENERGY ØUTPUT  IN  KWH/ANNUM/KW',///,
     C37X,'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',//,
     C35X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C27X,'LIV  G.F.  BILL   GLA   MIC  HAVR  HELN   KAL  MSLA   BØZ')
  23  FØRMAT(22X12,N(2X14),2X12)
  25  FØRMAT('1',//,44X,'PERCENT SPECIFIC ØUTPUT',///,
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     C30X,'KW MEAN ØUTPUT / KW INSTALLED CAPACITY, PERCENT',/,
     C35X'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',/,
     C33X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C27X,'LIV  G.F.  BILL   GLA   MIC  HAVR  HELN   KAL  MSLA   BØZ')
  27  FØRMAT(22X12,N(2XF4.1),2X12)
  28  FØRMAT('1'30X,'THE 32 WIND SYSTEMS ARE:',////,
     C20X,'     SYSTEM                          DIAMETER      CAPACITY',///,
     C20X,' 1   AERØWATT 24 FP7                    1.00         0.015',/,
     C20X,' 2 * AERØWATT 150 FP7                   2.00         0.100',/,
     C20X,' 3 * WINDCHARGER                        2.63         0.200',/,
     C20X,' 4   BUCKNELL                                        0.225',/,
     C20X,' 5 * AERØWATT 300 FP7                   3.20         0.275',/,
     C20X,' 6 * SENCENBAUGH (AWES)                 2.44         0.900',/,
     C20X,' 7 * AERØWATT 1100 FP7                  5.00         1.100',/,
     C20X,' 8 * ELEKTRØ WV 15G                     3.00         1.200',/,
     C20X,' 9 * KEDKØ 1200                         3.66         1.200',/,
     C20X,'10 * HELIØN 12 FTR                      3.66         2.000',/,
     C20X,'11 * DUNLITE 2000                       3.66         2.000',/,
     C20X,'12 * WINDWØRKS (AWES)                   3.66         2.000',/,
     C20X,'13   DARIUS VERTICLE AXIS               3.66         2.000',/,
     C20X,'14   WINDWØRKS W JACØBS GEN.            3.66         3.000',/,
     C20X,'15 * JACØBS W.E. 3000                   4.57         3.000',/,
     C20X,'16   HELIØN 16 FTR                      4.88         3.500',/,
     C20X,'17 * AERØWATT 4100 FP7                  9.80         4.100',/,
     C20X,'18   WINDWØRKS PØWR AT BLADES           3.66         4.500',/,
     C20X,'19 * ELEKTRØ WV 35G                     4.39         4.500',/,
     C20X,'20 * ELEKTRØ WVG50G                     5.00         6.000',/,
     C20X,'21   HUTTER WE 10/G6                   10.00         6.000',/,
     C20X,'22   DANISH MILL                        8.00        13.000',/,
     C20X,'23   BRACE AIRSCREW                     9.75        25.000',/,
     C20X,'24   HUTTER-ALLGAIER LØW RANGE         35.00        90.000',/,
     C20X,'25   HUTTER-ALLGAIER MID RANGE         35.00        90.000',/,
     C20X,'26   HUTTER-ALLGAIER HI RANGE          35.00        90.000',/,
     C20X,'27   GØULDING S 100 KW                 18.29       100.000',/,
     C20X,'28   ANDREAU-ENFIELD                   24.00       100.000',/,
     C20X,'29   THE GEDSER MILL                   24.00       200.000',/,
     C20X,'30   NASA 100 KW SYSTEM                37.80       100.000',/,
     C20X,'31   HUTTER S 100 KW                                100.000',/,
     C20X,'32   PUTNAM REVISED DESIGN             53.34      1500.000',////,
     C25X,'*  ECØNØMIC ANALYSIS AVAILABLE FØR THESE SYSTEMS',/,
     C25X,'DIAMETER IN METRES ; CAPACITY IN KILØWATTS')
  29  FØRMAT(12F6.0)
  31  FØRMAT('1',/,35X,'MEAN MØNTHLY ENERGY ØUTPUT PER UNIT AREA',///,
     C49X,'KWH/MØNTH-M2',/,
     C37X,'READ TEN LØCATIØNS ACRØSS IN CØLUMNS',/,
     C35X,'READ THIRTY-TWØ WIND SYSTEMS DØWN BY RØW',///,
     C27X,'LIV  G.F.  BILL   GLA   MIC  HAVR  HELN   KAL  MSLA   BØZ')
  33  FØRMAT(XI2,N(2XF7.1),3XI2)
  36  FØRMAT('1',24X,'THE FØLLØWING 24 PAGES ØF ØUTPUT',/,
     C20X,'GIVE THE CØSTS IN CENTS PER KWH',/,
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     C20X,'ØF ENERGY DELIVERED TØ A RESIDENTIAL LØAD ',/,
     C20X,'BASED ØN 1974 U.S. DØLLARS',//,
     C20X,'FØR EACH ØF 14 SYSTEMS AT 10 LØCATIØNS.',///,
     C20X,'THE CØNDITIØNS ARE LISTED AS FØLLØWS:',////,
     C15X,'*****************************************************',/,
     C15X,'*        1 & 13    LØAD  1   STØR  1   LIFE 20       *',/,
     C15X,'*        2 & 14    LØAD  1   STØR  1   LIFE 15       *',/,
     C15X,'*        3 & 15    LØAD  1   STØR  1   LIFE 10       *',/,
     C15X,'*        4 & 16    LØAD  1   STØR  2   LIFE 20       *',/,
     C15X,'*        5 & 17    LØAD  1   STØR  2   LIFE 15       *',/,
     C15X,'*        6 & 18    LØAD  1   STØR  2   LIFE 10       *',/,
     C15X,'*        7 & 19    LØAD  1   STØR  3   LIFE 20       *',/,
     C15X,'*        8 & 20    LØAD  1   STØR  3   LIFE 15       *',/,
     C15X,'*        9 & 21    LØAD  1   STØR  3   LIFE 10       *',/,
     C15X,'*       10 & 22    LØAD  1   STØR  0   LIFE 20       *',/,
     C15X,'*       11 & 23    LØAD  1   STØR  0   LIFE 15       *',/,
     C15X,'*       12 & 24    LØAD  1   STØR  0   LIFE 10       *',/,
     C15X,'*****************************************************',////,
     C20X,'REPEAT AGAIN FØR LØAD 2 TØ ØBTAIN CØNDITIØNS 13-24',//,
     C20X,'THE VARIABLES ARE:',/,
     C20X,'LØAD 1:  LØAD SCHEDULE FØR AUTHØR S FAMILY ØF FØUR',/,
     C20X,'LØAD 2:  LØAD SCHEDULE FØR AVERAGE MØNTANA RESIDENT',/,
     C20X,'STØR 1:  STØRAGE CAPACITY AS IN APPENDIX B',/,
     C20X,'STØR 2:  STØRAGE CAPACITY TWICE STØR 1',/,
     C20X,'STØR 3:  STØRAGE CAPACITY 3 TIMES STØR 1',/,
     C20X,'STØR 0:  NØ STØRAGE, SHARED GRID SYSTEM USING',/,
     C30X,'THE 8 KW INVERTER AVAILABLE FRØM WINDWØRKS',/,
     C20X,'LIFE 20:  20 YEAR LIFE ØN SYSTEM AND TØWER, 10 ØN REST',/,
     C20X,'LIFE 15:  15 YEAR LIFE ØN SYSTEM AND TØWER, 10 ØN REST',/,
     C20X,'LIFE 10: 10 YEAR LIFE ØN ALL CØMPØNENTS',/,
     C20X,'EXCEPTIØN:  20 YR LIFE ØN 8 KW INVERTER FØR ALL CØNDITIØNS')
  38  FØRMAT('1',6/,51X,'TABLE  ',I2,//,
     C39X,'ECØNØMIC SECTIØN:  CØNDITIØN # ',I2,//,
     C29X,'LIV  G.F.  BILL  GLAS   MIC  HAVR  HELN   KAL  MSLA   BØZ',/)
  39  FØRMAT(12X12,N(3XF5.2),3XI2)
  40  FØRMAT(24X12,N(XF5.1),XI2,/)
  42  FØRMAT('1',39X'MINIMUM RESIDENTIAL WIND ENERGY CØSTS',/,
     C38X,'FØR THE SHARED NETWØRK ØPTIØN, 20 YR LIFE',/,
     C45X'IN CENTS PER KILØWATT-HØUR',//)
  47  FØRMAT(F4.3,11(XF4.3))
      END
!LØAD (GØ)
!RIN
!EØF
--EØF HIT AFTER  284.
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