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Simplified Design Guide for Estimating Photovoltaic Flat Array and System Performance

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SIMPLIFIED DESIGN GUIDE FOR ESTIMATING PHOTOVOLTAIC FLAT ARRAY AND SYSTEM PERFORMANCE

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ABSTRACT

Simplified, non-computer based methods are presented for predicting photovoltaic array and system performance. The array performance prediction methods are useful for calculating the potential output of passively cooled, flat, south facing max-power tracked arrays. A solar/weather data base for 97 different U.S. and U.S. affiliated stations is provided to aid in these calculations. Also, performance estimates can be made for photovoltaic systems (array, battery, power conditioner) that are backed-up by non-solar reserves capable of meeting the load when the solar system cannot. Such estimates can be made for a total of 41 different sinusoidal, unimodal, and bimodal diurnal load profiles from appropriate graphs included. These allow easy determination of the fraction of the load met by the solar photovoltaic system as a function of array size and (dedicated) battery storage capacity. These performance graphs may also be used for systems without battery storage. Use of array manufacturer's specification sheet data is discussed. Step-by-step procedures, along with suggested worksheets, are provided for carrying out the necessary calculations.

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TABLE OF CONTENTS

Nomenclature

Symbol	Significance	Most Common Units in this Guide
B	Capacity of the dedicated electrical energy storage (see eq. 3.1)	watt-hours
B/Aη	A dimensional ratio of storage capacity to the product of array area and monthly average array efficiency. This parameter is important in predicting system performance in meeting a given load. When used in Table III, units must be $Wh/(m^2 \cdot \%)$ (see eq. 3.3)	$Wh/(m^2 \cdot \%)$
F	Monthly average solar fraction or fraction of the load that is met by the solar system. The back-up energy source must meet (1-F) of the load	dimensionless decimal
KT	The clearness number or ratio of monthly total radiation (beam and diffuse) on a horizontal surface to what would fall on that surface if the surface were located above the atmosphere (the latter is referred to as the extraterrestrial radiation)	dimensionless
I	Current	amps
L	Monthly average daily load	kWh
NOCT	Nominal Operating Cell Temperature or the temperature of the cell in an array or module under specified irradiation, ambient temperature and wind speed conditions	C
QE/A	Monthly average daily electrical output from the power conditioning unit per unit array area if the instantaneous array output could always be used to meet the load or some part of the load	kWh/m^2
QE/L	The ratio of the daily potential power conditioning electrical output (for the full array) to the daily load. Monthly average daily values are used. This is a potential solar fraction that would be realized with infinite, loss-free storage	dimensionless decimal
QS/A	Monthly average daily array insolation or solar energy falling on the array	kWh/m^2
$(QS/A)_i$	Instantaneous insolation	kW/m^2

P	Power	various
s	Array tilt up from horizontal	degrees
s_M	Optimum s for maximum monthly energy collection (see Table II pg. A-58)	degrees
T_a	Ambient temperature	C
T_c	Monthly average cell temperature for calculating monthly average conversion efficiency	C
$T_{c,i}$	Instantaneous cell temperature	C
TM	Monthly average ambient temperature (averages of all the daily high and low temperatures for the month) as compiled by the National Weather Service	C
T_r	Some reference cell temperature for which module efficiency (or maximum-power) is given by a manufacturer	C
U_L	Thermal loss coefficient for heat rejection between the cells in an array or module and ambient (see eq. 2.1)	$kW/(m^2 \cdot C)$
V	Voltage	volts
WS	Monthly average wind speed	m/s

Greek Symbols	Significance	Most Common Units in this Guide
α	Solar absorptance of the photovoltaic array	dimensionless decimal
β	Temperature coefficient for array efficiency	C^{-1}
η	Array or module efficiency for conversion of incident solar energy to electrical output	%
η_{pc}	Power conditioning efficiency	%
η_r	A reference array or module efficiency for converting solar energy to electrical output when the cells in the array or module are at a stated temperature T_r	%
ϕ	Latitude	degrees

Subscripts	Significance
a	Ambient
c	Cell
high	A typical high value of the subscripted variable that may be expected over many years
i	Instantaneous value
lat	The value of the subscripted variable when the array tilt is equal to the local latitude angle
low	A typical low value of the subscripted variable that may be expected over many years
mp	Maximum power point
pc	Power conditioning
r	Reference

CHAPTER 1

INTRODUCTION

1.0 PHOTOVOLTAICS

Although the photovoltaic effect was first observed in 1839, it was the space program of the 1960's that stimulated interest in and demand for solar cells. Solar photovoltaic systems on earth satellites and space probes offered the advantage of directly tapping a renewable resource, thus allowing extended missions in hostile environments.

Interest in the terrestrial use of photovoltaic solar systems has blossomed over the past 6 to 8 years for exactly the same reason: the need to harness renewable resources for extending the mission of human habitation of the planet earth at the energy consuming level to which man has become accustomed.

Terrestrial photovoltaic solar systems are presently economical for many remote applications where costs of other alternatives, such as extending utility power lines or transporting fuel, are very high. Past examples have included remote repeater, phone and radar stations, navigational buoy lights, off-shore platforms, and pipeline corrosion protection. Figure 1.1, for example, shows a 3.5 kilowatt (peak) photovoltaic array that provides some electrical power for the remote town of Schuchuli, Arizona, U.S.A., which is not connected to a utility grid. Figure 1.2 shows a 60 kilowatt, 1,110 square meter (12,000 square feet) array at Mount Laguna Air Force Station in California that is backed up by a diesel powered grid.

In order to reduce costs and speed the introduction of photovoltaics into more energy intensive terrestrial markets, the national solar program is expending considerable effort in all areas of this discipline, including solar cell physics, array manufacturing techniques and stimulation, system studies and the removal of barriers to acceptance. There is evidence that the national program is on target for meeting its factory f.o.b. module price goals of $2.80 per peak watt by 1982 and $0.70 per peak watt by 1986 (1980 U.S. dollars assumed). Even though there can be no guarantees that these goals can be met, it is exciting to speculate about the possible wide-scale use of this technology.

As the markets grow and prices drop further and further toward the program goals, many new applications will become feasible. For example, the widespread use of photovoltaics in residential and commercial buildings will hopefully become a reality in the near future. Figure 1.3 shows a prototype of a photovoltaic powered residence that was established in the summer of 1980, to study component and system operation and problems. This system is connected to a utility for back-up and feeds any excess solar generated electricity to the grid.

In addition to the hardware costs of photovoltaic systems, significant amounts of the total cost of installation are presently due to the engineering design work involved. This is primarily a result of the lack of both design experience and easy to use design aids for dealing with this emerging technology.

1.1 INTRODUCTION TO THIS GUIDE

This Guide is intended to help bridge the gap between high cost, sophisticated, one-of-a-kind design and low cost, wide-scale, rapid-but-reliable design. It is a part of the overall national plan for speeding the widespread adoption of photovoltaic solar energy systems.

The purpose is to provide information for sizing photovoltaic arrays and battery storage for meeting particular electrical loads in various geographical locations. A designer may make use of the design procedures recommended in this Guide if he has chosen to use south facing, flat, unconcentrated, max-power tracked photovoltaic arrays and has some basic information on array behavior that is generally available from manufacturer's data. The array output calculations, along with the basic data sources and worst case insolation results, are widely applicable to many types of photovoltaic systems. However, the systems (array, power conditioning, and battery used to satisfy a given diurnal load shape) analysis is restricted to systems that have a back-up power source capable of meeting the load when the photovoltaic system cannot.

This Guide is not necessarily intended to be an alternative to hourly computer simulation, but it should be useful for preliminary design work and could eliminate simulation studies for small and/or routine installations. Hourly simulation can answer some design questions that are not addressed by the simplified techniques described here (for example, frequency distributions of the power output). On the other hand, it is easy to overlook the assumptions that are necessary in hourly computer simulation and become overconfident in the results.

Any design method will be subject to uncertainties due to many factors. Chief among these are: (a) the extent to which photovoltaic manufacturer's sales data represent the modules that are sold and the extent that module data can be used to infer array behavior, (b) the extent to which the designer knows his load (size, shape and fluctuations), and (c) the extent to which long term insolation and weather data (including fluctuations from the long term data) are known.

Fig. 1.1 Photovoltaic Village Power Project - Schuchuli, AZ, USA.

This 3.5 kilowatt (peak) solar photovoltaic system is designed to meet the basic needs of the people of Schuchuli, AZ. This stand-alone system has lead-acid storage batteries but no other back-up power system. It provides power for 40, 20 watt flourescent lights distributed among the homes and community buildings, a water pump (up to 5000 gallons per day), 15 refrigerator/freezer units, a clothes washer, and a sewing machine. (Photo courtesy of NASA, Lewis Research Center.)

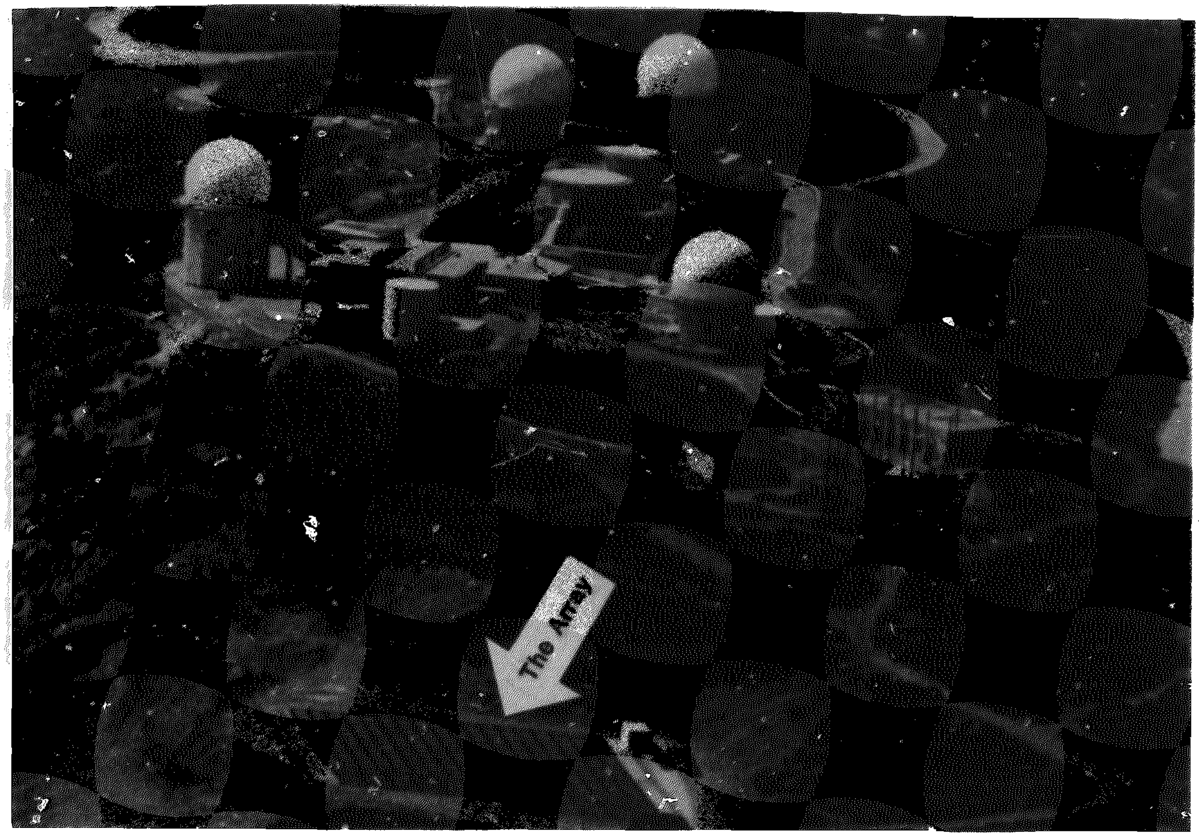

Fig. 1.2 Solar Photovoltaic Power Augmentation - Mt. Laguna, CA, USA.

U.S. Air Force personnel at Mt. Laguna Air Force Station, CA, receive an average of 10 percent of their electrical energy from the sun. The 60 (peak) kilowatt photovoltaic flat array system has an array area of 1,110 sq m (12,000 sq ft), occupies 3,000 sq m (32,000 sq ft) of land area, and consists of nearly 98,000 individual silicon solar cells. The arrays are tilted 25° up from horizontal. A power conditioner maximum-power tracks the array and converts d-c to a-c to match the station's 480 volt, 3-phase power from a diesel generator plant. (Photo courtesy of U.S. Army Mobility Equipment Research and Development Command.)

Fig 1.3 Residential Photovoltaic System—Phoenix, AZ, USA

This model tract home in Phoenix, AZ, has its south sloping roof covered with solar cell modules. The array consists of 5 paralleled sub-arrays, each of which runs laterally across the roof. Interconnections are made in the batten seams that run vertically up the roof. The small shed like structure on the near end of the residence houses the power conditioning equipment. No on-site electrical storage is provided; excess power is fed back to the utility grid. Although the array produces roughly enough energy to meet the total requirements of the home, the solar system supplies, directly, only 30 to 40% of the total need because of the diurnal mismatch of array output and load. (Photo courtesy of ARCO Solar, Inc.)

CHAPTER 1

What This Guide Will Do:

Provided a designer has some information about the load he intends to satisfy and the particular arrays he intends to use, he may use this Guide to:

A. Compute potential array performance for his location and season if he has certain site specific solar/weather data available. Data for 97 representative U. S. or U. S. affiliated stations are included in this Guide in case site specific data are not available. Performance parameters addressed include:

a. monthly average array efficiency,
b. monthly average array insolation or solar irradiation
c. monthly average array and power conditioning output.

These parameters are immediately useful for systems in which all of the photovoltaic array and power conditioner output can be used in meeting the load (i.e., if the load always exceeds the array and power conditioner output). In systems where the array and power conditioner output can exceed the load and action must be taken to store, to dump, to avoid collection, or to feed the excess power back to a utility or grid, then these parameters can still be useful by aiding in the determination of system performance.

B. Compute monthly average system (array, storage, and power conditioning) performance for 41 different monthly average diurnal load profiles. The system performance procedures are restricted to flat arrays operating with a back-up grid that is capable of supplying reserve power any time the photovoltaic system is unable to meet the load. Various amounts of dedicated storage (i.e., storage that is chargeable only from the photovoltaic array and not from the back-up grid) can be accommodated including zero storage.

What This Guide Will Not Do:

This Guide is not intended to be a primer on solar energy, solar cells, photovoltaic arrays, or batteries. Although it will allow the determination of overall system performance in terms of the fraction of a given load supplied by solar, this Guide will not give details on how to evaluate the economics of a particular system choice. Designers are referred to Reference 1 for a detailed discussion of life cycle costing or cost-benefit analyses and to Reference 2 for a step-by-step economic evaluation for photovoltaics.

Also, this Guide will not provide information on detailed design either from a mechanical (mounting structure, wind loading, etc.), civil (building codes, regulations, etc.), or electrical (electrical connections, diodes, transient protection, module matching, etc.)

standpoint. These are all outside the scope of this work. Designers are referred to, for example, Reference 3 for a treatment of many of the electrical design features.

1.2 ORDER OF THIS GUIDE

Most simple procedures, when laid out in a step-by-step format, look more complicated than they really are. Such is the case here. This may be confirmed by executing the process presented in Chapters 2 and 3 a few times.

The procedure for determining system performance, as presented in this Guide, consists of two major steps. In the first part, a user determines the array output that could potentially be obtained with either a load capable of absorbing all of the available output or the presence of infinite, lossless storage. In the second part, the user calculates the potential or maximum solar fraction, from the potential array output and the size of the load, and combines it with a battery capacity parameter to yield the actual solar fraction. This last combination is done with graphs prepared for various diurnal load shapes.

These two major steps are covered in Chapters 2 and 3. Chapter 2 outlines the procedure for estimating potential array performance and output for various geographical locations. It refers to an extensive table of solar/meteorological data for the U.S. and several of its affiliates which can be used in the absence of data that may be more site specific.

Chapter 3 outlines the procedure for predicting system performance and discusses its use and limitations. The procedure makes use of an extensive table of graphs found in the appendix.

Chapter 4 is devoted to example problems which demonstrate and clarify the procedures outlined in Chapters 2 and 3.

The development of much of the work underlying the procedures described herein is documented and discussed in Reference 4. Since the intent is to make this Guide as short and usable as possible no further documentation will be given.

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CHAPTER 2

PREDICTING POTENTIAL ARRAY AND POWER CONDITIONER PERFORMANCE

2.0 BACKGROUND

This chapter outlines a procedure for estimating monthly photovoltaic array performance using a minimum of information. It should be used only for south facing flat arrays having a fixed tilt during any given month. (The tilt may vary from month to month.) The procedure assumes that the arrays always operate at the maximum power points of their current-voltage (I-V) curves.

The electrical energy produced by a photovoltaic array is considerably less than the energy absorbed from the incident solar rays. The balance of the solar energy must be efficiently rejected in order for the array to remain cool. The procedure described here assumes that an array rejects this extra energy to the surroundings by passive means, i.e. radiation and natural convection. This Guide should not be used if the energy rejection occurs by other means, e.g. by cooling with blown air or flowing liquid.

In order to use this procedure for a particular photovoltaic array, certain performance related parameters must be obtained from the array manufacturer. Unfortunately, there is not yet a uniform standard for reporting this array information. In many cases, the necessary parameters can be calculated from the information that is supplied on product specification sheets while in others the manufacturer will have to be contacted. In some cases, estimates will have to be made.

2.1 ARRAY THERMAL PERFORMANCE

One important array property that is product dependent is the efficiency for rejecting thermal energy to the surroundings. This property is important since, for any given manufacturer's array, the operating efficiency is primarily a function of array temperature.*

*Of course actual efficiency is strongly dependent on cell physics, density of packing of cells in a module, encapsulants, etc., but for a given manufacturer's product, these are essentially fixed. Of the local environmental variables that affect array performance, temperature is the most dominant.

The poorer the heat rejection, the higher the array temperature and the lower the efficiency. A commonly cited parameter that contains information on this efficiency is the Nominal Operating Cell Temperature or NOCT. As mentioned above, the conditions under which NOCT is determined have not been standardized. However, the conditions under which a particular manufacturer has determined the NOCT for his array is usually available in product literature.

Four items should be noted when using NOCT data. They are:

1. the total insolation (beam and diffuse) or solar irradiation flux, QS/A, on (normal to) the array when the NOCT measurement is made,

2. the temperature of the ambient air surrounding the array, T_a,

3. the wind speed and direction (the wind should be near 1 meter per second and into the array),

4. the instantaneous cell temperature, $T_{c,i}$ (or NOCT), under these conditions.

The term ''loss coefficient'' (here given the symbol U_L) is commonly used to express the efficiency of heat rejection for the array. In photovoltaic arrays the ratio of U_L to the solar absorptance (α) of the array is important, not just U_L. This ratio of loss coefficient to absorptance can be computed from

$$U_L/\alpha = \frac{(QS/A)_i}{T_{c,i} - T_a} \qquad (2.1)$$

where $(QS/A)_i$, $T_{c,i}$, and T_a are simultaneous measurents of the array insolation per unit array area, cell temperature, and ambient temperature, respectively. U_L is implicitly related to wind speed; therefore, the value used in the procedures outlined below should be representative of the wind conditions experienced by the arrays.

The procedure in this chapter requires knowledge of either NOCT or U_L/α. If neither an NOCT nor information from which U_L/α can be calculated is available from the manufacturer, then the designer must resort to either estimation or thermal analysis.

2.2 ARRAY REFERENCE EFFICIENCY

Another property that is highly product dependent is the efficiency for converting incident sunlight into electricity. Maximum power* operation is assumed in the procedures outlined in this Guide. Under this condition, the actual conversion efficiency, η, is, to good approximation, linearly related to cell temperature T_c by

$$\eta = \eta_r[1-\beta(T_c-T_r)] \tag{2.2}$$

The procedure that follows predicts the monthly average cell temperature (T_c) which can be used to estimate monthly average efficiency from eq. (2.2) <u>if</u> η_r, T_r and β are known to the designer. These latter quantities are discussed in the following paragraphs.

Usually, product information is complete enough to allow calculation of a reference efficiency, η_r, at a stated (reference) <u>cell</u> temperature, T_r. For example, if an array module max-power current, I_{mp}, and max-power voltage, V_{mp}, (or their product, P_{mp}, the maximum power) are given at some temperature and insolation, an appropriate η_r can be calculated from

$$\eta_r = \frac{I_{mp} \cdot V_{mp}}{A \cdot (QS/A)_i} \cdot 100 = \frac{P_{mp}}{A \cdot (QS/A)_i} \cdot 100 \tag{2.3}$$

where $(QS/A)_i$ is the instantaneous insolation on a unit area of the array and A is the area of the array module (the 100's that appear in eq. 2.3 convert efficiencies to percent which is the way they are expressed in this guide). T_r is taken to be the <u>cell</u> temperature at which these electrical properties are measured. Care should be taken in eq. (2.3) to make certain η_r is dimensionless.

The array efficiency <u>temperature coefficient</u>, β, in eq. (2.2) is usually not explicitly given in product specification sheets. However, occasionally enough information is provided to allow the calculation of this parameter. Whenever two different efficiencies (or enough information to calculate two efficiencies) are given at two different <u>cell</u> temperatures <u>but the same insolation</u>, β can be calculated. Suppose these efficiencies are η_1 at $T_{c,i}=T_1$ and η_2 at $T_{c,i}=T_2$. Then

$$\beta = \frac{1-(\eta_2/\eta_1)}{T_2-T_1} . \tag{2.4}$$

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*In max-power operation the voltage on the array is continuously adjusted so that electrical power production is always maximized. The device that maintains the voltage at the max-power value is referred to as a max-power tracker, and is often an accessory item that accompanies the power conditioner or inverter.

If insufficient information is given, then the designer has to resort to estimation. Fortunately, β is mainly cell material dependent. For silicon arrays a reasonable value to use is 0.0045 C^{-1} and for cadmium sulfide arrays 0.006 C^{-1} is recommended.

2.3 POWER CONDITIONING

In the procedures outlined in Section 2.5, the designer must specify η_{pc}, the power conditioning efficiency (in percent). Many applications require alternating current (a-c) power, whereas photovoltaic arrays produce direct current (d-c) power. In these cases, the designer must use an inverter between the array and the load to convert the d-c to a-c. Where the application requires regulated d-c power, some sort of power conditioning unit must also be included in the design.

Although the conversion efficiencies of inverters and power conditioning equipment are typically functions of the amount of power being processed, they are surprisingly independent of part-load-ratios over a large part of their operating range. (It must be remembered that array output power will vary drastically over any particular day). This fact usually simplifies the selection of a monthly average power conditioning efficiency, η_{pc}. Typical values of η_{pc} are in the range of 80 to 95 percent.

2.4 MONTHLY AVERAGE POTENTIAL ARRAY AND POWER CONDITIONER OUTPUT

For an appropriately determined monthly average potential array efficiency, η, determined from eq. (2.2), the monthly average daily energy output per unit area of array (including power conditioning losses) is given by

$$QE/A = \frac{\eta_{pc}}{100} \cdot \frac{\eta}{100} \cdot QS/A \qquad (2.5)$$

where QS/A is the monthly average daily insolation on a unit area of the array. The procedure outlined in the next section provides the η that makes eq. (2.5) applicable for obtaining monthly average results.

2.5 THE PROCEDURE FOR CALCULATING POTENTIAL ARRAY AND POWER CONDITIONER OUTPUT

Worksheet 1, several copies of which can be found at the end of the appendix, should aid in the calculation of array monthly potential performance. The steps enumerated below are keyed to that worksheet:

<u>Step 1</u> Obtain η_r and T_r from manufacturer's data. Ente< these values at the top of Worksheet 1. Do not try to estimate or guess their values. If η_r for some cell temperature, T_r,* cannot be calculated from data supplied in specification sheets (see Section 2.2), contact the manufacturer directly.

<u>Step 2</u> Obtain β from manufacturer's data and enter it at the top of Worksheet 1. See Section 2.2 for the method of calculation. If sufficient information is not available, use 0.0045 C^{-1} for silicon and 0.006 C^{-1} for CdS arrays, or ask the manufacturer.

<u>Step 3</u> Obtain NOCT <u>and</u> NOCT conditions from manufacturer's specifications. This NOCT will be needed to enter Fig. 2.1 in Step 9 below. If the conditions given by the manufacturer fall outside the limits of scales A1, A2, A3 or A4 on that figure or cannot be used with these scales, calculate U_L/α from eq. (2.1) for entry on scale B of Fig. 2.1. If insufficient data exist to determine either NOCT or U_L/α, contact the manufacturer. Enter the appropriate values on the top of Worksheet 1.

<u>Step 4</u> If the array output power is to be processed through power conditioning equipment, estimate η_{pc} from the equipment manufacturer's data and enter its value on Worksheet 1.

<u>Step 5</u> From Table I in the appendix, determine which station for solar/meteorological data best represents your location. Use the key maps on pages A-1, A-2, and A-3, to aid in finding this station in Table I. Table I is arranged alphabetically by station, but lists of the stations sorted by station, state, and latitude can be found on pages A-4, A-5, and A-6, respectively. Of course, if more site specific weather/insolation data are available they should be used, but they must be exactly the same quantities as listed in Table I. See Section 2.8, Table I and the Use of Other Data Bases, for further discussion.

<u>Step 6</u> Calculate the monthly optimum tilts using the site latitude and the equations found in Table II on page A-58 of the appendix. Enter the computed values in column C3 of the worksheet. Decide upon the array tilt to be used. Arrays that are to be adjusted in tilt each month can be accomodated in this procedure. Enter the monthly tilts to be used in column C4 on Worksheet 1.

The choice of tilt, s, will depend on the application. If optimum energy is desired and monthly adjustment of the tilt can

*The specific value of T_r is not important as long as it is a cell temperature (not an ambient temperature) <u>and</u> η_r is the array efficiency at that T_r.

be made, s would be set equal to s_M each month. A designer would want to ascertain that the cost of monthly adjustment is more than offset by the value of the increased electrical output.

If a fixed yearly tilt is to be used and maximum yearly energy production is desired, s would essentially be set equal to the tilt giving the largest yearly total insolation. Differences in monthly efficiency would alter this choice only sightly. Table I lists yearly insolation (YRT) for various tilts.

If optimum energy collection is desired for a particular month or season but a fixed yearly s is required, s would be selected from Table I to maximize insolation during that period. Energy production at other times of the year will suffer, however.

<u>Step 7</u> Transfer WS, KT, TM and QS/A from the data for your station in Table I to columns C1, C2, C6 and C9, respectively, of Worksheet 1. A key for reading Table I can be found on page A-7.

The wind speeds, WS, that appear in Table I are SOLMET data from Reference 5. Something less than the WS's shown in Table I (but not less than 1 meter per second) should be entered on Worksheet 1 due to the fact that arrays are typically mounted lower in the earth's boundary layer than are the National Weather Service wind measuring instruments. A value that is 50 to 75 percent of the tabulated value is recommended. A sensitivity study of the influence of WS on η can easily be performed by computing η at several assumed wind speeds.

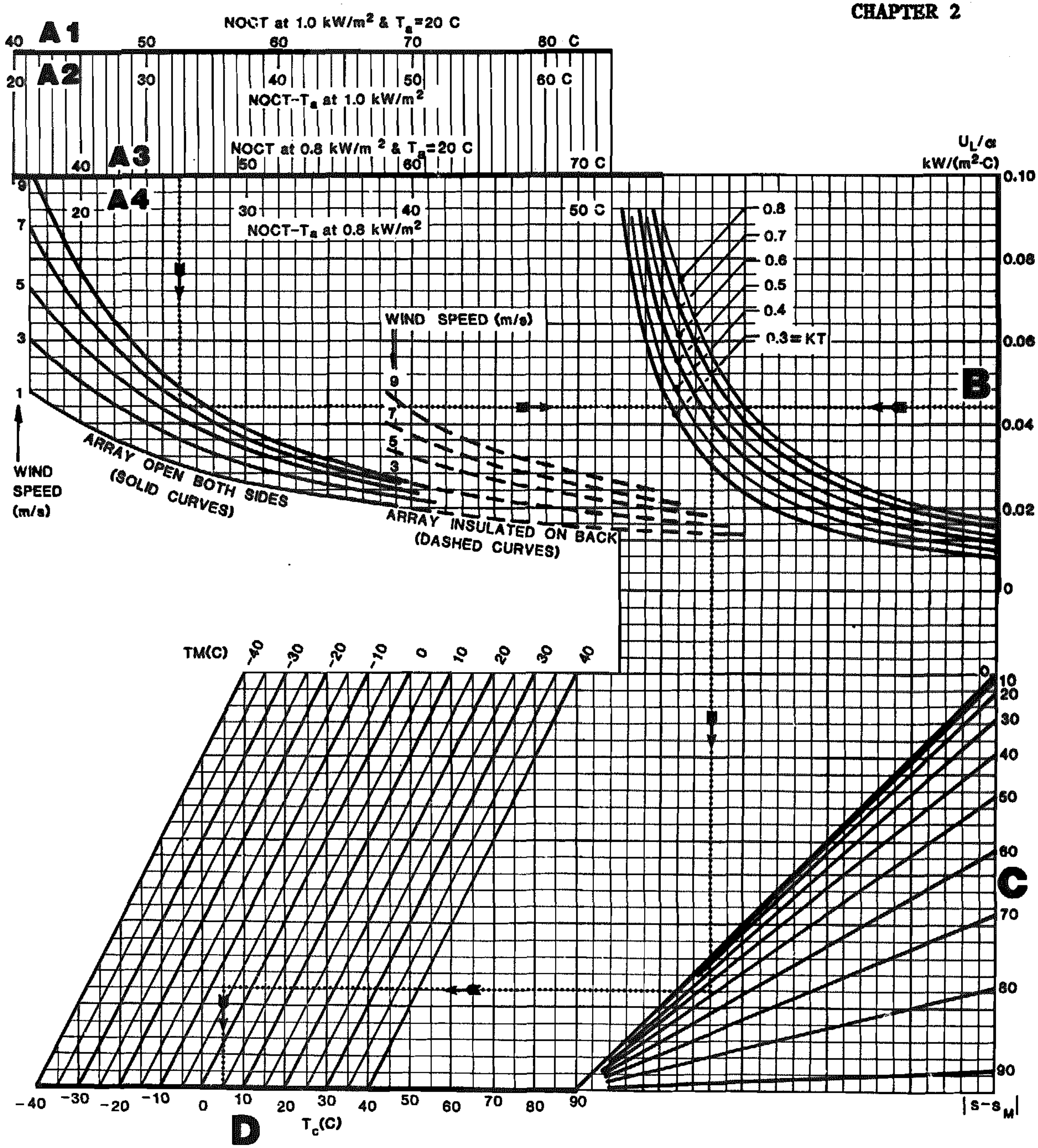
QS/A is the average daily array insolation per array area and must correspond to the monthly tilts given in column C4 of the worksheet. That is, enter Table I with the array tilt and month to locate the corresponding QS/A. Interpolation between tabulated tilts will probably be necessary.

<u>Step 8</u> Complete column C5 of Worksheet 1. "|···|" implies the absolute value of $s-s_M$. That is, if $(s-s_M)$ is negative, ignore the minus sign when entering the number in column C5.

<u>Step 9</u> Determine T_c, the average monthly cell temperature, by entering Fig. 2-1 each month with the values recorded on the worksheet. Enter on either axis A or axis B, depending on whether NOCT or U_L/α is known. If entering on axis A, begin at axis

A1 if the NOCT is known for an insolation of 1 kW/m² and an ambient temperature of 20 C,

A2 if the NOCT is known for an insolation of 1 kW/m² and the ambient temperature is different from 20 C. <u>Subtract the</u>



Graph for Estimating Monthly Average Cell Temperature

Figure 2.1

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known ambient temperature from the NOCT before entering this axis,

A3 if the NOCT is known for an insolation of 0.8 kW/m² and an ambient temperature of 20 C,

A4 if the NOCT is known for an isolation of 0.8 kW/m² and the ambient temperature is different from 20 C. Subtract the known ambient temperature from the NOCT before entering this axis.

After entering axis A proceed downward until intersecting the wind speed curve appropriate for your location and month.* After the intersection proceed to the right until reaching the clearness number, KT, curve for your location and month. If entry needs to be made into Fig. 2.1 with a U_L/α, begin at axis B and proceed to the left until intersecting the appropriate KT curve. From the KT curve proceed downward until intersecting the appropriate sloping $|s-s_M|$ curves (labeled along axis C) for your installation and month. Then move to the left until reaching the appropriate mean monthly temperature, TM, curve for the month and site. Proceed downward to the horizontal axis D to obtain the monthly average cell temperature, T_c, that can be used in eq. (2.2). Enter this T_c in column C7 of Worksheet 1.

Step 10 Calculate the monthly average array efficiency, η, from eq. (2.2) and enter the results in column C8.

Step 11 Calculate the monthly average daily energy potentially available from the power conditioning unit per unit area of array, QE/A, from eq. (2.5) and enter the result in column C10. (Note that η, η_r, and η_{pc} are assumed to be in percent when entered in the worksheet. Thus the 100's appear in the legend of column C10.

2.6 DEPARTURES FROM LONG TERM AVERAGE BEHAVIOR

If the data of Table I have been used, the procedure outlined above predicts long term monthly average array performance, since the values given in that table are averages over approximately 25 years of

*Note there are two sets of wind speed curves in Fig 2.1; the solid curves represent arrays that are open on both sides (e.g., free standing arrays with no thermal insulation) and the dashed curves represent arrays that are well insulated on their back sides (e.g., integral roof mounting). It is imperative that the mounting and testing of the arrays during NOCT tests be equivalent to the way they will be mounted and used in your application. Do not use the free standing NOCT's for arrays that will be insulated on the back and vice versa.

data. It is often desirable, however, to know the departures from the long term average that may be expected in array performance.

The most influential variable affecting array output is the array insolation or solar irradiation. Therefore, knowing the variation in insolation that can be expected over the years allows one to predict array output variations to be expected.

For any one location and month the monthly average array insolation varies nearly in proportion to the monthly clearness number, KT, for that location and month. Monthly departures from the long term average KT for any location and month typically have a standard deviation of 0.04, although this increases somewhat in low KT locations and decreases somewhat in high KT locations. Thus, multiples of this standard deviation can be added to (subtracted from) the long term monthly KT to obtain reasonable statistics on high (low) array insolation levels. For example, since 95.4 percent of any normally distributed set of numbers lie within ± 2 standard deviations of the average, a monthly average array insolation level of

$$(QS/A)_{high} = (QS/A)\,\frac{[KT + 2(0.04)]}{KT}$$

would be exceeded only 2.3 percent of the time. Likewise, a monthly average insolation level of

$$(QS/A)_{low} = (QS/A)\,\frac{[KT - 2(0.04)]}{KT}$$

would be exceeded 97.7 percent of the time. Here the unsubscripted parameters are the long term average values taken from Table I of the appendix. Using such high and low values for QS/A in eq. (2.5) gives reasonable estimates of the high and low monthly average array output to expect over the years.

2.7 CORRECTIONS TO BE APPLIED

The values of QS/A's listed in Table I do not account for losses in available solar energy that occur in the early morning and late afternoon when the angle between the normal to the array and the incoming solar rays is large. Also not considered are losses due to shading of the array surface by either other parts of the array or by nearby non-array elements, and losses due to scattering of the incident rays by dirt accumulated on the array surface.

Although losses at high incidence angles have not been quantified here, they should be of the order of 5 percent or less.

Shading losses are strongly dependent on the manner in which the cells and modules are wired together and the ratio of array area to the land area (this latter ratio is often referred to as the land packing factor). For near latitude tilts, self shading of the array (shading of one part of the array by other parts) is not significant at packing factors up to 0.3 to 0.4 and may be insignificant at values larger than 0.4. Due to differences in the sun's elevation in the sky, the self shading losses are always much greater in the winter than in the summer. By using diodes or by wiring series strings of cells across the arrays (rather than up and down the arrays) shading losses can be held to less than 1 or 2 percent at packing factors as high as 0.6. Shading by non-array elements (buildings, trees, power poles, etc.) is highly site specific and should not be disregarded by the designer.

Losses due to dust and dirt accumulation are typically on the order of 3 to 5 percent although they have been observed to be as high as 13 percent. In most locations rain is frequent enough to keep such deposits at a near negligible amount.

Designers should use some discretion in the removal of such losses as those discussed above from the calculated monthly QE/A's. The losses are difficult, if not impossible to quantify in a general way; the choice of magnitudes needs to be tempered with experience.

2.8 TABLE I AND THE USE OF OTHER DATA BASES

The data base included as Table I is based on the monthly mean temperatures, wind speeds and daily total (global) radiation on the horizontal from Reference 5. The data represent averages for the period 1952 through 1976. The original source for Reference 5 was the SOLMET tapes (Reference 6).

The SOLMET data base was originally established by rehabilitating measured data for 26 sites. Most of the systematic errors in the original data were removed in the correction process while other random and systematic errors were introduced. Insolation data for over 200 other sites were then constructed by applying regression analysis coefficients on a month to month basis, from the closest SOLMET location, to synoptic data available for these additional sites. The largest errors in the original SOLMET sites apparently occur in winter in northern latitudes and may be as large as 10%. Probable errors in the ''regressed'' data base are difficult to quantify but are undoubtedly larger.

KT was computed from Reference 5 data by dividing the total radiation on the horizontal by the extraterrestrial radiation on the horizontal. Total radiation on the tilt data in Table I were then computed using the method of Reference 7, assuming a ground reflectance of 0.2. (The accuracy of this computation is discussed below.)

Although the regionalization developed in Reference 5 (see page A-2) is convenient, anomalies that can occur within any region, particularly in mountainous or coastal regions, can lead to errors. Users of Table I are urged to apply discretion in this regard.

There are many data bases in use in the solar design community. Unfortunately, very seldom do any two or more of these bases give identical results. Indeed, one of the largest uncertainties in solar design may result from uncertainties in the choice of data bases.

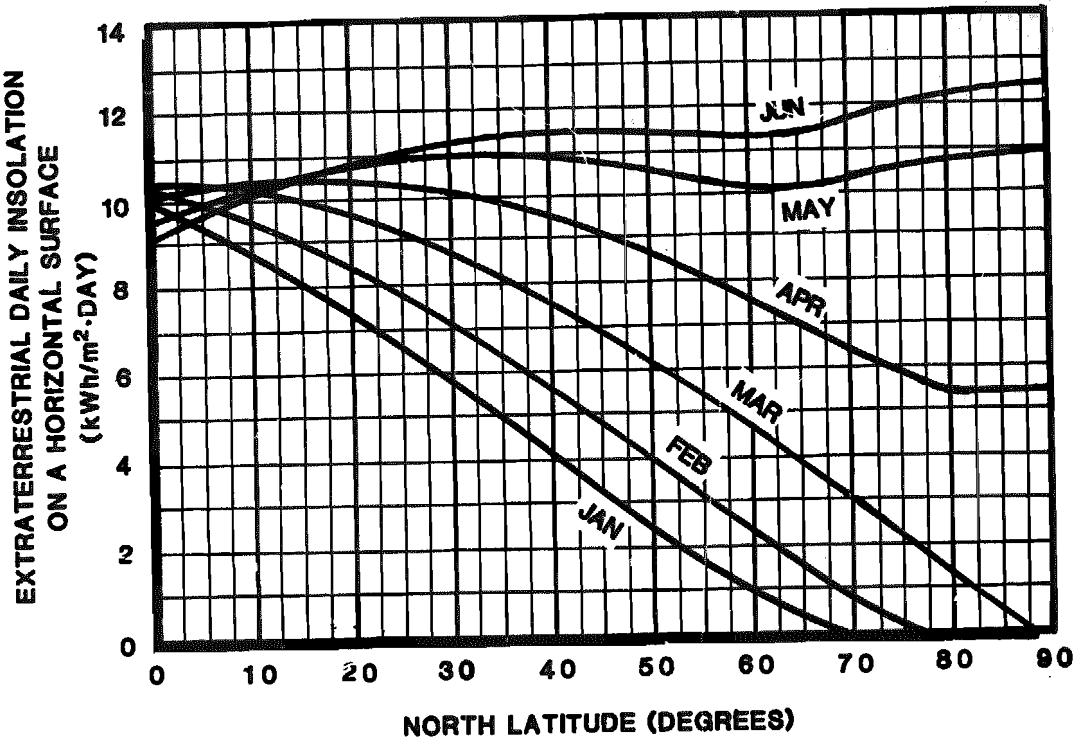
Because designers often have their favorite data bases and because Table I can and will eventually be replaced with more accurate data, some discussion of the use of other information may be in order.

Usually if any data exist for a site they are total radiation on the horizontal. In order to use the procedure developed here, a designer must know KT. If a data base does not provid KT, it can be computed by ratioing the monthly (or monthly average daily) total radiation on the horizontal to the monthly (or monthly average daily) extraterrestrial radiation. This latter quantity can be obtained from Fig 2.2 for the month and latitude of interest.

A designer also needs the monthly average temperature, TM. This is often available from meteorological data characteristic of the site. Some data contain the monthly average temperature during daylight hours which is typically three degrees above the average temperature over all hours. Therefore, TM would be this daylight temperature minus three degrees.

In principle, the wind speed information required is the monthly average wind speed during daylight hours at the array height above the ground with the array in place. Such extensive information is rarely available. Usually, at best, there may be some monthly average (all hours) data at another height. Fortunately for many situations, system performance is not strongly tied to wind speed.

The total radiation on the tilt, which is perhaps the most important variable, is usually the most difficult to obtain; few measurements exist. If the data base to be used does not include radiation on the tilt, a designer is usually faced with converting total radiation on the horizontal to total radiation on the tilt. Although volumes of papers have been written on such a conversion, no standard or ''best'' method exists for doing this. Reference 8 does outline one step-by-step procedure for making this conversion. Various existing data bases that all start with the same total horizontal radiation data show discrepancies of 3 to 5% and occasionally as much as 10% in total radiation on the tilt.



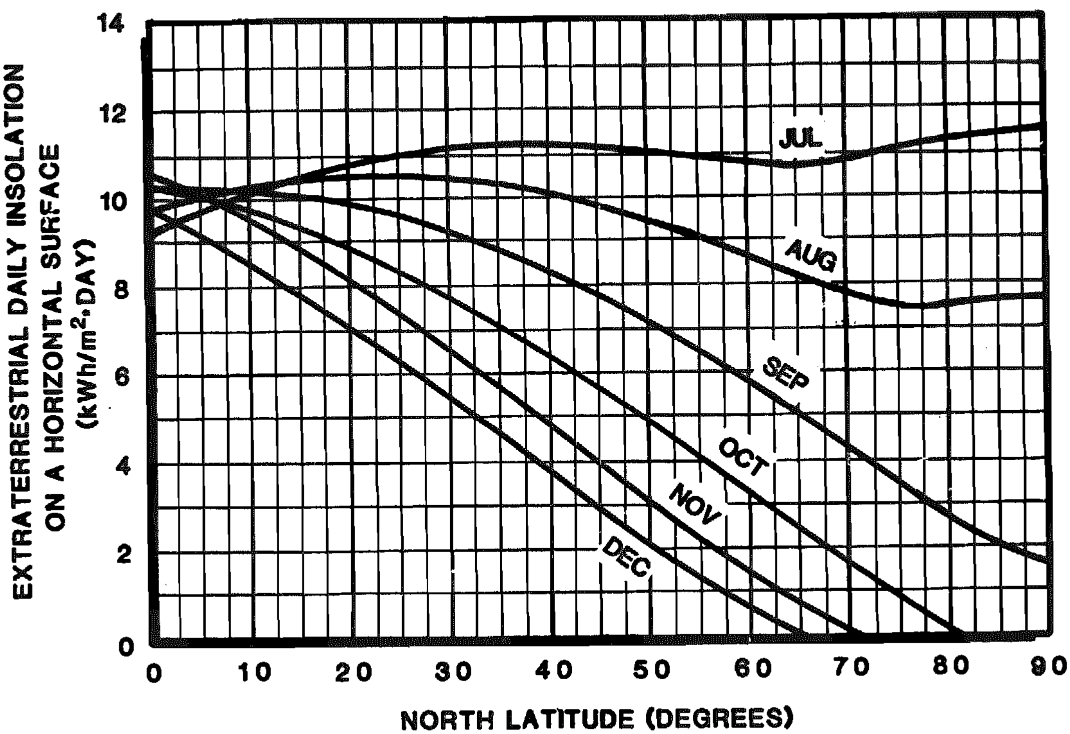


Figure 2.2 Extraterrestrial Daily Insolation Received on a Horizontal Surface as a Function of Month and Latitude

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CHAPTER 3

PREDICTING SYSTEM PERFORMANCE

3.0 BACKGROUND

The information contained in this chapter is used to estimate system performance, given an array performance prediction from Chapter 2. The results from Chapter 2 that are necessary here are the monthly effective array output per unit area, QE/A, and the monthly array efficiency, η.

This chapter introduces several additional quantities:

- L – Monthly average daily electrical load (kWh)
- B – Electrical energy storage capacity (Wh)
- F – Solar fraction, or the portion of the electrical load supplied by the photovoltaic system.

3.1 LOAD

This number is determined by the application and must be supplied by the designer. The monthly average daily electrical load, L, is most accurately estimated by dividing the electrical load for an entire month in kWh by the number of days in that month if the magnitude is relatively constant from day to day. If significant variations occur from day to day, then the techniques of this chapter will overestimate the actual solar fraction, since the performance curves used assume repetitive daily loads over the month. If significant differences occur on certain days of the week (e.g., if weekend loads are different from weekday loads), then separate average daily loads should be computed for these days and separate performance estimates should be made. Monthly performance can be approximated by taking a weighted average of these separate daily estimates.

3.2 ELECTRICAL STORAGE CAPACITY

Lead-acid batteries having a round trip efficiency of 80 percent are represented in these calculations. Electrical energy storage capacity, B (in Watt-hrs), is calculated from:

$$B\ [\text{Wh}] = \text{Capacity per battery [Ah]} \times \text{Average voltage per battery [V]} \times \text{Fraction of battery used} \times \text{Number of batteries} \qquad (3.1)$$

Battery manufacturers commonly size their products by amp-hour capacity at a moderate discharge rate, e.g., ''30 amp-hours at the 10 hour rate.'' The amp-hour capacity entered in eq. (3.1) should be this value, i.e., the capacity measured at a rate which causes complete discharge in 10±2 hours.

In the present application, the average voltage per battery is the average voltage during both charge and discharge at approximately the 10-hour rate. A voltage per cell of 2.17 has been implicitly assumed in the performance curves that are used in the procedure presented in this Guide. Therefore, the voltage per battery to be used in eq. (3.1) must be 2.17 times the number of nominal 2 volt cells in series within the battery. This value differs only slightly from the average voltage of 2.12 which can be computed from the information of Reference 9.

The ''fraction of battery used'' depends upon how deep a discharge and how high a charge are permitted during battery operation. For example, if 60% of the total available battery capacity is utilized, this factor would be 0.6. (The system's power conditioner or regulator must monitor battery state of charge and/or voltage and regulate battery current accordingly.)

The number of batteries entered into eq. (3.1) is the total number of batteries in the storage system. For example, if the storage is arranged with 3 batteries in series and 4 batteries in parallel, then the total number of batteries is 3 x 4 = 12.

3.3 SOLAR FRACTIONS

This chapter outlines how to calculate solar fractions, F, on a monthly and on an annual basis. Steps 1 to 7, listed in Section 3.4 below, detail how to estimate F for a single month. If these steps are carried out for all 12 months, then an annual F can be computed by following steps 8 and 9.

In Step 5, several of the quantities discussed in Chapter 2 and Section 3.2 are combined to give the variables which are necessary to eventually obtain solar fractions. These variables are:

$$QE/L = (QE/A) \cdot (1/L) \cdot A \qquad (3.2)$$

and

$$B/A\eta = \frac{1}{\eta} \cdot B \cdot \frac{1}{A} \cdot \frac{(QS/A)_{lat}}{QS/A} \cdot \frac{90}{\eta_{pc}} \qquad (3.3)$$

QE/L is the potential solar fraction in that is represents the fraction of the load which could potentially be satisfied by electrical energy from the array if infinite, loss free storage were available. In many cases part of the available array output cannot be used immediately and must be stored, ''dumped'' (or not collected), or fed back to the grid (if that option is available). Other losses are due to battery inefficiencies. These cause the solar fraction, F, to always be less than QE/L.

QE/L is a dimensionless parameter and can be changed, for a given load and location, by increasing or decreasing array area (changing A), by changing the array tilt [which changes QS/A that is used in calculating QE/A via eq. (2.5)], or by using different arrays [changing η in eq.(2.5)].

For individual months, the parameter B/Aη has been empirically found to collapse solar fraction data for different geographic and climatological locations onto nearly a single family of curves in the (B/Aη, F) plane which have only QE/L as a parameter. However, such a collapse of data appears to be possible only if the arrays are tilted at the local latitude angle for each location and if the same power conditioning efficiency, η_{pc}, is used in all cases compared. This is an extremely important point since B/Aη is a dimensional parameter.

Since designers often desire to use various (non-latitude) tilts and other power conditioning efficiencies, it is necessary to be able to ''correct'' these latitude tilt, fixed η_{pc} data in order to improve their usefulness. The ''correction term,'' $[(QS/A)_{lat}/(QS/A)]$, that appears in eq. (3.3) allows the data of Table III, which were computed for latitude tilts, to be used for other array tilts. $(QS/A)_{lat}$ is the local array insolation (from Table I) corresponding to a tilt angle equal to the local latitude, while (QS/A) is the insolation for the array tilt actually used in the system. Likewise, since the data in Table III were computed with η_{pc}=90 percent, the ''correction'' $[90 / \eta_{pc}]$ allows that data to be used with other values of η_{pc}.

B/Aη can be changed by increasing or decreasing storage size (changing B), changing array area (A), controlling the array tilt (this latter option affects B/Aη through the ''correction term'' referred to above), using different arrays (i.e., different η's), and/or using different power conditioning efficiencies (i.e., different η_{pc}'s). Notice that A and η affect both QE/L and B/Aη; the interplay of variables should not be ignored.

The next two sections outline a step-by-step procedure for calculating QE/L and B/Aη and obtaining estimates of F.

3.4 THE PROCEDURE FOR ESTIMATING MONTHLY AND ANNUAL SOLAR FRACTIONS (F'S)

Worksheet 2, found on the back of Worksheet 1 at the end of the appendix, facilitates these calculations. The following steps refer to the worksheet.

Step 1 The designer must select A (array area) and B (storage capacity). Enter these values at the top of Worksheet 2.

Once the location, array tilt, and array specifications are set, a designer might use A to provide different QE/L's (Step 5 below); i.e., he might investigate the effect of array area on the solar fraction. For most load shapes, the relationship between A and solar fraction F is not linear, especially above F = 0.4; that is, there are diminishing returns for additional array area. Above F = 0.4, each increment of area added supplies a smaller fraction of the load. At some point it becomes economical to use the back-up source instead of increasing array size. For example, an array chosen to provide a potential solar fraction QE/L of 0.20 (or 20%) would have an area of $0.2 \cdot L/(QE/A)$. For many load shapes (at least for those included in Table III) the actual solar fraction would be nearly 0.20 (or 20%). For a potential solar fraction QE/L of 0.8 (or 80%), an array area of $0.8 \cdot L/(QE/A)$ would be required. For most load shapes unless there is excellent diurnal matching between the array output and the load, the actual solar fraction would be less than 0.8 by an amount that depends on the storage capacity and storage efficiency.

Once an array area is chosen, a ''rule of thumb'' on electrical storage is that an upper limit on capacity can be found by noting that storage capacities larger than about $B \simeq 40 \cdot \eta \cdot A$ seldom result in increasing the solar fraction. In fact, the ''knees'' of the F vs. storage capacity curves occur at about $B \simeq 10 \cdot \eta \cdot A$ to $20 \cdot \eta \cdot A$. This should be more obvious to the designer after he has completed steps 6 and 7 below. Of course, if the back-up grid is to be used as the storage medium (e.g., if utility sellback is permitted), B = 0.

Step 2 Enter the monthly QE/A and L (columns C10 and C8, respectively, from Worksheet 1) in columns C12 and C13, respectively.

Step 3 Enter into column C14, the array insolation, $(QS/A)_{lat}$, from Table I that corresponds to an array tilt equal to the local latitude angle. Usually this value will have to be interpolated in the table.

Step 4 Estimate the average daily electrical load for each month and enter in column C15.

Step 5 Calculate QE/L and $B/A\eta$ from eqs. (3.2) and (3.3) and enter in columns C16 and C17. These values also vary monthly.

Step 6 From Table III of the appendix, select the system performance graphs which best resemble the application load profile. The key to and choice of graphs is discussed in Section 3.5.

<u>Step 7</u> Enter the appropriate performance graphs of Table III with QE/L and B/Aη to obtain the monthly solar fractions. A reading key for Table III is given on page A-63.

For example, for a winter month with QE/L = 0.6 and B/Aη = 10 Wh/(m²·%), the example graph in Figure 3.1 yields F = 0.43.

For QE/L other than 0.2, 0.4, 0.6, etc., a simple interpolation is done, as illustrated in the examples in Chapter 4 of this Guide.

The final steps in this chapter's procedure give an estimate of the annual solar fraction:

<u>Step 8</u> Multiply L x d for each month and enter in column 19.

<u>Step 9</u> Perform the calculation presented at the bottom of the worksheet. '' '' denotes a summation of the indicated quantities over all 12 months.

3.5 KEY TO GRAPHS OF TABLE III

Selection of a particular page from among the 41 pages of system performance graphs in Table III of the appendix depends upon the shape of the average daily electrical load. The 41 pages are divided into four classifications:

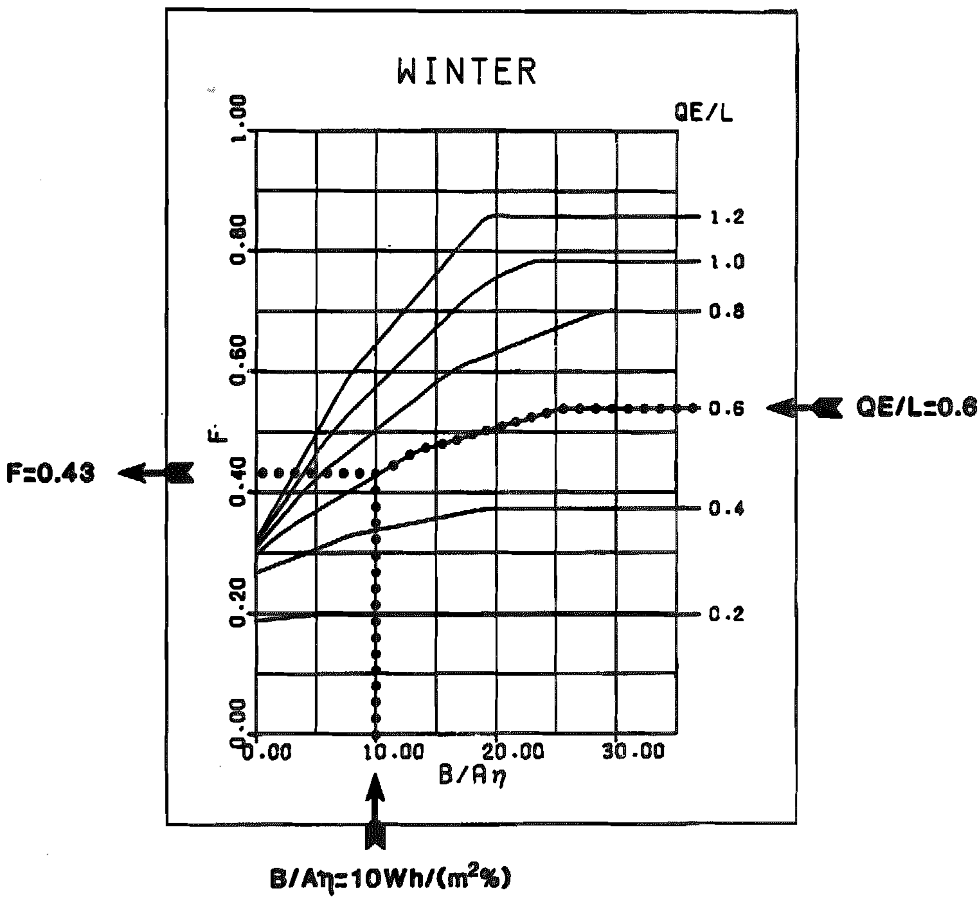
1. Constant (1)
2. Sinusoidal (20)
3. Unimodal (17)
4. Bimodal (3)

The numbers in parentheses indicate the number of load profiles in each category for which there are performance graphs in this Guide.

The constant load shape needs no further explanation. The profiles in category 2 are indexed on pages A-59 and A-60, while those for categories 3 and 4 are indexed on pages A-61 and A-62. These curves are based upon the average daily load profiles for all the two-digit SIC (Standard Industrial Codes) applications listed in Reference 10. Several of the sinusoidal profiles may also be representative of residential loads, but note the comments on residential loads in Section 3.7.

Four comments pertain to the use of the profiles and indices:

(1) Note that in the Unimodal and Bimodal plots, the vertical scale may vary for different profiles.



How to Use the Performance Curves of Table III to Find F

Figure 3.1

(2) Select the profile which most closely resembles that of the application. In some cases, the use of graphs pertaining to several profiles and averaging of the results may be necessary.

(3) Only the shape of the curve is important in profile selection. The size of the load or the area under the curve enter the procedure through the quantity QE/L.

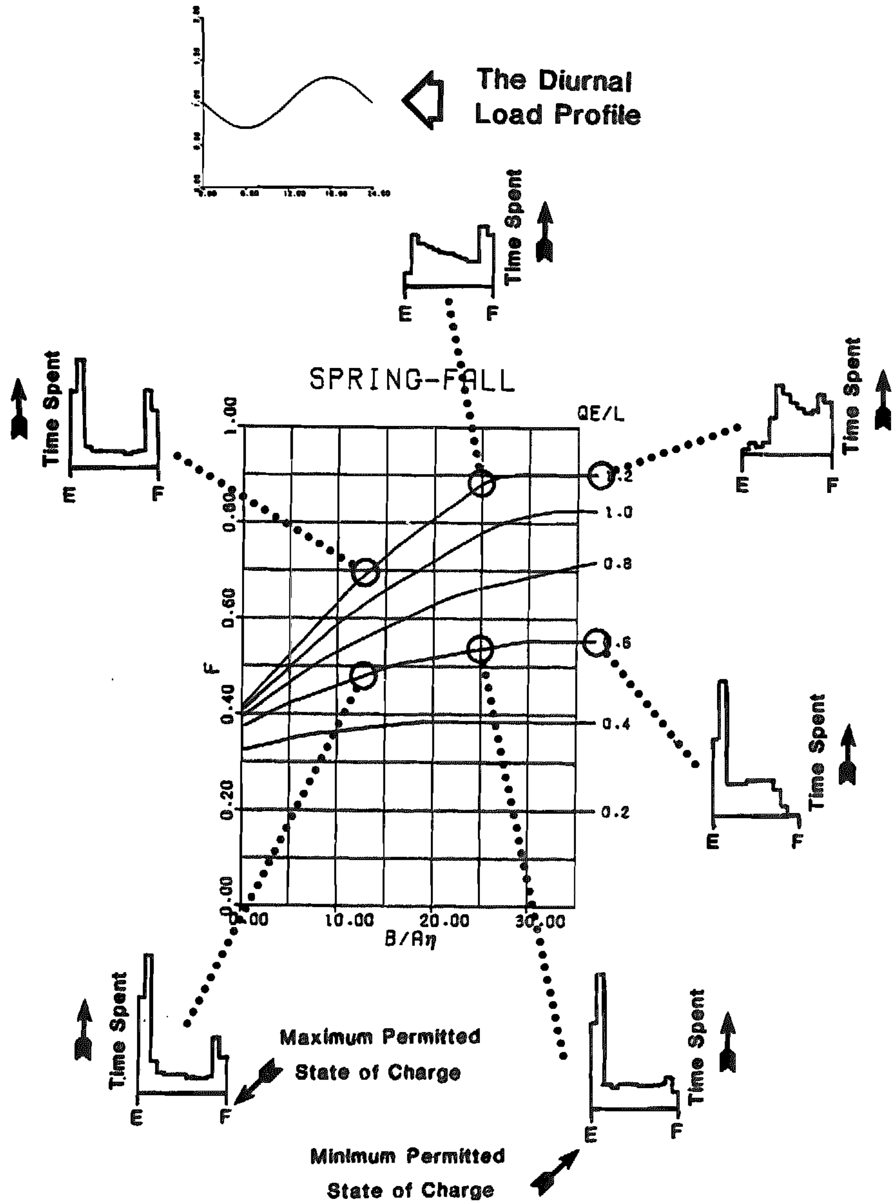
(4) The ''Spring-Fall'' graphs are for the months of February, March, April, August, September, and October. For Northern Hemisphere locations, the ''Summer'' graphs cover May, June, and July, and the ''Winter'' graphs are for November, December, and January. The summer and winter months are reversed for Southern Hemisphere sites.

3.6 USE OF THE ELECTRICAL STORAGE

Figure 3.2 illustrates how the electrical storage would be utilized during operation of a typical photovoltaic system. Although the calculations presented there are for the spring and fall months for a sinusoidal load profile of amplitude to mean ratio of 0.3 and time of peak of 18:00 (profile 18.3 in Table III), they should be typical of other months and many other types of load shapes.

The small diagrams on the periphery of Figure 3.2 are histograms of the battery state of charge which essentially tell how the battery would spend its time. For example, these show that small storage capacities [$B/A\eta \sim 10$ Wh/($m^2 \cdot$%)] would cover the entire permitted range of state of charge, since they typically would charge quickly during the day and then discharge quickly near or after sundown. Most of the time would be spent either fully charged or at the minimum permitted state of charge. For QE/L=0.6, photovoltaic array output would be insufficient to fill a large capacity storage [$B/A\eta \sim 40$ Wh/($m^2 \cdot$%)]. As a result, the state of charge would be at or near the minimum permitted value most of the time. If this minimum happens to be near zero state of charge (i.e., if the storage were allowed to be fully discharged), such operation would not favor long battery lifetimes. This situation reverses for large arrays (e.g., QE/L=1.2) and large storage capacities. Here the array output would maintain the batteries at full charge most of the time since there is more than enough energy to meet the average daily load. Such operation would favor long battery lifetimes.

Note that a fixed $B/A\eta$ does not infer the same battery capacity at QE/L=0.6 as it does at QE/L=1.2. For the same load, it takes twice the array size for a QE/L=1.2 as it does for a QE/L=0.6. Equal $B/A\eta$ thus requires twice the storage capacity for QE/L=1.2 as for QE/L=0.6.



Histograms Showing How the Electrical Storage is Used

Figure 3.2

3.7 ERRORS IN SYSTEM PERFORMANCE PREDICTIONS

This section describes three sources of error in the predictions of F. They are discussed in order of increasing importance.

Effect of ''Noisy'' Loads

An actual load profile will seldom have the ''smooth'' appearance of those on pages A-59 to A-62. Although the load shape may, on the average, approximate one of those for which performance data is given in Table III, fluctuations or ''noise'' will usually be superposed on the load curve for any given day.

Deviations from a smooth profile will generally cause a negligible difference between actual system performance and this chapter's predictions. However, when the fluctuations become large enough, the solar fraction will be less than what is estimated in the given procedure.

Specifically, when the amplitude of the noise is equal to or greater than the average load, then the solar fraction will be at least 5% less than the estimate.

Residential load applications, in which switching of appliances can lead to significant deviations from a ''smooth'' load profile, may be subject to significant error. Caution is urged in the use of these performance curves for such applications. Probably just as important in residential applications are the day to day variations in daily load. The performance curves of Table III were constructed assuming repetitive daily loads over each month. If the loads vary significantly from day to day the procedures using Table III will overestimate F.

Dependence of Performance Estimates upon KT and Latitude

The system performance graphs of Table III are constructed to take into account the two major factors which affect the interaction of array output and electrical load. The first consideration is load profile and the second is daylength, which varies appreciably from one season to another. Thus Table III contains three seasonal performance curves for each of 41 load profiles.

Two minor effects are ignored in the generation of these graphs. The first of these is the variation of KT within a given season, as the location of interest varies. A relatively large value of KT implies that the weather is consistently good from one day to another. A small KT, on the other hand, indicates either frequently cloudy weather with a high degree of day-to-day variability or uniformly poor weather.

The graphs of Table III are actually predictions for a location having KT's approximately equal to the average values for each season of the 97 locations listed in Table II. Figure 3.3 gives the monthly distributions of KT for these 97 locations, while Table 3.1 gives the values used in constructing Table III.

The other effect ignored in Table III is the variation of daylength during summer or winter due to latitude differences among locations. Table 3.2 shows how much the daylength varies at the two solstices over the latitude range covered in this Guide. (The daylength is 12.0 hours worldwide at the spring and fall equinoxes.)

Table 3.1

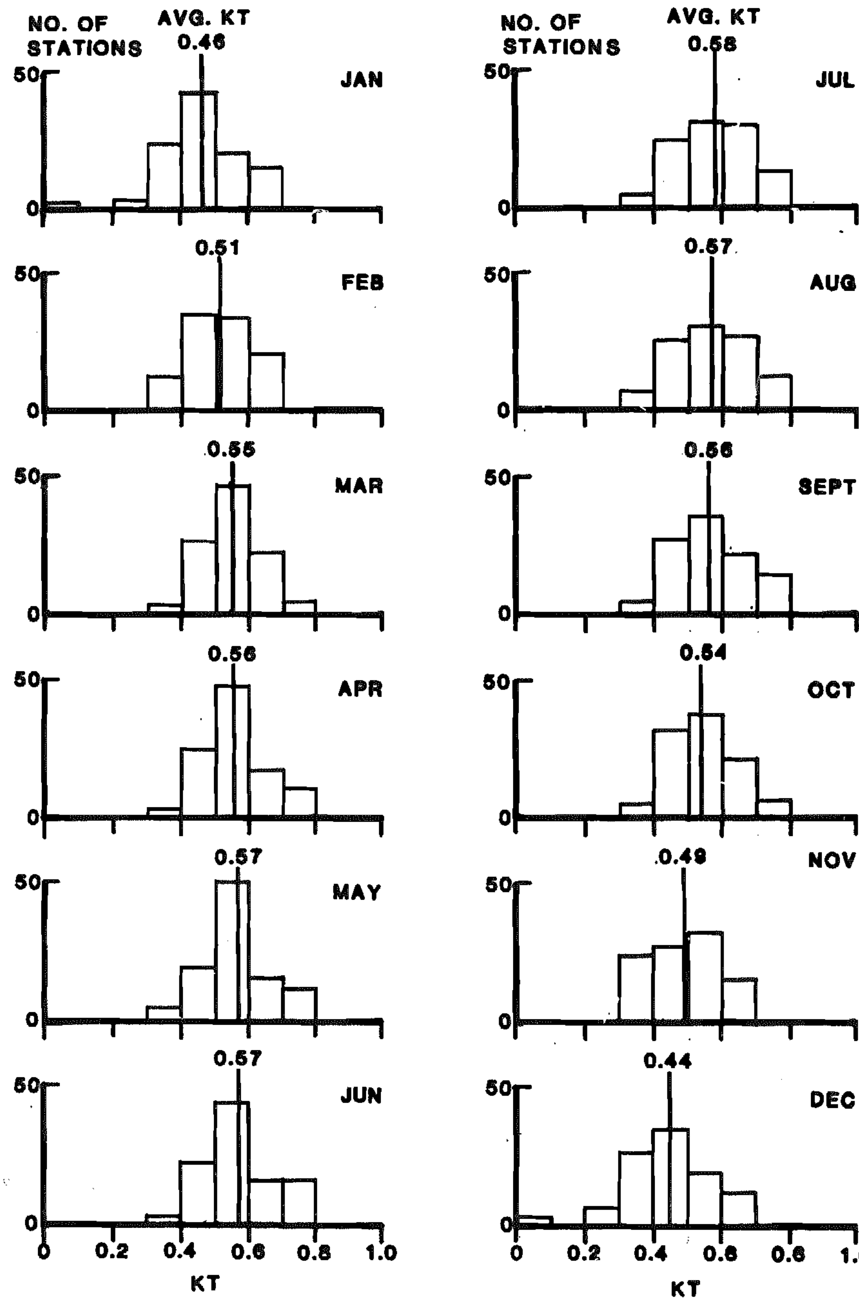
Approximate Values of KT Used in Generating the System Performance Graphs of Table III

Season	Average KT
Spring	.545
Summer	.573
Fall	.560
Winter	.442

Table 3.2

Variation of Latitude and Daylength

Date	Location	Latitude	Daylength
June 22	Barrow, AK	71.3	24.0
	Caribou, ME	46.9	15.7
	Lake Charles, LA	30.1	13.9
	Koror Is.	7.3	12.4
December 22	Barrow, AK	71.3	0.0
	Caribou, ME	46.9	8.3
	Lake Charles LA	30.1	10.1
	Koror Is.	7.3	11.6



Monthly KT Distributions for the 97 Stations for Which Data Are Included in Table I.

Figure 3.3.

The significance of the factors of KT and latitude/daylength for locations within the contiguous United States is displayed in Figs. 3.4 and 3.5. The data points in these plots are the results of computer simulations using data for the four locations indicated and assuming a sinusoidal #18.3 load profile.

The rationale behind the selection of the locations other than Albuquerque is described below. Results for Albuquerque are shown because these served as the starting point in the development of this entire system performance estimation procedure. Likewise, the sinusoidal #18.3 load profile closely resembles the ''baseline load'' used in the background work. (See Reference 4.)

The influence of KT is illustrated by a comparison of the results for Lake Charles and El Paso, which have approximately the same latitude (30.1 N and 33.7 N, respectively) but much different KT's for any given month. Notable differences in predicted solar fractions for these two locations appear for two cases: (1) winter months, small B/Aη, (2) spring or fall months, large QE/L and large B/Aη.

These variations in predicted F's due to KT are less severe if the load profile is a better match to the average daily array output curve than the sinusoidal #18.3 one, and are more serious if the load shape differs from the array output shape to a greater extent than the sinusoidal #18.3 curve.

The effect of latitude and hence daylength variation in summer and winter months is depicted via the results in Figs. 3.4 and 3.5 for Caribou and Lake Charles. These two locations have roughly the same KT's during the months of interest, yet they differ considerably in latitude and solstice daylengths, as indicated in Table 3.2. The Figures show that this causes appreciable (>5%) differences in F only during winter months and when QE/L is large.

Computer simulations for locations outside the contiguous U.S. have not been done, but the solar fractions for these sites may differ considerably from the results for summer and winter presented in Figs. 3.4 and 3.5, due to the latitude/daylength effect. It is therefore recommended that extreme caution be exercised in making use of system performance estimates for the Alaskan and island locations in summer and winter.

Figure 3.4

Comparison of the Simplified System Performance Curves with Hourly Simulation Results

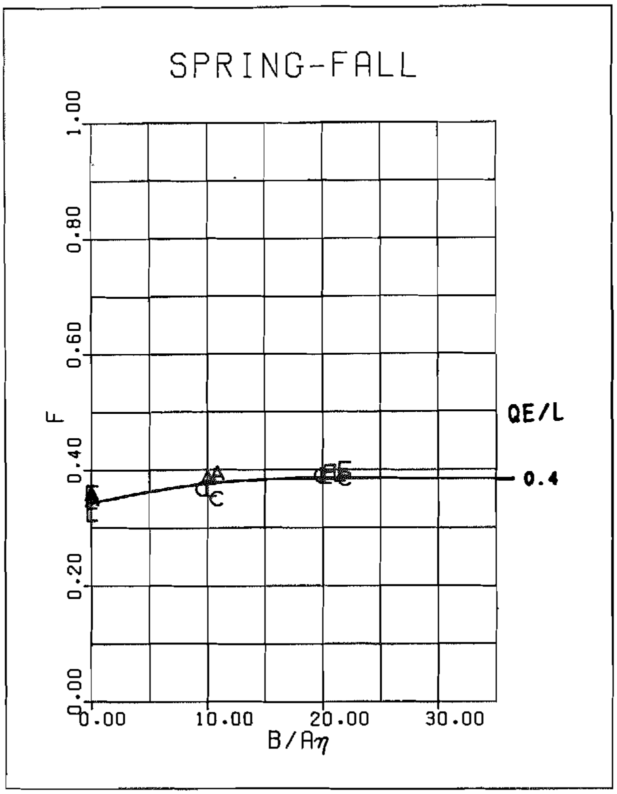
Load Profile - Sinusoidal#18.3(pg.A-81)

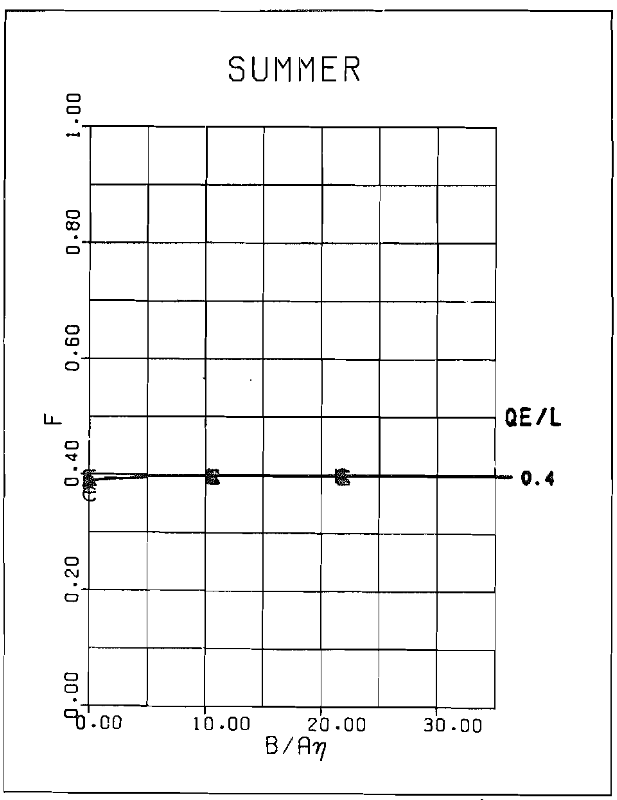
QE/L..............................0.4

Solid Lines - Performance Esitmates from this Guide

Data Points - Hourly Simulation Results

A	**Albuquerque, NM**
C	**Caribou, ME**
E	**El Paso, TX**
L	**Lake Charles, LA**





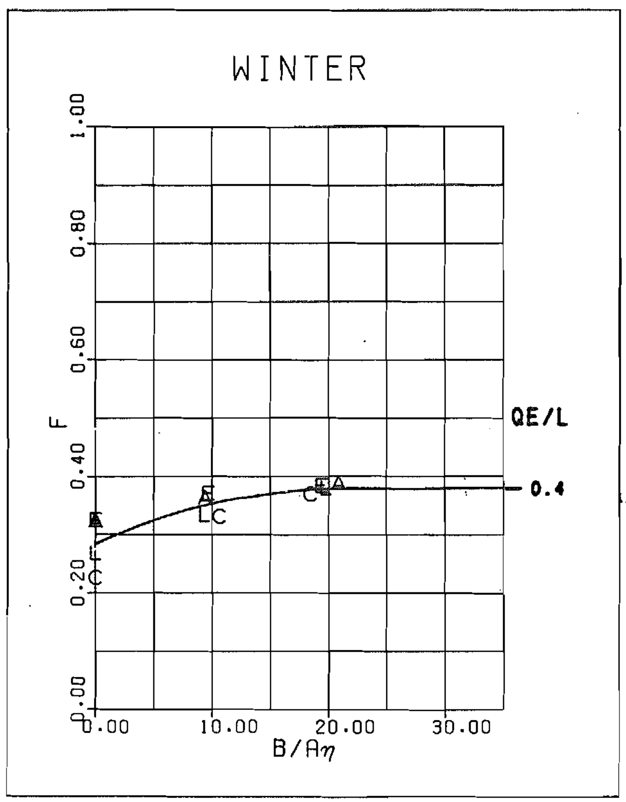


Figure 3.5

Comparison of the Simplified System Performance Curves with Hourly Simulation Results

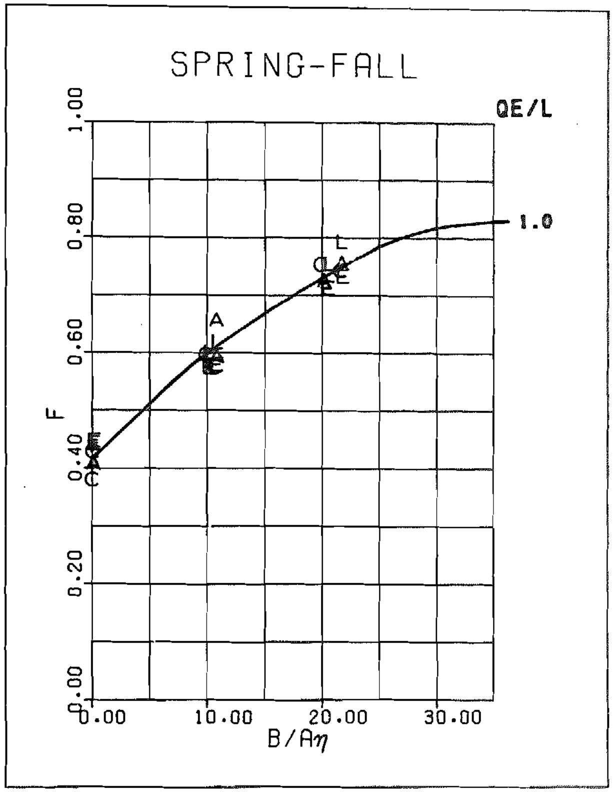
Load Profile – Sinusoidal#18.3(pg.A-81)

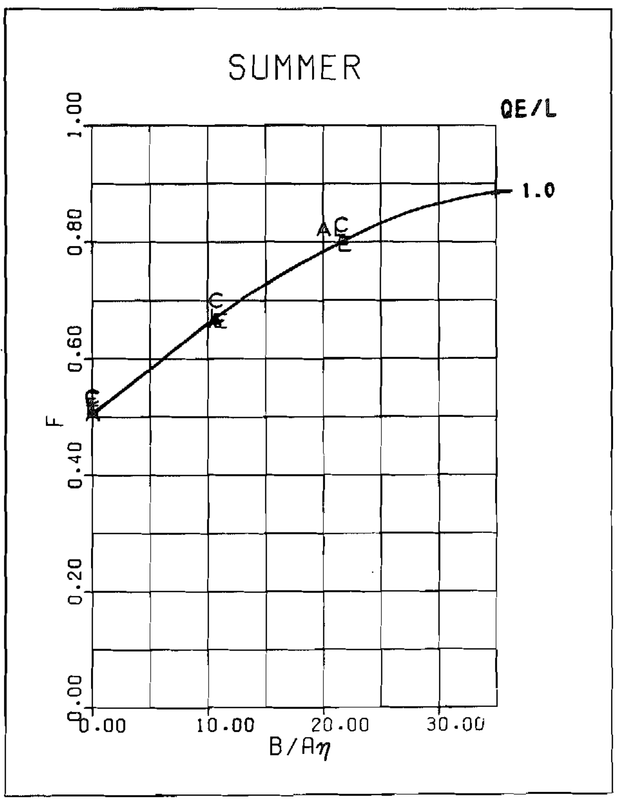
QE/L 1.0

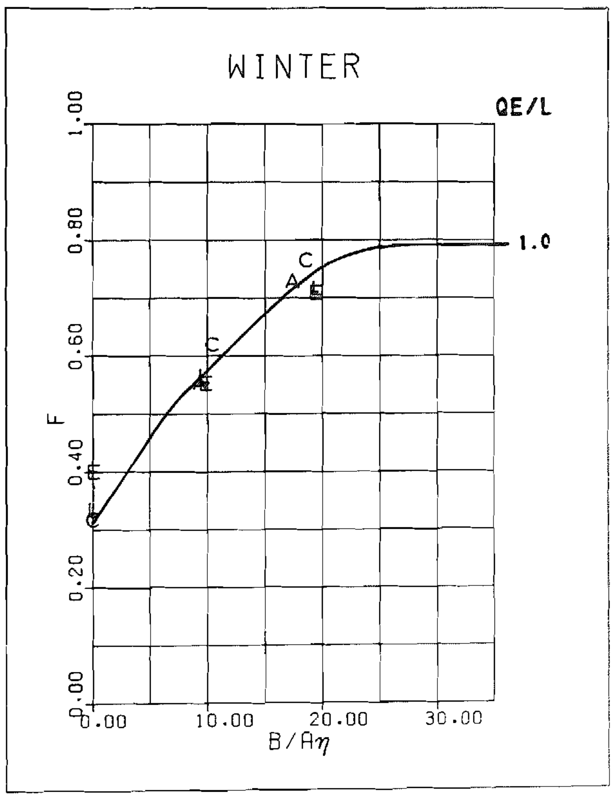
Solid Lines – Performance Esitmates from this Guide

Data Points – Hourly Simulation Results

A	**Albuquerque, NM**
C	**Caribou, ME**
E	**El Paso, TX**
L	**Lake Charles, LA**







CHAPTER 4

EXAMPLES

4.0 INTRODUCTION

This chapter contains six examples of array and system performance calculations and demonstrates use of the information of Chapters 2 and 3 and the Appendix. Data on photovoltaic modules are from actual manufacturers' specification sheets. Factors such as location, season, and load profile vary from one example to another to illustrate diverse (though fictitious) applications. Examples 1 to 5 are single month calculations. Example 6 shows how to obtain an annual performance estimate and includes completed worksheets, while Example 7 compares a result using this Guide's method with that from another approach. Table 4.1 summarizes the Examples.

Table 4.1

Summary of Examples

Example	Location	Month	Load Profile	Application	QE/L	B/Aη*	F	Demonstration
1	Harrisburg, PA	OCT	Sinusoidal #15.3	Residential Load Center	0.77	20.1	0.63	Fundamentals of procedure
2	Savannah, GA	APR	Unimodal #1	Bank	0.49	0	0.42	KT from another source, utility feedback
3	Honolulu, HI	FEB	Constant/ Sinusoidal #12.2	Printing Shop	0.65	11.2	0.50	Non-optimum tilt, not standard load
4	St. Louis, MO	AUG	Bimodal #3	Service Station	0.70 to 0.75	6.1 to 7.0	0.61 to 0.63	Variable tilt
5	Flagstaff, AZ	NOV	Unimodal #6	Lumber Mill	0.21 to 0.83	10.0	0.21 to 0.60	Variable A, B
6	Oakland, CA	All year	Constant	Post Office	0.16 to 0.72	5.2 to 10.0	0.16 to 0.52	12 month and annual calculations
7	Madison, WI	JAN	Constant	(Unknown)	0.70 0.77	17.4	0.56 0.59	Comparison of Methods

*[Wh/(m²·%)]

4.1 EXAMPLE 1: Harrisburg, PA (latitude 40.2 N), October

Chapter 2 Calculations:

Step 1: Manufacturer's data for the photovoltaic modules to be used include the max-power current output equal to 1.83 amps at 14.19 volts when the insolation is 0.8 kW/m². The area of each module is 0.36 m². Then from eq. (2.3)

$$\eta_r = \frac{(1.83A)(14.19V)}{(0.36m^2)(0.8kW/m^2)} \cdot \frac{1kW}{1000W} \cdot 100\% = 9.02\%.$$

This is at a stated cell (reference) temperature, T_r, of 47 C.

Step 2: The module specification sheets give insufficient information to calculate β. Because the cells are silicon, use $\beta = 0.0045\ C^{-1}$.

Step 3: The module data give NOCT = 47 C at 0.8kW/m² and T_a = 20 C, with a wind speed of 1 m/s.

Step 4: The two power conditioning components in this case are assumed to be a max-power tracker and an inverter. The assumed manufacturer estimates their efficiencies to be 98% and 90% respectively. Then the overall power conditioning efficiency is

$$\eta_{pc} = 0.98 \cdot 0.90 \cdot 100\% = 88.2\%.$$

Step 5: The map on page A-2 indicates that calculations for Harrisburg should use the Wilkes-Barre, PA solar/meteorological data on page A-54 of Table I.

Step 6: From Table II, $s_M = 40.2° + 10° = 50.2°$. In order to maximize array output during October, we set $s = 50.2°$.

Step 7: From the Wilkes-Barre data for October, WS = 3 m/s. The corrected WS = 2/3 · 3 = 2 m/s. Table I also lists KT = 0.455, TM = 11 C, and for a tilt of approximately 50°, QS/A = 3.73 kWh/m².

Step 8: $|s-s_M| = 0$.

Step 9: For the given NOCT information, start at 47 C on axis A3 in Fig. 2.1. Continuation through the chart using the above WS, KT, $|s-s_M|$, and TM yields T_c = 29 C.

Step 10: From eq. (2.2),

$$\eta = 9.02\%\ [1-0.0045(29-47)] = 9.75\%.$$

Step 11: From eq. (2.5),

$$QE/A = \frac{88.2}{100} \cdot \frac{9.75}{100} \cdot 3.73 = 0.32\ kWh/m^2.$$

Chapter 3 Calculations:

Step 1: Select an array area $A = 720\ m^2$ (thus requiring 200 of the $0.36\ m^2$ modules) and storage capacity $B = 140{,}000$ Wh.

Step 2: η and QE/A are given above in Steps 10 and 11, respectively.

Step 3: $(QS/A)_{lat} = 3.69\ kWh/m^2$.

Step 4: The monthly average daily electrical load, L, is estimated to be 300 kWh.

Step 5: From eq. (3.2),

$$QE/L = 0.32 \cdot \frac{1}{300} \cdot 720 = 0.77,$$

and from eq. (3.3),

$$B/A\eta = \frac{1}{9.75} \cdot 140{,}000 \cdot \frac{1}{720} \cdot \frac{3.69}{3.73} \cdot \frac{90}{88.2} = 20.1\ Wh/(m^2 \cdot \%).$$

Step 6: Suppose that the load is a residential load center (several houses), with a sinusoidal shape, a peak at around 3 PM and an amplitude-to-mean ratio of about 0.3. The key on pages A-59 to A-62 clearly suggests using the sinusoidal #15.3 performance graphs on page A-76 in Table III.

Step 7: October is a fall month. For $QE/L = 0.77$ and $B/A\eta = 20.1\ Wh/(m^2 \cdot \%)$, the Spring-Fall graph on page A-76 shows F to be 0.65 or 65%.

720m² of array area and 140,000 Wh of utilizable storage capacity will thus provide 65% of the given load in Harrisburg in October. ''Dumping'' of excess energy at certain times and storage inefficiencies cause F to be less than the potential solar fraction of $QE/L = 0.77$.

4.2 EXAMPLE 2: Savannah, GA (latitude 32.1 N), April

Chapter 2 Calculations:

Step 1: In this example the module specifications list $I_{mp} = .551$ A and $V_{mp} = 16.2$ V at $(QS/A)_i = 100\ mW/cm^2$. The dimensions of each module are 287 mm x 502 mm. Therefore,

$$A = 287mm \cdot 502mm \cdot \frac{1cm^2}{100mm^2} = 1440.7cm^2$$

and by eq. (2.3)

$$\eta_r = \frac{(.551A)(16.2V)}{(1440.7cm^2)(100mW/cm^2)} \cdot \frac{1000mW}{1W} \cdot 100\% = 6.18\%.$$

The reference cell temperature, T_r, is 28 C.

Step 2: With insufficient manufacturer's information to calculate β, and with the module comprised of silicon cells, use $\beta = 0.0045\ C^{-1}$.

Step 3: No NOCT data for this particular module are given in the spec sheets, but it is given that $T_{cell} = 40$ C when QS/A = 80 mW/cm² and $T_a = 28$ C. Since a cell temperature, ambient temperature and an insolation are given, eq. (2.1) yields

$$U_L/\alpha = \frac{80mW \cdot cm^2}{40C-28C} \cdot \frac{1kW}{10^6mW} \cdot \frac{10^4cm^2}{1m^2} = 0.067\ kW/(m^2 \cdot C)$$

Step 4: Assume that the same types of power conditioning components are used in this application as in Example 1. Then $\eta_{pc} = 88.2\%$.

Step 5: According to the location of Savannah and the map on page A-2, data from Tallahassee (page A-51) should be used. But suppose it is known from another source that the long term KT for Savannah in April is 0.530. The corresponding value for Tallahassee in Table I, 0.573, is considerably higher. Use of the Tallahassee data for QS/A could then lead to an overestimate of array output for this case.

From page A-2 and the list of cities on page A-6, Meridian, MS has approximately the same latitude as Savannah and its proximity suggests that it may have similar KT values. In Table I, page A-35, the KT for Meridian in April is .527. Since this is close to the known Savannah value of .530, QS/A data from Meridian can be used in this example.

The preceding discussion demonstrates how locally varying insolation or weather patterns can invalidate direct use of the locational maps on pages A-1 to A-3. Specifically, if the KT for a particular location is not within about 0.03 of the value in Table 1 for the suggested station, then QS/A data from a station of nearly the same latitude and for the same month may be used, if its KT is a better match to the known value.

Step 6: From Table II, $s_M = 32.1-10 = 22.1$ degrees. We select s = 30 degrees.

Step 7: Although the Meridian QS/A data will be used, WS and TM should still be obtained from the Tallahassee listings in Table I. For April, WS is given as 3 m/s, and the corrected value is 2 m/s. TM is 19 C. KT is known to be .530, and QS/A = 5.32 kWh/m² (from Meridan tables, page A-35).

<u>Step 8</u>: $|s-s_M| = |30-22.1| = 7.9$ degrees

<u>Step 9</u>: To determine T_c, begin at $U_L/\alpha = 0.067$ kW/(m²·C) on axis B in Fig. 2.1. Proceeding through the chart using the above KT, $|s-s_M|$, and TM, gives $T_c = 28$ C.

<u>Step 10</u>: From eq. (2.2),

$$\eta = 6.18\% \, [1-0.0045(28-28)] = 6.18\%$$

<u>Step 11</u>: From eq. (2.5),

$$QE/A = \frac{88.2}{100} \cdot \frac{6.18}{100} \cdot 5.32 = 0.29 \text{ kWh/m}^2.$$

<u>Chapter 3 Calculations</u>:

<u>Step 1</u>: Suppose A = 432 m² (i.e., 3000 of the 0.144 m² modules) and in this example let there be no on-site storage. Assume that array output which is in excess of the load at any given time is fed back into the electrical grid. (The utility can be thought of as furnishing the storage medium in this case.)

<u>Step 2</u>: η and QE/A have been determined above.

<u>Step 3</u>: $(QS/A)_{lat} = 5.28$ kWh/m² (interpolated from Meridan data) but will not be needed since B = 0.

<u>Step 4</u>: L is estimated to be 256 kWh.

<u>Step 5</u>: From eq. (3.2),

$$QE/L = 0.29 \cdot \frac{1}{256} \cdot 432 = 0.49,$$

and $B/A\eta = 0$.

<u>Step 6</u>: Assume that the load profile resembles that of many businesses (e.g., banks and real estate offices) and is approximated by the unimodal #1 profile on pages A-61 and A-85.

<u>Step 7</u>: April is a spring month. QE/L = 0.49 and $B/A\eta = 0$ in the Spring-Fall graph on page A-85 yield F = 0.42.

In this example 42% of the electrical load is supplied directly by the array. The remaining array output, which is fed back to the utility on an average day, is equal to

$$[(QE/L)-F] \cdot L = (0.49-0.42) \cdot 256 = 17.9 \text{ kWh}.$$

4.3 EXAMPLE 3: Honolulu, HI (latitude 21.3 N), February

Chapter 2 Calculations:

Step 1: Specifications for the selected modules state that the max-power output is 40 watts when the insolation is 1.0 kW/m^2. The area of each array module is 0.403 m^2. Therefore, by eq. (2.3)

$$\eta_r = \frac{40W}{(1.0kW/m^2)(0.403m^2)} \cdot \frac{1kW}{1000W} \cdot 100\% = 9.93\%.$$

The cell temperature under these conditions (the reference temperature, T_r) is 28 C.

Step 2: The specifications also list a module output of 36.6 watts when the insolation is once again 1.0 kW/m^2 but when the cell temperature is 50 C. The given information is sufficient to calculate the temperature coefficient β.

First, another efficiency, η_2, is determined from the second set of data and eq. (2.3):

$$\eta_2 = \frac{36.6W}{(1.0kW/m^2)(0.403m^2)} \cdot \frac{1kW}{1000W} \cdot 100\% = 9.08\%$$

T_2 is 50 C, and from step 1, η_1 = 9.93% and T_1 = 28 C.
Now β is determined by substitution in eq. (2.4):

$$\beta = \frac{1-(9.08/9.93)}{50-28\ C} = 0.0039\ C^{-1}$$

Step 3: For this module, it is specified that NOCT=48 C at 0.8 kW/m^2. The environmental conditons of the NOCT test are unspecified, but it may be assumed that they are the most common ones, namely T_a = 20 C and a wind speed of 1 m/s.

Step 4: A max-power tracker with 96% efficiency and an 87% efficient inverter are to be used. Then

$$\eta_{pc} = 0.96 \cdot 0.87 \cdot 100\% = 83.5\%.$$

Step 5: Honolulu data, according to the map on page A-1, can be found on page A-30 of Table I.

Step 6: From Table II, $s_M = 21.3° + 18° = 39.3°$. Suppose that the array tilt is not adjusted to be the optimum every month, and in this case it is equal to the best value for the prior month, January. Then from Table II,

$$s = 21.3° + 29° = 50.3°.$$

Step 7: From Table I,

$$WS = 2/3 \cdot 5 = 3.5 \text{ m/s},$$

KT = 0.540, TM = 22 C, and by interpolation between the insolation values for tilts of 50° and 60°,

$$QS/A = 5.09 - (5.09-4.86) \cdot \frac{(50.3-50)}{(60-50)} = 5.08 \text{ kWh/m}^2.$$

Step 8: $|s-s_M| = |50.3°-39.3°| = 11°$.

Step 9: The NOCT data for this array are almost identical to those of Example 1. Again begin at axis A3 in Fig. 2.1, this time with NOCT = 48 C. Moving through the chart eventually yields T_c = 42 C. Note that use of the optimum tilt line, $|s-s_M|=0$, makes a difference of only about 0.5 C in T_c. In general, T_c changes only slightly when $|s-s_M|$ varies between 0° and 20°. The small improvement in cell temperature caused by using a non-optimum tilt must be traded off against the slight decrease in insolation (QS/A) when the tilt is other than the ideal value. This concept will be explored further in Example 4.

Step 10: From eq. (2.2),

$$\eta = 9.93\% \,[1-0.0039\,(42-28)] = 9.4\%.$$

Step 11: From eq. (2.5),

$$QE/A = \frac{83.5}{100} \cdot \frac{9.4}{100} \cdot 5.08 = 0.40 \text{ kwh/m}^2.$$

Chapter 3 Calculations:

Step 1: Use 700 of the 0.403m² modules, so that A = 282.1m². Also choose B = 27.9 kWh.

Step 2: η and QE/A have been calculated above.

Step 3: $(QS/A)_{lat}$ = 5.04 kWh/m² by interpolation between the 20 and 30° values.

Step 4: L is estimated to be 174 kWh.

Step 5: From eq. (3.2),

$$QE/L = 0.40 \cdot \frac{1}{174} \cdot 282.1 = 0.65$$

and from eq. (3.3),

$$B/A\eta = \frac{1}{9.41} \cdot 27.9 \cdot \frac{1}{282.1} \cdot \frac{1000\text{Wh}}{1\text{kWh}} \cdot \frac{5.04}{5.08} \cdot \frac{90}{83.5} = 11.2\ \text{Wh/(m}^2\cdot\%)$$

Step 6: Consider the load profile to be typical of a printing or publishing shop. The curve is nearly constant but has a slight peak at noon and a small minimum at midnight. According to the convention of this Guide it can be characterized as a sinusoidal #12.1 profile.

This is not one of the curves shown in the key on pages A-59 to A-62, but a good system performance estimate can be obtained by averaging the results of using profiles which ''bracket'' the given one in appearance. In this case averaging of the solar fractions from the constant and sinusoidal #12.2 graphs (on pages A-64 and A-70) is appropriate.

Step 7: February is a spring month. The above QE/L and $B/A\eta$ in the constant, Spring-Fall graph yield $F = 0.51$. The same quantities entered in the sinusoidal #12.2 Spring-Fall graph give $F = 0.52$. These two results are essentially identical, precluding the need to average them.

4.4 EXAMPLE 4: St. Louis, MO (latitude 38.8 N), August

Chapter 2 Calculations:

Step 1: In this example we design a system using a module comprised of cadmium sulfide cells. The manufacturer specifications give 65 watts as the max-power output when the insolation is 100 mW/cm². Each module is 262 cm x 85 in size, so that

$$A = 262\ \text{cm} \cdot 85\ \text{cm} = 22270\ \text{cm}^2.$$

Then by eq. (2.3)

$$\eta_r = \frac{65\text{W}}{(22270\text{cm}^2)(100\text{mW/cm}^2)} \cdot \frac{1000\text{mW}}{1\text{W}} \cdot 100\% = 2.92\%.$$

The reference temperature, T_r, is 28 C.

Step 2: Insufficient information is included in the specifications in order to calculate β. Contacting the manufacturer disclosed that $\beta = 0.006\ \text{C}^{-1}$.

Step 3: The manufacturer also provided the NOCT of 43 C at 0.8 kW/m² when $T_a = 20$ C and the wind speed is 1 m/s.

<u>Step 4</u>: If the same power conditioning equipment as in Example 3 is used, then η_{pc} = 83.5%.

<u>Step 5</u>: The key map on page A-2 indicates that data for Kansas City should be used and that it can be found on page A-31.

<u>Step 6</u>: From Table II, s_M = 38.8-10 = 28.8 degrees. In this example the effects of varying array tilt are investigated by letting s = 10, 20, 30, 40, and 50°. These values and the results which follow are displayed in Table 4.2.

Table 4.2

Effects of Tilt Variation, Example 4

s	QS/A, kWh/m²	$\lvert s-s_M \rvert$	T_c,C	η, %	QE/A, kWh/m²	QE/L	B/Aη Wh/(m²·%)	F
10	6.05	18.8	43	2.60	0.13	0.75	6.2	0.63
20	6.09	8.8	44	2.64	0.13	0.754	6.1	0.63
30	5.99	1.2	44	2.64	0.13	0.75	6.2	0.63
40	5.76	11.2	44	2.64	0.13	0.75	6.4	0.63
50	5.41	21.2	43	2.60	0.12	0.70	7.0	0.61

<u>Step 7</u>: From Table I, the corrected wind speed is WS = 2/3 · 4 = 2.7 m/s, KT = 0.579, and TM = 26 C. The QS/A values corresponding to the selected tilts are listed in Table 4.2.

<u>Step 8</u>: Table 4.2 gives the five values of $\lvert s-s_M \rvert$.

<u>Step 9</u>: The NOCT specifications mean starting with axis A3 in Fig. 2.1, at NOCT = 43 C. Variation of the array tilt does not affect use of the chart until the $\lvert s-s_M \rvert$ lines are reached. After that intersection, five slightly different paths (corresponding to the five values of $\lvert s-s_M \rvert$ in Table 4.2) eventually lead to five T_c's. These are also given in Table 4.2; note they are within about 1 C of each other.

<u>Step 10</u>: Use of eq. (2.2) yields the five values of η in Table 4.2. For example, for T_c = 43 C,

$$\eta = 2.92\% \, [1-0.006(43-28)] = 2.60\%.$$

Step 11: Similarly, five values of QE/A follow from use of eq. (2.5). For the s = 10° case,

$$QE/A = \frac{83.5}{100} \cdot \frac{2.60}{100} \cdot 6.05 = 0.13 \text{ kWh/m}^2.$$

Chapter 3 Calculations:

Step 1: Select A = 446 m², requiring 200 of the 2.23 m² modules, and let B = 7000 Wh.

Step 2: η and QE/A are listed in Table 4.2.

Step 3: $(QS/A)_{lat}$ = 5.79 kWh/m² by interpolation.

Step 4: Let L be equal to 77 kWh.

Step 5: Results for QE/L and B/Aη, from use of eqs. (3.2) and (3.3), are in Table 4.2.

Step 6: The application in this example is an automobile repair shop. A typical average daily load curve resembles the bimodal #3 profile. From the index on pages A-61, 62, the performance graphs are on page A-104.

Step 7: August is a fall month. Entering the five sets of QE/L and B/Aη into the bimodal #3 Spring-Fall graph yields the solar fractions in Table 4.2.

In this example, varying the tilt by 40° leads to a 0.02 variation in F. In this case it would probably be wise to explore the effect of tilt on winter performance before selecting a final value.

4.5 EXAMPLE 5: Flagstaff, AZ (latitude 35.0 N), November

Step 1: In this example the same kind of module will be used as in Example 1. Thus η_r = 9.02% and T_r = 47 C.

Step 2: Assume β = 0.0045 C^{-1}.

Step 3: NOCT = 47 C at 0.8 kW/m², T_a = 20 C and 1 m/s wind speed

Step 4: Also use the same power conditioner as in Example 1, so that η_{pc} = 88.2%.

Step 5: The page A-2 map shows that the data for Bryce Canyon on page A-14 are appropriate.

Step 6: From Table II, s_M = 35.0°+23° = 58.0°. Also, s is chosen to be s_M.

Step 7: From Table I, the corrected wind speed is WS=2/3·3=2.0 m/s, KT = .658, and TM = -1 C. Without formally carrying out the mathematical interpolating, it should be clear that QS/A = 5.68 kWh/m².

Step 8: $|s-s_M| = 0$.

Step 9: With a start at NOCT = 47 C on axis A3 in Fig. 2.1, progression through the chart yields T_c = 23 C.

Step 10: From eq. (2.2),

$$\eta = 9.02\% \,[1-0.0045(23-47)] = 9.99\%.$$

Step 11: From eq. (2.5),

$$QE/A = \frac{88.2}{100} \cdot \frac{9.75}{100} \cdot 5.98 = 0.51 \text{ kWh/m}^2.$$

Chapter 3 Calculations:

Step 1: In this example, the array area and storage capacity are varied. Specifically, suppose 400, 800, 1200, and 1600 of the 0.36 m² modules are used, resulting in A = 144, 288, 432, and 576 m². If B is varied such that B/Aη is to remain constant and equal to 10, then B = 16.2, 32.4, 48.5, and 64.7 kWh.

Step 2: QE/A and η are given above.
Step 3: $(QS/A)_{lat}$ = 5.20 kWh/m².

Step 4: L is estimated to be 354 kWh.

Step 5: Use of eq. (3.2), for the four array areas selected in Step 1, results in the four values of QE/L given in Table 4.3. The values of B were chosen in Step 1 such that B/Aη equals 10.0 in all cases.

Step 6: In this example the application is a lumber mill, for which the unimodal #6 load profile may be representative of the load curve. The relevant performance graphs are on page A-90.

Step 7: November is a winter month. The values of QE/L listed in Table 4.3 and B/Aη = 10, when entered into the unimodal #6 Winter performance graph, give the solar fractions in Table 4.3.

Table 4.3

Effects of A and B Variation, Example 5

$A[m^2]$	B[kWh]	QE/L	F
144	16.2	0.21	0.21
288	32.4	0.41	0.38
432	48.5	0.62	0.51
576	64.7	0.83	0.60

4.6 EXAMPLE 6: Oakland, CA (latitude 37.7 N), All Year

In this example, performance estimates are made for all 12 months and then for the entire year. The completed Worksheets 1 and 2 of Table 4.4 accompany this example.

Chapter 2 Calculations:

Step 1: For this example, module specifications give 30 watts as the max-power output when the insolation is 100 mW/cm^2. The dimensions of each module are 121.7 cm x 30.2 cm, giving an array area of

$$A = 121.7cm \cdot 30.2cm = 3675.3cm^2.$$

Then by eq. (2.3)

$$\eta_r = \frac{30W}{(3675.3cm^2)(100mW/cm^2)} \cdot \frac{1000mW}{1W} \cdot 100\% = 8.16\%.$$

The reference temperature, T_r, is 45 C.

Step 2: The specifications also include a max-power output of 33 watts at an insolation level of 100 mW/cm^2 (same as above) and a cell temperature of 28 C.

This second set of data yield a second array efficiency, via eq. (2.3):

$$\eta_2 = \frac{33W}{(3675.3cm^2)(100mW/cm^2)} \cdot \frac{1000mW}{1W} \cdot 100\% = 8.98\%.$$

TABLE 4.4 Worksheets for Example 6

WORKSHEET 1

Location Oakland, CA — T_r = 45 [C] — β = 0.0059 [C^{-1}]

Latitude 37.7 N — η_r = 8.16 [%] — η_{pc} = 88.2 [%]

NOCT = 45 [C] — 1.0 kW/m², T_a = 20 [C] — or — U_L/α = ______ kW/(m²·C)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Month	WS [m/s] from Table I	KT from Table I	s_M from Table II	s designer's choice	$= \|s-s_M\|$ = |C4−C3|	TM [C] from Table I	T_c from Fig. 2.1	η[%] from Eq. 2.2	QS/A [kWh/m²]	QE/A [kWh/m²] $= \frac{\eta_{pc}}{100}\cdot\frac{C8\cdot C9}{100}$
JAN	2.	.497	66.7	37.7	29	9	23	9.22	3.56	0.29
FEB	2.	.548	55.7	"	18	11	26	9.07	4.55	0.36
MAR	3.	.596	40.7	"	3	12	27	9.03	5.62	0.45
APR	3.	.631	27.7	"	10	13	28	8.98	6.31	0.50
MAY	3.	.641	15.7	"	22	14	29	8.93	6.42	0.51
JUN	3.	.648	12.7	"	25	16	31	8.83	6.45	0.50
JUL	3.	.653	13.7	"	24	17	31	8.83	6.52	0.51
AUG	3.	.634	27.7	"	10	17	32	8.79	6.36	0.49
SEP	3.	.632	35.7	"	2	17	32	8.79	6.16	0.48
OCT	2.	.584	47.7	"	10	16	32	8.79	5.16	0.40
NOV	2.	.534	60.7	"	23	13	25	9.12	4.04	0.32
DEC	2.	.496	67.7	"	30	9	22	9.27	3.40	0.28

WORKSHEET 1

WORKSHEET 2

A = 147.2 [m²] (designer's choice)

B = 5000 [Wh] (designer's choice)

	C11	C12	C13	C14	C15	C16	C17	C18	C19
Month	d	QE/A [kWh/m²] from WORKSHEET 1	η[%] from WORKSHEET 1	$(QS/A)_{1st}$ [kWh/m²] from Table 1	L [kWh]	QE/L $= \frac{C12\cdot A}{C15}$	B/Aη [Wh/m²%] $= \frac{B}{A\cdot C13}\cdot\frac{C14}{C9}\cdot\frac{90}{\eta_{pc}}$	F from C16, C17 in TABLE III	L·d [kWh] = C11·C15
JAN	31	0.29	9.22	3.56	260	0.16	3.76	0.16	8060
FEB	28	0.36	9.07	4.55	243	0.22	3.82	0.21	6804
MAR	31	0.45	9.03	5.62	230	0.29	3.84	0.26	7130
APR	30	0.50	8.98	6.31	187	0.39	3.86	0.33	5610
MAY	31	0.51	8.93	6.42	155	0.48	3.88	0.42	4805
JUN	30	0.50	8.83	6.45	102	0.72	3.93	0.51	3060
JUL	31	0.51	8.83	6.52	118	0.64	3.93	0.49	3658
AUG	31	0.49	8.79	6.36	135	0.53	3.94	0.39	4185
SEP	30	0.48	8.79	6.16	129	0.55	3.94	0.36	3870
OCT	31	0.40	8.79	5.16	141	0.42	3.94	0.35	4371
NOV	30	0.32	9.12	4.04	181	0.26	3.80	0.23	5430
DEC	31	0.28	9.27	3.40	202	0.20	3.74	0.19	6262

Annual F $= \frac{\Sigma(F\cdot L\cdot d)}{\Sigma(L\cdot d)} = \frac{\Sigma(C18\cdot C19)}{\Sigma C19}$ = 0.30

WORKSHEET 2

It is also known that T_2 = 28C, and from Step 1, η_1 = 8.16% and T_1 = 45 C. Therefore, by eq. (2.4)

$$\beta = \frac{1-(8.98/8.16)}{28-45\ C} = 0.0059\ C^{-1}.$$

__Step 3__: It is given that NOCT = 45 C at 100 mW/cm² (i.e., 1kW/m²). As in Example 3, the ambient conditions are unspecified, so they are assumed to be T_a = 20 C and 1 m/s wind speed.

__Step 4__: The power conditioner is the same as in Examples 1 and 2, and η_{pc} = 88.2%.

__Step 5__: The key map on page A-2 shows that the data in this example are on page A-38.

__Step 6__: The optimum array tilts, based upon Table II and ϕ = 37.7°, are listed in Table 4.4. Assume that the tilt is always 37.7°.

__Step 7__: The monthly WS (corrected to 0.6 of the tabulated value), KT, TM, and QS/A (on the appropriate tilt for each month) are given in Table 4.4.

__Step 8__: With s always equal to ϕ, $|s-s_M|$ is simply the magnitude of the number added to or subtracted from ϕ in Table II.

__Step 9__: Calculation of T_c for each month always begins at axis A1 in Fig. 2.1, at NOCT = 45 C. The values of WS, KT, $|s-s_M|$, and TM then vary from month to month. The resulting T_c's are listed in Table 4.4.

__Step 10__: The corresponding monthly values of η are given in C8 of Table 4.4.
__Step 11__: η_{pc} = 88.2% and the calculated values of η and QS/A yield the QE/A's in Table 4.4.

__Chapter 3 Calculations__:

__Step 1__: Select A = 147.2 m², requiring 400 of the 0.368 m² modules, and let B = 5000 Wh.

__Step 2__: QE/A and η are carried over to Worksheet 2 from Worksheet 1.

__Step 3__: Because the array tilt angle is always equal to the latitude angle, the $(QS/A)_{lat}$ values of C14 are identical to the QS/A values of C9.

__Step 4__: Assume that the average daily loads for the 12 months are as given in Worksheet 2 of Table 4.4.

Step 5: The resulting values of QE/L and $B/A\eta$ are listed in Table 4.4. Note that the tilt correction factor, $(QS/A)_{lat}/(QS/A)$, is equal to 1 for every month, since the array is always tilted at the latitude angle.

Step 6: The application in this example is a Post Office for which the load is approximately constant throughout the day. The performance graphs are on page A-64 of Table III.

Step 7: The resulting monthly solar fractions are given in Table 4.4.

Step 8: The products of the average daily load and number of days each month are listed in C19 of Table 4.4.

Step 9: When the results in C18 and C19 of Table 4.4 are combined and summed, it is found that

$$\sum(F \cdot L \cdot d) = \sum(C18 \cdot C19) = 19658$$

$$\sum(L \cdot d) = \sum C19 = 63245,$$

and therefore the annual solar fraction is

$$F = \frac{19658}{63245} = 0.31.$$

4.7 EXAMPLE 7

This example compares the simplified procedure developed in Reference 11 with the procedure outlined in this Guide. Reference 9 makes use of the ''utilizability'' concept which is quite general, but the system analysis is restricted to a constant load profile. The data given in the example problem in Reference 11 are:

Location	Madison, WI (ϕ = 43)
Month	January
Tilt	$s = 23°$
Array Area	$A = 1\ m^2$
Array Loss Coefficient	$U_L = 0.02\ kW/(m^2 \cdot C)$
Solar Absorptance	$\alpha = 0.95$
Reference Efficiency	η_r = 12 percent
Reference Temperature	$T_r = 0\ C$
Temperature Coefficient	$\beta = 0.004\ C^{-1}$
Power Conditioner Efficiency	η_{pc} = 90 percent
Average Daily Load	$L = .014(24) = 0.336$ kWh
Storage Capacity	$B = 100(2.17)(0.76)(1) = 165$ Wh

The battery capacity in Wh is slightly larger than that shown in Reference 11 due to the required use of 2.17 volts per cell (see Section 3.2).

According to the key on page A-2, the data for La Crosse, WI on page A-33 should be representative of Madison, WI. From that data:

$$(QS/A)_{23°} = 2.30 \text{ kWh/m}^2$$
$$(QS/A)_{lat} = 2.76 \text{ kWh/m}^2$$
$$KT = 0.44$$
$$TM = -9 \text{ C}$$

Table II on page A-58 gives

$$s_M = \phi + 29 = 43+29 = 72$$

Thus

$$|s-s_M| = |s_M-s| = 72-23 = 49°$$

Figure 2.1 entered at axis B with $U_L/\alpha = 0.21$ and the above $|s_M-s|$ yields

$$T_c = 11 \text{ C}$$

Equation (2.2) then yields

$$\eta = 12[1-0.004(11-0)]$$
$$= 11.5\%$$

This is less than 1% different than the value obtained in the example of Reference 11

QE/L and $B/A\eta$ now need to be computed in order to obtain the solar fraction F. Equation 3.3 yields

$$B/A\eta = (1/11.5) \cdot (165) \cdot (1/1) \cdot [2.76/2.30] \cdot [90/90]$$
$$= 17.2 \text{ Wh/(m}^2\cdot\%)$$

The array insolation in Table I (2.3 kWh/m^2) is somewhat less than the array insolation used in Reference 11 (2.52 kWh/m^2). Therefore, two sets of calculations will be carried out (denoted by the subscripts 1 and 2), to determine the uncertainty in F introduced by those differences. Then eq (3.2) yields:

$$(QE/L)_1 = \left[\frac{90}{100} \cdot \frac{11.5}{100} \cdot (2.30)\right] \cdot (1/0.336) \cdot (1)$$
$$= 0.71$$

$$(QE/L)_2 = \left[\frac{90}{100} \cdot \frac{11.5}{100} \cdot (2.52)\right] \cdot (1/0.336) \cdot (1)$$
$$= 0.78$$

For $B/\eta A$ and $(QE/L)_1$, the winter data on page A-64 of Table III gives:

$F_1 = 0.55$ or 55%.

For $B/\eta A$ and $(QE/L)_2$, the graph for winter on page A-64 of Table III gives:

$F_2 = 0.60$ or 60%.

Reference 11 gives F = 59 percent. Therefore, for the same monthly average daily array insolation ($QS/A = 2.52$ kWh/m², the 2 subscripted variables), both Reference 11 and this Guide give nearly identical results. The 9 percent relative uncertainty in array insolation gives only a 3 percent incremental (5 percent relative) uncertainty in F.

If a comparison is made at B=0 (no battery) then

$F_1 = 0.30$ or 30%

and

$F_2 = 0.31$ or 31%.

Reference 11 would yield F = 31 percent for no storage. Again, for the same array insolation, both Reference 11 and this Guide give nearly identical results.

REFERENCES

1. R.T. Ruegg, Solar Heating and Cooling of Buildings: Methods of Economic Evaluation, US, Dept. of Commerce, NBS Report NBSIR-78-712 (Springfield: NTIS, 1975).

2. S. Young, et. al., Photovoltaic Power Systems Design Handbook, SAND 80-7147 (Albuquerque: Sandia Laboratories, 1980).

3. R.M. Turfler, T.J. Lambarski, R.T. Grant, Design Guidelines for Large Photovoltaic Arrays, SAND 79-7001 (Albuquerque: Sandia Laboratories, 1979).

4. D.L. Evans, W.A. Facinelli, L. P. Koehler, Simulation and Simplified Design Studies of Photovoltaic Systems, SAND 80-7013 (Albuquerque: Sandia Laboratories, 1980).

5. W.H. Hoecker, G.F. Cotton, W.A. Hass, Solar Radiation and Climatic Data for Quasi-Homogeneous Climatic Regions of the United States, ERL ARL-77 (Silver Springs: NOAA Environmental Research Laboratories).

6. NOAA, SOLMET, Volume 1, User's Manual, TD-9724 (Ashville, NC: National Climatic Center, 1978) and NOAA, SOLMET II, Volume 2, Final Report, TD-9724 (Ashville, NC: National Climatic Center, 1979).

7. T. Kusuda and K. Ishii, Hourly Solar Radiation Data for Vertical and Horizontal Surfaces on Average Days in the United States and Canada, US, Dept. of Commerce, NBS Building Science Series 96 (Washington: Government Printing Office, 1977).

8. W.A. Beckman, S.A. Klein and J.A. Duffie, Solar Heating Design (New York: John Wiley and Sons, 1977).

9. G.W. Vinal, Storage Batteries (New York: John Wiley and Sons, 1955).

10. R.A. Whisnant, C.B. Morrison, N.G. Staffa, R.D. Alberts, Application Analysis and Photovoltaic System Conceptual Design for Service/Commercial/Institutional and Industrial Sectors, SAND 79-7020 (Albuquerque: Sandia Laboratories, 1979).

11. M.D. Siegel and W.A. Beckman, ''Simplified Design Methods for Photovoltaic Systems,'' Proceedings of the 1980 Annual Meeting American Section of the International Solar Energy Society, Phoenix (1980).

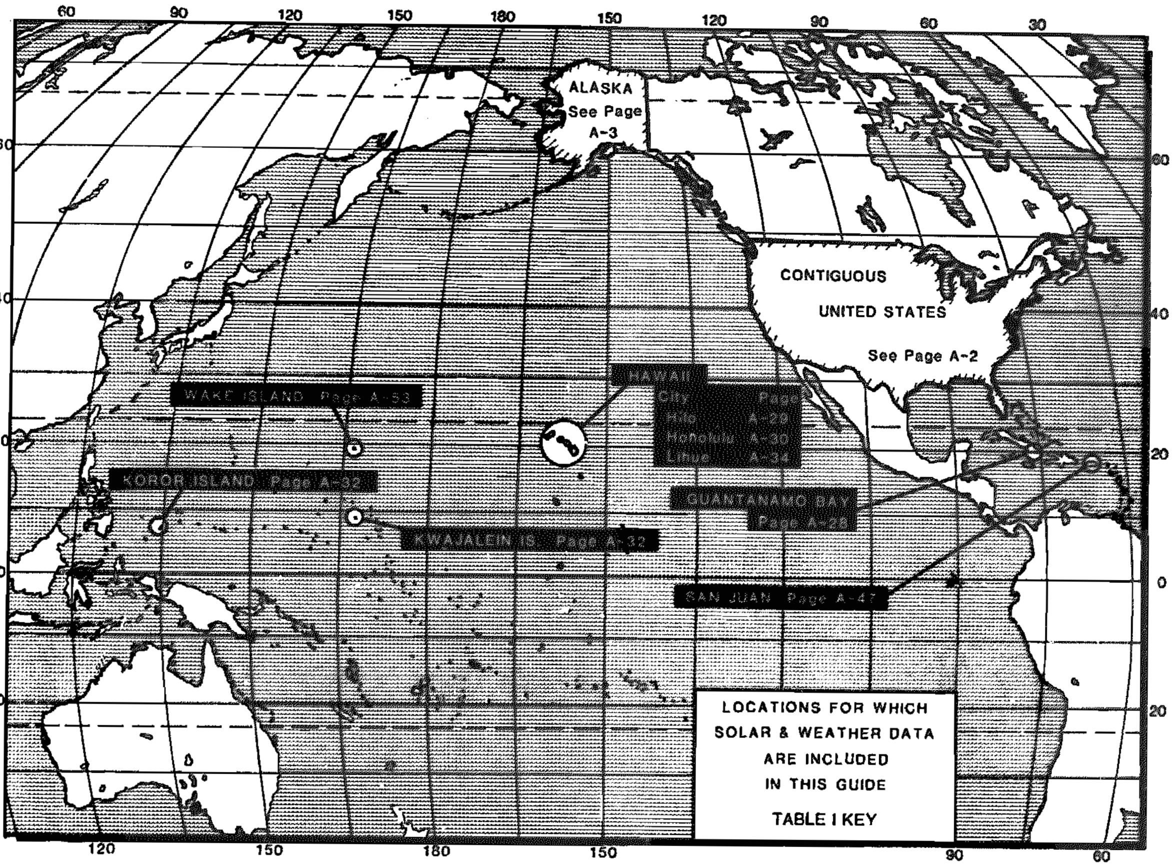
Table I Key

Table II

Table III Key

WORKSHEETS

APPENDIX

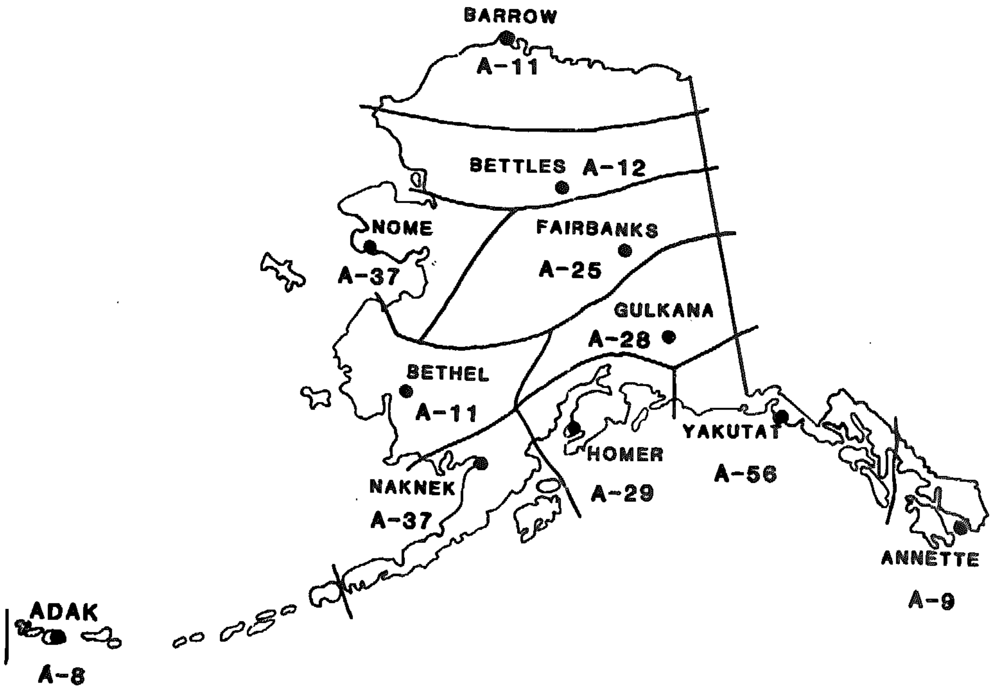


Map Showing United States and Affiliated Regions for Which Solar/Weather Data Are Included in Table I. (The number A-xx shown for each location is the page number in this appendix on which more information can be found)

TABLE I KEY

Map of Contiguous United States Stations and Regions for Which Solar/Weather Data Are Included in Table I. The region boundaries follow county borders. (From Ref. 5) (The number A-xx shown for each location is the page number in this appendix on which more information can be found)

TABLE I KEY



Map of Alaskan Stations of Representative Regions for Which Solar/Radiation Data are Included in Table I. (From Ref. 5) (The number A-xx shown for each station is the page in this appendix on which the data can be found)

TABLE I KEY

Key to TABLE I.
List of Stations for Which Solar Radiation and Climatic Data are Presented in Table I

Listed Alphabetically by Station

Station	State	Lat.	Page
Adak	AK	51.88	A-8
Albuquerque	NM	35.05	A-8
Amarillo	TX	35.23	A-9
Annette	AK	55.03	A-9
Arcata	CA	40.98	A-10
Astoria	OR	46.15	A-10
Barrow	AK	71.30	A-11
Bethel	AK	60.78	A-11
Bettles	AK	66.92	A-12
Binghamton	NY	42.22	A-12
Boise	ID	43.57	A-13
Boston	MA	42.37	A-13
Bryce Canyon	UT	37.70	A-14
Burlington	VT	44.47	A-14
Burns	OR	43.58	A-15
Caribou	ME	46.87	A-15
Casper	WY	42.92	A-16
Charleston	SC	32.90	A-16
Charleston	WV	38.37	A-17
Chattanooga	TN	35.03	A-17
Cleveland	OH	41.40	A-18
Columbia	SC	33.95	A-18
Columbus	OH	40.00	A-19
Cutbank	MT	48.60	A-19
Daggett	CA	34.87	A-20
Dallas	TX	32.85	A-20
Dillon	MT	45.25	A-21
Dodge City	KS	37.77	A-21
Duluth	MN	46.83	A-22
Eagle	CO	39.65	A-22
El Paso	TX	31.80	A-23
El Toro	CA	33.67	A-23
Elko	NV	40.83	A-24
Evansville	IN	38.05	A-24
Fairbanks	AK	64.82	A-25
Fargo	ND	46.90	A-25
Fort Smith	AR	35.33	A-26
Fresno	CA	36.77	A-26
Grand Junction	CO	39.12	A-27
Grand Rapids	MI	42.90	A-27
Guantanamo Bay	CU	19.90	A-28
Gulkana	AK	62.15	A-28
Hilo	HI	19.72	A-29
Homer	AK	59.63	A-29
Honolulu	HI	21.33	A-30
Indianapolis	IN	39.73	A-30
Kansas City	MO	39.12	A-31
Kingsville	TX	27.52	A-31
Koror Is.	PI	7.33	A-32
Kwajalein Is.	PI	8.72	A-32
La Crosse	WI	43.87	A-33
Lake Charles	LA	30.12	A-33
Lihue Kauai	HI	21.98	A-34
Lovelock	NV	40.07	A-34
Memphis	TN	35.05	A-35
Meridian	MS	32.33	A-35
Miles City	MT	46.43	A-36
Missoula	MT	46.92	A-36
Naknek	AK	58.68	A-37
Nome	AK	64.50	A-37
Norfolk	VA	36.90	A-38
Oakland	CA	37.73	A-38
Orlando	FL	28.55	A-39
Pendleton	OR	45.68	A-39
Philadelphia	PA	39.88	A-40
Phoenix	AZ	33.43	A-40
Pocatello	ID	42.92	A-41
Portland	ME	43.65	A-41
Prescott	AZ	34.65	A-42
Red Bluff	CA	40.15	A-42
Redmond	OR	44.27	A-43
Richmond	VA	37.50	A-43
Rochester	NY	43.12	A-44
Rock Springs	WY	41.60	A-44
Roswell	NM	33.30	A-45
Salem	OR	44.92	A-45
Salt Lake City	UT	40.77	A-46
San Angelo	TX	31.37	A-46
San Juan	PR	18.43	A-47
Scotts Bluff	NE	41.87	A-47
Seattle/Tacoma	WA	47.45	A-48
Sheridan	WY	44.77	A-48
Shreveport	LA	32.47	A-49
Sioux City	IA	42.40	A-49
Spokane	WA	47.63	A-50
Springfield	MO	37.23	A-50
Tallahassee	FL	30.38	A-51
Tampa	FL	27.97	A-51
Tonopah	NV	38.07	A-52
Tulsa	OK	36.20	A-52
Wake Is.	PI	19.28	A-53
Wichita	KS	37.63	A-53
Wichita Falls	TX	33.97	A-54
Wilkes-Barre	PA	41.33	A-54
Winslow	AZ	35.02	A-55
Yakima	WA	46.57	A-55
Yakutat	AK	59.52	A-56

Key to TABLE I.
List of Stations for Which Solar Radiation and Climatic Data are Presented in Table I

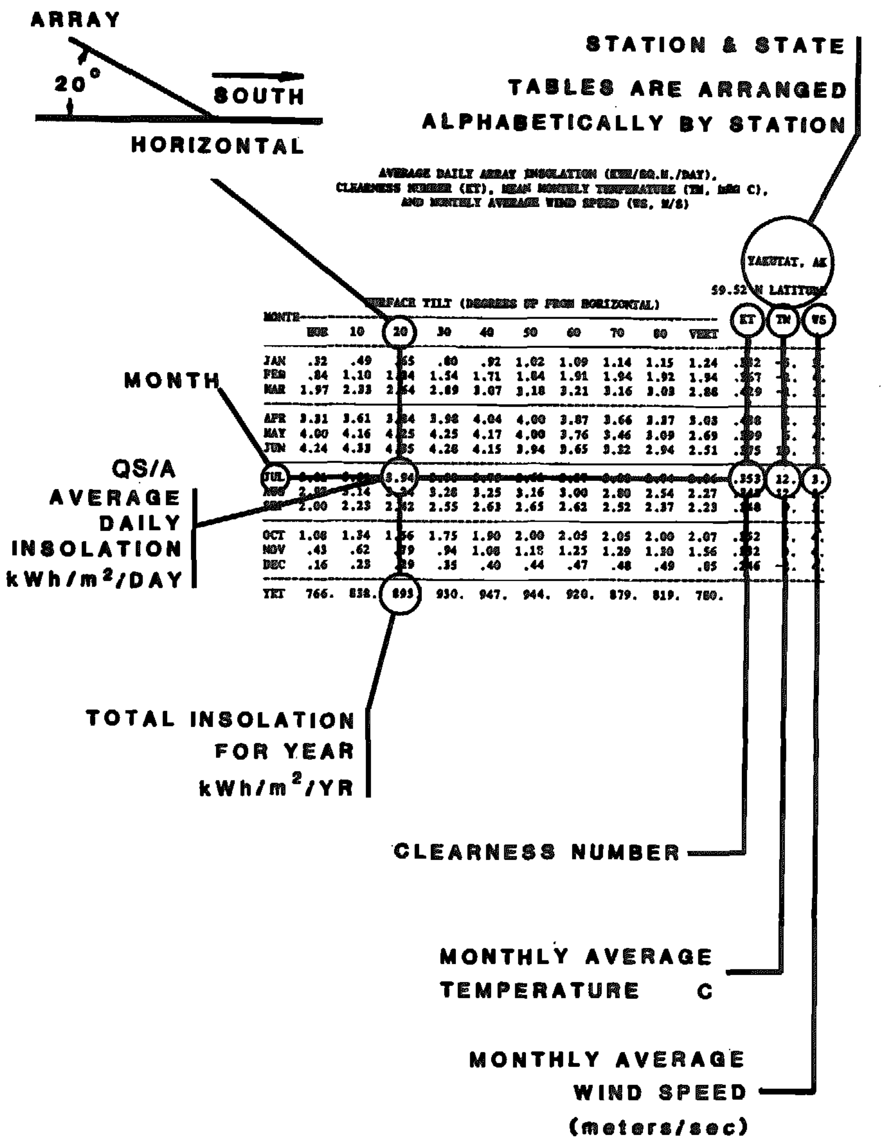
Listed Alphabetically by State

State	Station	Lat.	Page
AK	Adak	51.88	A-8
AK	Annette	55.03	A-9
AK	Barrow	71.30	A-11
AK	Bethel	60.78	A-11
AK	Bettles	66.92	A-12
AK	Fairbanks	64.82	A-25
AK	Gulkana	62.15	A-28
AK	Homer	59.63	A-29
AK	Naknek	58.68	A-37
AK	Nome	64.50	A-37
AK	Yakutat	59.52	A-56
AR	Fort Smith	35.33	A-26
AZ	Phoenix	33.43	A-40
AZ	Prescott	34.65	A-42
AZ	Winslow	35.02	A-55
CA	Arcata	40.98	A-10
CA	Daggett	34.87	A-20
CA	El Toro	33.67	A-23
CA	Fresno	36.77	A-26
CA	Oakland	37.73	A-38
CA	Red Bluff	40.15	A-42
CO	Eagle	39.65	A-22
CO	Grand Junction	39.12	A-27
CU	Guantanamo Bay	19.90	A-28
FL	Orlando	28.55	A-39
FL	Tallahassee	30.38	A-51
FL	Tampa	27.97	A-51
HI	Hilo	19.72	A-29
HI	Honolulu	21.33	A-30
HI	Lihue Kauai	21.98	A-34
IA	Sioux City	42.40	A-49
ID	Boise	43.57	A-13
ID	Pocatello	42.92	A-41
IN	Evansville	38.05	A-24
IN	Indianapolis	39.73	A-30
KS	Dodge City	37.77	A-21
KS	Wichita	37.63	A-53
LA	Lake Charles	30.12	A-33
LA	Shreveport	32.47	A-49
MA	Boston	42.37	A-13
ME	Caribou	46.87	A-15
ME	Portland	43.65	A-41
MI	Grand Rapids	42.90	A-27
MN	Duluth	46.83	A-22
MO	Kansas City	39.12	A-31
MO	Springfield	37.23	A-50
MS	Meridian	32.33	A-35
MT	Cutbank	48.60	A-19
MT	Dillon	45.25	A-21
MT	Miles City	46.43	A-36
MT	Missoula	46.92	A-36
ND	Fargo	46.90	A-25
NE	Scotts Bluff	41.87	A-47
NM	Albuquerque	35.05	A-8
NM	Roswell	33.30	A-45
NV	Elko	40.83	A-24
NV	Lovelock	40.07	A-34
NV	Tonopah	38.07	A-52
NY	Binghamton	42.22	A-12
NY	Rochester	43.12	A-44
OH	Cleveland	41.40	A-18
OH	Columbus	40.00	A-19
OK	Tulsa	36.20	A-52
OR	Astoria	46.15	A-10
OR	Burns	43.58	A-15
OR	Pendleton	45.68	A-39
OR	Redmond	44.27	A-43
OR	Salem	44.92	A-45
PA	Philadelphia	39.88	A-40
PA	Wilkes-Barre	41.33	A-54
PI	Koror Is.	7.33	A-32
PI	Kwajalein Is.	8.72	A-32
PI	Wake Is.	19.28	A-53
PR	San Juan	18.43	A-47
SC	Charleston	32.90	A-16
SC	Columbia	33.95	A-18
TN	Chattanooga	35.03	A-17
TN	Memphis	35.05	A-35
TX	Amarillo	35.23	A-9
TX	Dallas	32.85	A-20
TX	El Paso	31.80	A-23
TX	Kingsville	27.52	A-31
TX	San Angelo	31.37	A-46
TX	Wichita Falls	33.97	A-54
UT	Bryce Canyon	37.70	A-14
UT	Salt Lake City	40.77	A-46
VA	Norfolk	36.90	A-38
VA	Richmond	37.50	A-43
VT	Burlington	44.47	A-14
WA	Seattle/Tacoma	47.45	A-48
WA	Spokane	47.63	A-50
WA	Yakima	46.57	A-55
WI	La Crosse	43.87	A-33
WV	Charleston	38.37	A-17
WY	Casper	42.92	A-16
WY	Rock Springs	41.60	A-44
WY	Sheridan	44.77	A-48

Key to TABLE I.
List of Stations for Which Solar Radiation and Climatic Data are Presented in Table I

Listed Numerically by Latitude

Lat.	Station	State	Page	Lat.	Station	State	Page
7.33	Koror Is.	PI	A-32	40.00	Columbus	OH	A-19
8.72	Kwajalein Is.	PI	A-32	40.07	Lovelock	NV	A-34
18.43	San Juan	PR	A-47	40.15	Red Bluff	CA	A-42
19.28	Wake Is.	PI	A-53	40.77	Salt Lake City	UT	A-46
19.72	Hilo	HI	A-29	40.83	Elko	NV	A-24
19.90	Guantanamo Bay	CU	A-28	40.98	Arcata	CA	A-10
21.33	Honolulu	HI	A-30	41.33	Wilkes-Barre	PA	A-54
21.98	Lihue Kauai	HI	A-34	41.40	Cleveland	OH	A-18
27.52	Kingsville	TX	A-31	41.60	Rock Springs	WY	A-44
27.97	Tampa	FL	A-51	41.87	Scotts Bluff	NE	A-47
28.55	Orlando	FL	A-39	42.22	Binghamton	NY	A-12
30.12	Lake Charles	LA	A-33	42.37	Boston	MA	A-13
30.38	Tallahassee	FL	A-51	42.40	Sioux City	IA	A-49
31.37	San Angelo	TX	A-46	42.90	Grand Rapids	MI	A-27
31.80	El Paso	TX	A-23	42.92	Casper	WY	A-16
32.33	Meridian	MS	A-35	42.92	Pocatello	ID	A-41
32.47	Shreveport	LA	A-49	43.12	Rochester	NY	A-44
32.85	Dallas	TX	A-20	43.57	Boise	ID	A-13
32.90	Charleston	SC	A-16	43.58	Burns	OR	A-15
33.30	Roswell	NM	A-45	43.65	Portland	ME	A-41
33.43	Phoenix	AZ	A-40	43.87	La Crosse	WI	A-33
33.67	El Toro	CA	A-23	44.27	Redmond	OR	A-43
33.95	Columbia	SC	A-18	44.47	Burlington	VT	A-14
33.97	Wichita Falls	TX	A-54	44.77	Sheridan	WY	A-48
34.65	Prescott	AZ	A-42	44.92	Salem	OR	A-45
34.87	Daggett	CA	A-20	45.25	Dillon	MT	A-21
35.02	Winslow	AZ	A-55	45.68	Pendleton	OR	A-39
35.03	Chattanooga	TN	A-17	46.15	Astoria	OR	A-10
35.05	Albuquerque	NM	A-8	46.43	Miles City	MT	A-36
35.05	Memphis	TN	A-35	46.57	Yakima	WA	A-55
35.23	Amarillo	TX	A-9	46.83	Duluth	MN	A-22
35.33	Fort Smith	AR	A-26	46.87	Caribou	ME	A-15
36.20	Tulsa	OK	A-52	46.90	Fargo	ND	A-25
36.77	Fresno	CA	A-26	46.92	Missoula	MT	A-36
36.90	Norfolk	VA	A-38	47.45	Seattle/Tacoma	WA	A-48
37.23	Springfield	MO	A-50	47.63	Spokane	WA	A-50
37.50	Richmond	VA	A-43	48.60	Cutbank	MT	A-19
37.63	Wichita	KS	A-53	51.88	Adak	AK	A-8
37.70	Bryce Canyon	UT	A-14	55.03	Annette	AK	A-9
37.73	Oakland	CA	A-38	58.68	Naknek	AK	A-37
37.77	Dodge City	KS	A-21	59.52	Yakutat	AK	A-56
38.05	Evansville	IN	A-24	59.63	Homer	AK	A-29
38.07	Tonopah	NV	A-52	60.78	Bethel	AK	A-11
38.37	Charleston	WV	A-17	62.15	Gulkana	AK	A-28
39.12	Grand Junction	CO	A-27	64.50	Nome	AK	A-37
39.12	Kansas City	MO	A-31	64.82	Fairbanks	AK	A-25
39.65	Eagle	CO	A-22	66.92	Bettles	AK	A-12
39.73	Indianapolis	IN	A-30	71.30	Barrow	AK	A-11
39.88	Philadelphia	PA	A-40				



TM, WS and Total Radiation on the Horizontal Data for Table I were Taken from Ref. 5. KT and Total Radiation Data on the Tilt were Computed Using the Method of Ref. 7. A ground reflectance of 0.2 was assumed.

KEY for reading TABLE I

TABLE I

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

ADAK, AK

51.88 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.72	.95	1.15	1.33	1.47	1.58	1.64	1.67	1.65	1.59	.344	1.	6.
FEB	1.36	1.66	1.92	2.13	2.29	2.40	2.45	2.44	2.36	2.23	.383	0.	7.
MAR	2.26	2.54	2.77	2.94	3.04	3.07	3.03	2.92	2.75	2.51	.391	1.	7.
APR	3.25	3.46	3.59	3.64	3.62	3.52	3.35	3.11	2.81	2.46	.388	3.	7.
MAY	3.72	3.81	3.84	3.79	3.67	3.47	3.22	2.92	2.57	2.18	.357	5.	6.
JUN	3.73	3.77	3.74	3.65	3.50	3.28	3.02	2.71	2.36	2.01	.327	7.	5.
JUL	3.53	3.58	3.57	3.50	3.36	3.16	2.92	2.64	2.31	1.98	.321	9.	5.
AUG	2.99	3.10	3.15	3.14	3.07	2.94	2.77	2.54	2.27	1.98	.321	10.	6.
SEP	2.39	2.60	2.75	2.85	2.89	2.86	2.77	2.63	2.43	2.20	.351	9.	6.
OCT	1.66	1.95	2.20	2.39	2.53	2.61	2.63	2.58	2.48	2.34	.382	6.	7.
NOV	.97	1.25	1.51	1.73	1.91	2.04	2.12	2.14	2.11	2.06	.388	3.	7.
DEC	.59	.80	.98	1.15	1.28	1.39	1.45	1.48	1.48	1.48	.335	1.	6.
YRT	828.	897.	949.	981.	993.	983.	954.	905.	838.	760.			

ALBUQUERQUE, NM

35.05 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.20	3.90	4.51	5.00	5.36	5.57	5.64	5.56	5.34	5.00	.650	1.	3.
FEB	4.22	4.90	5.45	5.87	6.14	6.25	6.19	5.98	5.61	5.12	.676	4.	4.
MAR	5.58	6.12	6.51	6.75	6.81	6.70	6.42	5.98	5.40	4.71	.694	8.	4.
APR	7.02	7.33	7.45	7.39	7.15	6.74	6.17	5.45	4.61	3.69	.718	13.	5.
MAY	8.00	8.06	7.92	7.59	7.09	6.44	5.64	4.72	3.77	2.79	.734	18.	5.
JUN	8.44	8.37	8.09	7.62	6.99	6.22	5.32	4.34	3.35	2.40	.741	24.	4.
JUL	7.84	7.82	7.62	7.23	6.69	6.02	5.22	4.32	3.42	2.52	.700	25.	4.
AUG	7.22	7.41	7.41	7.23	6.89	6.39	5.75	4.97	4.09	3.20	.701	24.	4.
SEP	6.21	6.68	6.97	7.10	7.04	6.81	6.42	5.86	5.16	4.36	.710	20.	4.
OCT	4.88	5.55	6.08	6.46	6.67	6.71	6.58	6.28	5.81	5.22	.704	14.	4.
NOV	3.57	4.29	4.91	5.40	5.75	5.95	5.99	5.88	5.60	5.20	.674	6.	3.
DEC	2.93	3.62	4.23	4.73	5.10	5.34	5.44	5.40	5.20	4.90	.640	2.	3.
YRT	2105.	2254.	2348.	2384.	2363.	2285.	2152.	1968.	1743.	1491.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

AMARILLO, TX

35.23 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	3.03	3.67	4.22	4.67	5.00	5.19	5.26	5.18	4.97	4.64	.618	2.	6.
FEB	3.91	4.52	5.01	5.37	5.61	5.69	5.64	5.44	5.10	4.65	.629	4.	6.
MAR	5.14	5.62	5.97	6.17	6.21	6.11	5.85	5.45	4.92	4.29	.642	8.	7.
APR	6.36	6.62	6.72	6.66	6.45	6.08	5.58	4.94	4.20	3.39	.652	14.	7.
MAY	6.97	7.02	6.89	6.61	6.19	5.65	4.99	4.22	3.43	2.60	.639	19.	7.
JUN	7.54	7.48	7.25	6.84	6.30	5.64	4.87	4.03	3.17	2.35	.662	24.	6.
JUL	7.19	7.17	6.99	6.64	6.16	5.56	4.85	4.05	3.24	2.43	.641	26.	6.
AUG	6.63	6.79	6.79	6.63	6.32	5.87	5.29	4.60	3.81	3.01	.644	25.	5.
SEP	5.55	5.93	6.17	6.27	6.21	6.00	5.65	5.17	4.56	3.87	.636	20.	6.
OCT	4.43	5.00	5.46	5.77	5.95	5.97	5.85	5.57	5.16	4.64	.642	14.	6.
NOV	3.25	3.88	4.41	4.83	5.12	5.29	5.32	5.21	4.96	4.61	.618	7.	6.
DEC	2.75	3.38	3.93	4.39	4.72	4.94	5.02	4.98	4.80	4.51	.605	3.	6.
YRT	1911.	2042.	2125.	2156.	2137.	2068.	1951.	1788.	1590.	1367.			

ANNETTE IS, AK

55.03 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	.56	.77	.97	1.15	1.29	1.41	1.48	1.52	1.52	1.94	.345	1.	5.
FEB	1.18	1.48	1.75	1.98	2.16	2.29	2.36	2.37	2.32	2.23	.390	2.	5.
MAR	2.26	2.61	2.89	3.11	3.26	3.33	3.32	3.23	3.07	2.85	.427	3.	5.
APR	3.62	3.91	4.11	4.22	4.23	4.15	3.99	3.73	3.40	3.01	.449	6.	5.
MAY	4.64	4.82	4.89	4.88	4.75	4.53	4.22	3.84	3.39	2.89	.453	9.	4.
JUN	4.62	4.71	4.71	4.62	4.45	4.18	3.85	3.47	3.02	2.55	.407	12.	4.
JUL	4.54	4.66	4.68	4.62	4.47	4.22	3.91	3.53	3.10	2.61	.416	14.	4.
AUG	3.67	3.87	3.99	4.02	3.97	3.84	3.63	3.36	3.01	2.63	.405	14.	4.
SEP	2.56	2.84	3.07	3.22	3.30	3.31	3.24	3.10	2.89	2.65	.401	12.	4.
OCT	1.33	1.57	1.78	1.95	2.07	2.15	2.18	2.15	2.07	1.98	.347	8.	5.
NOV	.68	.91	1.12	1.29	1.44	1.55	1.62	1.65	1.64	1.62	.347	4.	5.
DEC	.39	.53	.67	.79	.89	.97	1.02	1.05	1.05	1.06	.301	2.	6.
YRT	916.	996.	1055.	1092.	1105.	1094.	1060.	1004.	927.	852.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

ARCATA, CA

40.98 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.67	2.02	2.32	2.57	2.76	2.87	2.92	2.90	2.80	2.67	.423	8.	3.
FEB	2.49	2.88	3.20	3.44	3.61	3.68	3.67	3.57	3.38	3.15	.468	9.	3.
MAR	3.57	3.91	4.17	4.32	4.38	4.34	4.20	3.96	3.63	3.26	.489	9.	3.
APR	5.00	5.24	5.37	5.37	5.25	5.02	4.67	4.23	3.70	3.12	.533	9.	4.
MAY	5.81	5.90	5.86	5.70	5.40	5.02	4.53	3.95	3.32	2.68	.537	11.	3.
JUN	6.18	6.20	6.08	5.83	5.45	4.99	4.43	3.80	3.14	2.47	.539	13.	3.
JUL	5.70	5.74	5.66	5.45	5.13	4.73	4.24	3.67	3.07	2.46	.508	13.	3.
AUG	4.98	5.13	5.17	5.10	4.91	4.64	4.26	3.80	3.27	2.72	.496	13.	2.
SEP	4.23	4.55	4.77	4.88	4.88	4.77	4.54	4.22	3.80	3.33	.519	13.	2.
OCT	2.95	3.34	3.65	3.88	4.01	4.05	4.00	3.85	3.60	3.31	.486	12.	2.
NOV	1.87	2.22	2.53	2.78	2.96	3.07	3.10	3.06	2.94	2.87	.432	10.	3.
DEC	1.48	1.82	2.11	2.36	2.55	2.67	2.73	2.72	2.65	2.61	.415	8.	3.
YRT	1399.	1491.	1549.	1573.	1561.	1517.	1439.	1329.	1195.	1053.			

ASTORIA, OR

46.15 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.99	1.19	1.37	1.52	1.63	1.71	1.74	1.74	1.69	1.71	.323	5.	4.
FEB	1.71	1.99	2.23	2.42	2.56	2.63	2.64	2.59	2.48	2.34	.381	6.	4.
MAR	2.73	3.01	3.23	3.38	3.45	3.45	3.36	3.20	2.97	2.71	.413	7.	4.
APR	3.95	4.17	4.29	4.32	4.26	4.10	3.87	3.55	3.16	2.74	.442	9.	4.
MAY	5.07	5.19	5.20	5.10	4.89	4.59	4.20	3.74	3.21	2.66	.476	11.	4.
JUN	5.12	5.17	5.11	4.95	4.68	4.34	3.93	3.45	2.93	2.41	.447	14.	4.
JUL	5.51	5.59	5.56	5.41	5.15	4.79	4.35	3.83	3.25	2.67	.494	15.	4.
AUG	4.72	4.91	5.00	4.98	4.85	4.61	4.29	3.88	3.40	2.89	.485	16.	3.
SEP	3.73	4.06	4.31	4.46	4.50	4.44	4.28	4.02	3.67	3.29	.494	15.	3.
OCT	2.25	2.58	2.85	3.06	3.20	3.26	3.25	3.16	2.99	2.80	.426	12.	3.
NOV	1.19	1.43	1.64	1.81	1.94	2.02	2.05	2.04	1.97	1.95	.345	8.	4.
DEC	.82	.99	1.15	1.28	1.38	1.44	1.48	1.48	1.44	1.45	.305	6.	4.
YRT	1152.	1228.	1278.	1300.	1294.	1260.	1201.	1116.	1009.	901.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

BARROW, AK

71.30 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	-26.	5.
FEB	.23	.53	.82	1.09	1.33	1.53	1.68	1.78	1.84	1.84	.484	-29.	5.
MAR	1.55	2.22	2.84	3.38	3.84	4.18	4.42	4.53	4.51	4.37	.595	-27.	5.
APR	3.31	3.86	4.32	4.68	4.92	5.04	5.04	4.91	4.67	4.32	.544	-18.	5.
MAY	3.59	3.78	3.91	3.97	3.96	3.88	3.72	3.49	3.20	2.86	.374	-7.	5.
JUN	4.81	4.93	5.00	5.01	4.92	4.77	4.52	4.18	3.79	3.34	.410	1.	5.
JUL	4.60	4.77	4.89	4.94	4.89	4.76	4.54	4.22	3.85	3.41	.422	4.	5.
AUG	2.69	2.92	3.10	3.21	3.26	3.24	3.15	3.00	2.79	2.55	.355	3.	5.
SEP	1.31	1.56	1.78	1.96	2.09	2.18	2.21	2.19	2.12	2.09	.335	-1.	6.
OCT	.39	.61	.82	1.01	1.17	1.30	1.40	1.45	1.47	1.84	.348	-10.	6.
NOV	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	-19.	6.
DEC	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	-25.	5.
YRT	687.	769.	838.	892.	926.	941.	934.	906.	859.	810.			

BETHEL, AK

60.78 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.30	.53	.74	.94	1.11	1.25	1.35	1.42	1.44	1.43	.390	-16.	6.
FEB	1.00	1.41	1.79	2.12	2.40	2.62	2.76	2.83	2.82	2.74	.481	-15.	6.
MAR	2.33	2.85	3.31	3.69	3.97	4.16	4.23	4.20	4.06	3.81	.532	-12.	6.
APR	3.78	4.19	4.50	4.70	4.80	4.78	4.65	4.42	4.09	3.67	.511	-5.	6.
MAY	4.58	4.81	4.93	4.96	4.89	4.71	4.43	4.09	3.66	3.17	.460	4.	5.
JUN	4.79	4.91	4.95	4.89	4.76	4.52	4.20	3.83	3.38	2.89	.424	10.	5.
JUL	4.06	4.19	4.24	4.20	4.10	3.92	3.65	3.35	2.98	2.57	.378	13.	5.
AUG	2.90	3.07	3.18	3.22	3.20	3.11	2.97	2.77	2.52	2.27	.339	11.	5.
SEP	2.21	2.51	2.77	2.96	3.08	3.13	3.11	3.01	2.85	2.68	.397	7.	5.
OCT	1.17	1.50	1.80	2.05	2.25	2.40	2.49	2.51	2.46	2.54	.406	-1.	5.
NOV	.43	.67	.90	1.11	1.28	1.43	1.53	1.59	1.61	1.91	.388	-8.	6.
DEC	.15	.27	.38	.48	.57	.64	.69	.73	.74	1.11	.304	-15.	6.
YRT	844.	942.	1019.	1075.	1108.	1115.	1096.	1055.	991.	935.			

TABLE I (Continued)
AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

BETTLES, AK
66.92 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.03	.11	.19	.27	.33	.39	.43	.46	.48	.93	.338	-26.	3.
FEB	.54	.93	1.30	1.63	1.91	2.14	2.32	2.42	2.46	2.76	.495	-23.	3.
MAR	1.94	2.57	3.14	3.63	4.03	4.32	4.49	4.54	4.46	4.34	.579	-17.	3.
APR	3.87	4.45	4.92	5.27	5.49	5.57	5.51	5.32	5.01	4.61	.583	-6.	4.
MAY	5.35	5.71	5.96	6.07	6.09	5.95	5.69	5.30	4.83	4.25	.554	6.	3.
JUN	5.85	6.06	6.16	6.16	6.05	5.83	5.48	5.04	4.52	3.92	.514	14.	3.
JUL	4.93	5.14	5.26	5.28	5.21	5.04	4.77	4.40	3.98	3.48	.462	15.	3.
AUG	3.39	3.69	3.90	4.05	4.10	4.06	3.93	3.72	3.44	3.12	.425	12.	3.
SEP	2.12	2.55	2.91	3.21	3.44	3.57	3.62	3.58	3.44	3.31	.460	4.	3.
OCT	.80	1.15	1.47	1.76	2.00	2.19	2.32	2.39	2.39	2.55	.431	-7.	3.
NOV	.13	.33	.51	.69	.84	.98	1.08	1.15	1.19	1.78	.425	-19.	3.
DEC	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00[illegible]	-24.	3.
YRT	884.	997.	1089.	1159.	1203.	1219.	1206.	1165.	1101.	1064.			

BINGHAMTON, NY
42.22 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.22	1.43	1.61	1.76	1.86	1.93	1.95	1.92	1.85	1.74	.326	-6.	5.
FEB	1.81	2.05	2.24	2.38	2.47	2.51	2.49	2.41	2.28	2.10	.353	-5.	5.
MAR	2.72	2.94	3.11	3.21	3.24	3.20	3.09	2.91	2.68	2.39	.380	-1.	5.
APR	3.92	4.08	4.17	4.16	4.07	3.89	3.63	3.31	2.92	2.47	.422	7.	5.
MAY	4.71	4.79	4.76	4.63	4.41	4.11	3.74	3.30	2.80	2.30	.437	13.	5.
JUN	5.30	5.32	5.23	5.03	4.72	4.35	3.90	3.38	2.84	2.27	.462	18.	4.
JUL	5.23	5.28	5.21	5.04	4.76	4.40	3.96	3.46	2.91	2.35	.467	20.	4.
AUG	4.49	4.63	4.67	4.61	4.45	4.21	3.88	3.48	3.01	2.52	.450	19.	4.
SEP	3.56	3.82	4.00	4.08	4.08	3.98	3.80	3.54	3.20	2.82	.445	15.	4.
OCT	2.46	2.76	3.01	3.19	3.30	3.33	3.28	3.16	2.96	2.73	.418	10.	4.
NOV	1.30	1.50	1.67	1.80	1.89	1.94	1.94	1.90	1.82	1.79	.317	3.	5.
DEC	.94	1.08	1.20	1.30	1.37	1.41	1.42	1.40	1.35	1.35	.280	-3.	5.
YRT	1148.	1209.	1245.	1254.	1237.	1195.	1129.	1040.	932.	816.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

BOISE, ID

43.57 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.53	1.90	2.22	2.49	2.70	2.84	2.91	2.91	2.83	2.77	.437	-1.	4.
FEB	2.64	3.14	3.56	3.90	4.14	4.28	4.31	4.22	4.04	3.78	.537	2.	4.
MAR	4.11	4.61	5.00	5.27	5.41	5.42	5.29	5.03	4.65	4.19	.591	5.	4.
APR	5.76	6.12	6.33	6.39	6.29	6.06	5.68	5.17	4.55	3.84	.628	9.	5.
MAY	7.18	7.36	7.37	7.20	6.86	6.39	5.79	5.06	4.22	3.37	.668	14.	4.
JUN	7.77	7.83	7.72	7.43	6.96	6.38	5.67	4.84	3.97	3.07	.677	19.	4.
JUL	8.23	8.37	8.31	8.05	7.59	6.99	6.24	5.35	4.38	3.39	.736	24.	4.
AUG	6.92	7.25	7.40	7.37	7.16	6.79	6.27	5.60	4.80	3.92	.700	23.	4.
SEP	5.48	6.05	6.47	6.73	6.83	6.74	6.49	6.08	5.51	4.83	.697	17.	4.
OCT	3.58	4.21	4.73	5.14	5.42	5.55	5.54	5.39	5.10	4.71	.632	11.	4.
NOV	1.98	2.45	2.87	3.21	3.47	3.64	3.72	3.71	3.60	3.49	.510	4.	4.
DEC	1.38	1.74	2.07	2.35	2.57	2.72	2.80	2.81	2.75	2.72	.441	0.	4.
YRT	1725.	1860.	1952.	1996.	1992.	1942.	1848.	1709.	1533.	1340.			

BOSTON, MA

42.37 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.50	1.82	2.10	2.34	2.51	2.63	2.68	2.66	2.58	2.54	.405	-2.	7.
FEB	2.23	2.58	2.87	3.10	3.25	3.32	3.32	3.23	3.07	2.86	.437	-1.	7.
MAR	3.20	3.51	3.74	3.89	3.95	3.91	3.79	3.58	3.30	2.97	.450	3.	7.
APR	4.18	4.37	4.47	4.47	4.37	4.18	3.91	3.56	3.13	2.67	.451	8.	6.
MAY	5.26	5.35	5.33	5.19	4.94	4.60	4.18	3.67	3.11	2.54	.488	14.	6.
JUN	5.73	5.75	5.65	5.44	5.11	4.70	4.20	3.63	3.04	2.42	.499	20.	5.
JUL	5.52	5.57	5.50	5.32	5.02	4.64	4.18	3.64	3.06	2.46	.493	23.	5.
AUG	4.68	4.84	4.88	4.82	4.66	4.41	4.07	3.64	3.15	2.63	.470	21.	5.
SEP	3.97	4.28	4.49	4.60	4.61	4.51	4.31	4.01	3.63	3.19	.497	18.	5.
OCT	2.80	3.19	3.50	3.73	3.88	3.93	3.88	3.75	3.52	3.25	.479	13.	6.
NOV	1.58	1.88	2.14	2.34	2.49	2.59	2.61	2.58	2.48	2.42	.387	7.	6.
DEC	1.27	1.56	1.81	2.02	2.19	2.30	2.35	2.35	2.28	2.26	.382	1.	6.
YRT	1278.	1361.	1416.	1439.	1430.	1391.	1323.	1226.	1106.	979.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

BRYCE CANYON, UT

37.70 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.88	3.58	4.19	4.69	5.06	5.31	5.41	5.37	5.18	4.96	.642	-7.	3.
FEB	3.89	4.57	5.13	5.57	5.86	6.00	5.98	5.81	5.49	5.05	.665	-5.	4.
MAR	5.31	5.89	6.32	6.59	6.69	6.62	6.39	6.00	5.46	4.81	.689	-2.	4.
APR	6.72	7.06	7.22	7.20	7.01	6.66	6.14	5.48	4.70	3.84	.700	3.	4.
MAY	7.73	7.83	7.74	7.47	7.02	6.44	5.71	4.85	3.94	2.99	.711	9.	4.
JUN	8.37	8.34	8.12	7.70	7.10	6.39	5.53	4.57	3.61	2.63	.732	14.	4.
JUL	7.64	7.67	7.51	7.17	6.68	6.07	5.32	4.47	3.60	2.69	.681	17.	3.
AUG	6.80	7.01	7.05	6.92	6.63	6.20	5.63	4.93	4.13	3.28	.666	16.	3.
SEP	6.05	6.56	6.90	7.07	7.07	6.88	6.53	6.01	5.35	4.57	.713	12.	3.
OCT	4.62	5.32	5.88	6.30	6.56	6.64	6.55	6.29	5.87	5.31	.705	6.	3.
NOV	3.20	3.91	4.53	5.02	5.39	5.61	5.69	5.61	5.39	5.19	.658	-1.	3.
DEC	2.58	3.26	3.85	4.35	4.73	4.99	5.11	5.10	4.95	4.83	.626	-6.	3.
YRT	2004.	2161.	2266.	2314.	2306.	2245.	2128.	1960.	1752.	1523.			

BURLINGTON, VT

44.47 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.34	1.66	1.93	2.16	2.34	2.47	2.53	2.52	2.46	2.49	.401	-8.	4.
FEB	2.13	2.50	2.82	3.06	3.24	3.33	3.35	3.28	3.13	2.93	.447	-7.	4.
MAR	3.33	3.69	3.97	4.16	4.25	4.24	4.14	3.93	3.64	3.28	.487	-2.	4.
APR	4.57	4.82	4.96	4.99	4.91	4.72	4.44	4.05	3.59	3.06	.502	6.	4.
MAY	5.57	5.69	5.69	5.57	5.32	4.97	4.53	4.01	3.40	2.79	.520	13.	4.
JUN	6.15	6.19	6.11	5.90	5.56	5.12	4.60	3.99	3.34	2.67	.536	18.	4.
JUL	6.15	6.24	6.19	6.01	5.69	5.27	4.76	4.15	3.48	2.80	.550	21.	3.
AUG	5.27	5.49	5.58	5.54	5.38	5.11	4.74	4.26	3.70	3.09	.536	19.	3.
SEP	3.98	4.33	4.58	4.72	4.76	4.68	4.50	4.21	3.83	3.39	.514	15.	3.
OCT	2.63	3.02	3.34	3.58	3.74	3.81	3.79	3.67	3.47	3.22	.475	9.	4.
NOV	1.37	1.63	1.86	2.05	2.19	2.28	2.32	2.30	2.22	2.17	.366	3.	4.
DEC	1.01	1.23	1.43	1.60	1.73	1.81	1.86	1.86	1.81	1.80	.340	-5.	4.
YRT	1326.	1417.	1477.	1503.	1495.	1456.	1386.	1285.	1157.	1024.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

BURNS, OR

43.58 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.55	1.92	2.25	2.52	2.74	2.88	2.95	2.95	2.87	2.80	.442	-3.	2.
FEB	2.49	2.94	3.32	3.62	3.83	3.95	3.97	3.89	3.71	3.48	.507	0.	3.
MAR	3.75	4.17	4.50	4.72	4.83	4.83	4.70	4.47	4.13	3.73	.538	2.	3.
APR	5.20	5.50	5.67	5.71	5.62	5.40	5.06	4.61	4.06	3.46	.567	6.	4.
MAY	6.47	6.62	6.62	6.47	6.17	5.75	5.22	4.57	3.84	3.10	.603	12.	4.
JUN	7.19	7.24	7.14	6.87	6.45	5.92	5.27	4.52	3.73	2.91	.626	16.	4.
JUL	7.75	7.87	7.81	7.57	7.14	6.58	5.89	5.07	4.17	3.26	.693	21.	3.
AUG	6.56	6.86	7.00	6.96	6.76	6.41	5.92	5.29	4.55	3.72	.664	20.	3.
SEP	5.11	5.62	5.99	6.22	6.29	6.21	5.97	5.59	5.07	4.45	.650	15.	3.
OCT	3.28	3.82	4.27	4.62	4.85	4.96	4.94	4.80	4.53	4.19	.579	8.	3.
NOV	1.87	2.30	2.68	2.99	3.22	3.38	3.45	3.43	3.32	3.23	.482	2.	3.
DEC	1.36	1.71	2.03	2.30	2.51	2.66	2.74	2.75	2.69	2.66	.435	-2.	2.
YRT	1603.	1724.	1806.	1845.	1840.	1794.	1707.	1580.	1420.	1246.			

CARIBOU, ME

46.87 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.32	1.70	2.03	2.32	2.54	2.71	2.80	2.82	2.77	2.74	.449	-11.	5.
FEB	2.28	2.76	3.18	3.52	3.77	3.93	3.99	3.94	3.80	3.65	.520	-10.	5.
MAR	3.57	4.04	4.41	4.68	4.84	4.87	4.79	4.59	4.28	3.89	.549	-4.	6.
APR	4.46	4.73	4.89	4.95	4.89	4.73	4.47	4.10	3.66	3.16	.502	3.	5.
MAY	4.97	5.10	5.11	5.02	4.82	4.52	4.15	3.70	3.19	2.64	.468	10.	5.
JUN	5.54	5.60	5.54	5.37	5.09	4.72	4.27	3.75	3.17	2.59	.484	16.	5.
JUL	5.56	5.65	5.62	5.48	5.22	4.86	4.43	3.91	3.31	2.72	.499	19.	4.
AUG	4.72	4.93	5.02	5.01	4.88	4.65	4.34	3.93	3.45	2.93	.488	17.	4.
SEP	3.47	3.78	4.01	4.15	4.19	4.14	3.99	3.76	3.44	3.08	.465	13.	5.
OCT	2.17	2.49	2.77	2.97	3.11	3.18	3.17	3.08	2.92	2.74	.420	6.	5.
NOV	1.16	1.39	1.60	1.77	1.91	1.99	2.03	2.02	1.96	1.92	.346	0.	5.
DEC	.98	1.25	1.50	1.71	1.88	2.00	2.08	2.09	2.06	2.04	.380	-9.	5.
YRT	1225.	1322.	1391.	1429.	1434.	1408.	1353.	1267.	1154.	1036.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

CASPER, WY

42.92 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.16	2.77	3.32	3.79	4.15	4.41	4.55	4.56	4.46	4.30	.597	-4.	8.
FEB	3.19	3.85	4.41	4.86	5.19	5.38	5.43	5.34	5.11	4.78	.635	-3.	7.
MAR	4.55	5.12	5.57	5.88	6.04	6.05	5.91	5.62	5.19	4.68	.645	0.	6.
APR	5.82	6.17	6.38	6.43	6.33	6.08	5.69	5.17	4.54	3.84	.631	5.	6.
MAY	6.95	7.11	7.11	6.93	6.60	6.14	5.55	4.84	4.04	3.23	.646	11.	5.
JUN	7.88	7.94	7.82	7.51	7.03	6.43	5.70	4.85	3.96	3.04	.688	17.	5.
JUL	7.99	8.11	8.04	7.77	7.32	6.73	6.00	5.14	4.21	3.26	.714	22.	5.
AUG	7.02	7.34	7.48	7.44	7.22	6.83	6.29	5.61	4.79	3.90	.706	21.	5.
SEP	5.51	6.07	6.49	6.74	6.82	6.72	6.46	6.04	5.47	4.78	.695	14.	5.
OCT	3.84	4.52	5.08	5.52	5.82	5.96	5.95	5.79	5.47	5.04	.665	8.	5.
NOV	2.42	3.04	3.60	4.06	4.42	4.66	4.77	4.76	4.63	4.48	.604	1.	6.
DEC	1.87	2.45	2.97	3.42	3.77	4.03	4.18	4.21	4.13	4.05	.580	-3.	7.
YRT	1804.	1965.	2079.	2142.	2152.	2112.	2023.	1883.	1702.	1500.			

CHARLESTON, SC

32.90 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.34	2.70	3.00	3.24	3.39	3.47	3.46	3.36	3.19	2.97	.444	9.	4.
FEB	3.14	3.50	3.79	3.98	4.09	4.10	4.01	3.83	3.56	3.24	.477	10.	5.
MAR	4.22	4.52	4.72	4.81	4.80	4.67	4.44	4.11	3.69	3.21	.511	13.	5.
APR	5.46	5.63	5.66	5.57	5.36	5.03	4.59	4.06	3.45	2.79	.552	18.	5.
MAY	5.87	5.87	5.74	5.49	5.13	4.67	4.12	3.50	2.86	2.22	.537	22.	4.
JUN	5.81	5.74	5.55	5.23	4.83	4.35	3.77	3.17	2.55	1.96	.512	26.	4.
JUL	5.66	5.62	5.46	5.18	4.81	4.36	3.81	3.22	2.62	2.03	.507	26.	4.
AUG	5.00	5.07	5.03	4.89	4.64	4.31	3.88	3.39	2.83	2.28	.481	26.	3.
SEP	4.39	4.62	4.74	4.75	4.67	4.47	4.19	3.81	3.35	2.84	.491	23.	4.
OCT	3.76	4.15	4.44	4.63	4.71	4.67	4.53	4.28	3.94	3.51	.521	18.	4.
NOV	2.94	3.40	3.78	4.07	4.26	4.34	4.32	4.19	3.96	3.64	.522	13.	4.
DEC	2.27	2.66	3.00	3.26	3.45	3.55	3.56	3.49	3.33	3.11	.460	10.	4.
YRT	1549.	1628.	1671.	1677.	1647.	1581.	1481.	1350.	1195.	1027.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

CHARLESTON, WV

38.37 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.57	1.83	2.05	2.22	2.34	2.41	2.42	2.37	2.27	2.14	.359	1.	3.
FEB	2.22	2.50	2.71	2.87	2.97	2.99	2.95	2.84	2.67	2.45	.387	3.	4.
MAR	3.18	3.43	3.60	3.70	3.71	3.65	3.50	3.27	2.98	2.64	.417	7.	4.
APR	4.27	4.43	4.49	4.46	4.33	4.11	3.81	3.43	2.99	2.50	.447	13.	3.
MAY	5.16	5.21	5.15	4.98	4.70	4.35	3.91	3.40	2.86	2.29	.475	18.	3.
JUN	5.60	5.58	5.45	5.20	4.85	4.43	3.92	3.35	2.78	2.18	.489	22.	2.
JUL	5.30	5.32	5.22	5.00	4.69	4.31	3.84	3.31	2.76	2.18	.473	23.	2.
AUG	4.78	4.89	4.90	4.81	4.61	4.33	3.96	3.51	3.00	2.47	.469	23.	2.
SEP	4.01	4.26	4.43	4.49	4.46	4.32	4.09	3.78	3.38	2.93	.476	19.	2.
OCT	3.07	3.43	3.71	3.91	4.02	4.03	3.95	3.78	3.52	3.20	.475	13.	2.
NOV	1.93	2.25	2.51	2.73	2.87	2.95	2.96	2.89	2.76	2.68	.407	7.	3.
DEC	1.39	1.63	1.84	2.00	2.12	2.20	2.22	2.18	2.10	2.08	.347	3.	3.
YRT	1294.	1363.	1403.	1412.	1391.	1342.	1264.	1160.	1036.	904.			

CHATTANOOGA, TN

35.03 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.98	2.29	2.56	2.76	2.90	2.97	2.97	2.90	2.76	2.67	.403	4.	3.
FEB	2.70	3.02	3.27	3.45	3.55	3.57	3.50	3.35	3.13	2.86	.432	6.	3.
MAR	3.71	3.98	4.16	4.25	4.25	4.15	3.96	3.68	3.32	2.92	.462	10.	4.
APR	4.88	5.04	5.09	5.02	4.85	4.58	4.21	3.75	3.22	2.65	.499	15.	3.
MAY	5.46	5.48	5.38	5.17	4.86	4.46	3.97	3.41	2.83	2.23	.500	20.	3.
JUN	5.77	5.73	5.56	5.27	4.88	4.42	3.87	3.27	2.66	2.07	.506	24.	2.
JUL	5.47	5.45	5.31	5.07	4.73	4.30	3.80	3.23	2.66	2.08	.488	25.	2.
AUG	5.14	5.24	5.22	5.09	4.85	4.52	4.10	3.59	3.02	2.44	.499	25.	2.
SEP	4.21	4.44	4.58	4.61	4.54	4.38	4.11	3.76	3.34	2.85	.481	22.	2.
OCT	3.50	3.87	4.16	4.36	4.45	4.44	4.32	4.10	3.79	3.40	.505	15.	2.
NOV	2.43	2.81	3.13	3.37	3.53	3.61	3.60	3.50	3.32	3.07	.460	9.	3.
DEC	1.83	2.14	2.41	2.63	2.78	2.86	2.88	2.83	2.70	2.53	.400	5.	3.
YRT	1434.	1507.	1548.	1554.	1527.	1468.	1377.	1259.	1118.	966.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

CLEVELAND, OH

41.40 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.23	1.42	1.59	1.73	1.82	1.88	1.89	1.86	1.79	1.69	.317	-3.	6.
FEB	1.89	2.13	2.33	2.47	2.57	2.60	2.57	2.49	2.35	2.17	.359	-2.	5.
MAR	2.91	3.15	3.33	3.44	3.47	3.43	3.31	3.12	2.86	2.56	.401	2.	6.
APR	4.26	4.44	4.53	4.53	4.42	4.22	3.94	3.57	3.14	2.65	.455	9.	5.
MAY	5.87	5.97	5.94	5.77	5.48	5.09	4.60	4.02	3.37	2.72	.543	15.	5.
JUN	5.81	5.82	5.72	5.49	5.14	4.72	4.21	3.62	3.02	2.39	.507	20.	4.
JUL	5.76	5.81	5.73	5.53	5.21	4.80	4.31	3.73	3.12	2.49	.514	22.	4.
AUG	4.99	5.15	5.19	5.12	4.94	4.66	4.29	3.83	3.30	2.74	.498	21.	4.
SEP	3.90	4.19	4.39	4.48	4.48	4.37	4.17	3.87	3.49	3.06	.482	18.	4.
OCT	2.73	3.09	3.37	3.57	3.70	3.73	3.68	3.54	3.32	3.05	.455	12.	5.
NOV	1.47	1.71	1.91	2.07	2.18	2.24	2.25	2.21	2.12	2.07	.346	6.	5.
DEC	1.01	1.16	1.29	1.40	1.47	1.52	1.53	1.51	1.45	1.46	.287	0.	5.
YRT	1275.	1343.	1381.	1390.	1367.	1318.	1241.	1138.	1014.	884.			

COLUMBIA, SC

33.95 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.39	2.79	3.13	3.39	3.57	3.67	3.67	3.59	3.42	3.26	.469	7.	3.
FEB	3.22	3.61	3.93	4.15	4.28	4.31	4.23	4.05	3.78	3.44	.501	9.	3.
MAR	4.27	4.60	4.82	4.93	4.93	4.81	4.59	4.25	3.83	3.35	.524	12.	4.
APR	5.50	5.69	5.74	5.66	5.46	5.14	4.70	4.17	3.55	2.88	.559	18.	4.
MAY	5.97	5.99	5.87	5.62	5.26	4.81	4.25	3.61	2.96	2.30	.547	22.	3.
JUN	6.13	6.07	5.88	5.55	5.13	4.61	4.01	3.36	2.70	2.06	.539	25.	3.
JUL	5.80	5.77	5.61	5.34	4.96	4.50	3.95	3.34	2.72	2.10	.518	26.	3.
AUG	5.37	5.46	5.43	5.29	5.03	4.67	4.22	3.68	3.08	2.46	.519	26.	3.
SEP	4.53	4.78	4.93	4.96	4.88	4.70	4.40	4.02	3.55	3.01	.513	23.	3.
OCT	3.82	4.24	4.56	4.78	4.88	4.86	4.73	4.48	4.13	3.69	.540	17.	3.
NOV	2.90	3.38	3.77	4.08	4.29	4.39	4.38	4.26	4.04	3.72	.530	12.	3.
DEC	2.28	2.70	3.06	3.35	3.56	3.68	3.70	3.64	3.48	3.26	.479	8.	3.
YRT	1589.	1677.	1727.	1738.	1711.	1646.	1545.	1412.	1253.	1080.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

COLUMBUS, OH

40.00 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.45	1.70	1.91	2.08	2.21	2.28	2.30	2.26	2.17	2.05	.353	-2.	5.
FEB	2.13	2.41	2.63	2.80	2.90	2.94	2.91	2.81	2.65	2.44	.388	0.	5.
MAR	3.09	3.34	3.53	3.63	3.66	3.60	3.47	3.26	2.98	2.65	.416	4.	5.
APR	4.27	4.44	4.51	4.49	4.38	4.17	3.88	3.51	3.07	2.58	.451	11.	5.
MAY	5.19	5.25	5.21	5.05	4.78	4.44	4.01	3.50	2.95	2.39	.479	16.	4.
JUN	5.71	5.71	5.60	5.36	5.01	4.59	4.08	3.50	2.91	2.29	.499	21.	3.
JUL	5.53	5.56	5.47	5.26	4.95	4.56	4.08	3.52	2.94	2.34	.493	23.	3.
AUG	4.99	5.13	5.16	5.08	4.89	4.60	4.22	3.76	3.22	2.66	.495	22.	3.
SEP	4.04	4.32	4.51	4.59	4.57	4.45	4.23	3.92	3.52	3.07	.489	19.	3.
OCT	2.98	3.36	3.66	3.87	3.99	4.02	3.96	3.80	3.55	3.25	.480	12.	3.
NOV	1.69	1.97	2.21	2.40	2.53	2.60	2.61	2.56	2.45	2.39	.378	6.	4.
DEC	1.22	1.44	1.62	1.77	1.88	1.94	1.96	1.94	1.87	1.86	.328	0.	4.
YRT	1289.	1360.	1402.	1413.	1393.	1346.	1270.	1167.	1043.	911.			

CUTBANK, MT

48.60 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.27	1.67	2.04	2.36	2.62	2.80	2.92	2.96	2.92	2.90	.478	-9.	6.
FEB	2.16	2.67	3.10	3.47	3.74	3.92	4.00	3.97	3.84	3.72	.528	-5.	6.
MAR	3.56	4.07	4.48	4.79	4.97	5.04	4.98	4.79	4.49	4.10	.568	-3.	6.
APR	4.68	5.00	5.21	5.30	5.27	5.11	4.85	4.48	4.01	3.47	.537	4.	6.
MAY	5.93	6.12	6.18	6.10	5.88	5.53	5.09	4.54	3.91	3.22	.562	10.	6.
JUN	6.45	6.54	6.50	6.32	6.01	5.57	5.05	4.43	3.73	3.04	.564	14.	5.
JUL	7.21	7.38	7.40	7.24	6.92	6.44	5.87	5.16	4.35	3.52	.650	18.	5.
AUG	5.98	6.32	6.51	6.54	6.42	6.15	5.76	5.23	4.59	3.84	.625	17.	5.
SEP	4.26	4.74	5.11	5.35	5.47	5.45	5.30	5.02	4.62	4.11	.588	12.	5.
OCT	2.74	3.28	3.75	4.11	4.38	4.53	4.57	4.49	4.30	4.01	.562	7.	6.
NOV	1.51	1.96	2.35	2.69	2.96	3.16	3.27	3.30	3.23	3.12	.498	-1.	6.
DEC	1.05	1.43	1.78	2.08	2.33	2.51	2.63	2.68	2.66	2.60	.461	-5.	7.
YRT	1427.	1561.	1658.	1717.	1735.	1712.	1652.	1554.	1419.	1267.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

DAGGETT, CA

34.87 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.02	3.65	4.18	4.62	4.93	5.12	5.17	5.09	4.87	4.57	.609	8.	4.
FEB	4.03	4.65	5.16	5.54	5.77	5.86	5.80	5.59	5.24	4.77	.642	11.	4.
MAR	5.59	6.13	6.53	6.75	6.81	6.70	6.42	5.98	5.39	4.68	.695	14.	6.
APR	7.17	7.48	7.61	7.54	7.30	6.88	6.29	5.55	4.69	3.73	.732	18.	6.
MAY	8.17	8.23	8.08	7.73	7.22	6.55	5.73	4.78	3.80	2.78	.749	23.	7.
JUN	8.72	8.64	8.35	7.85	7.19	6.40	5.45	4.44	3.41	2.42	.765	27.	7.
JUL	8.21	8.18	7.96	7.54	6.97	6.26	5.40	4.45	3.49	2.52	.732	31.	5.
AUG	7.51	7.71	7.71	7.53	7.17	6.64	5.96	5.14	4.21	3.26	.728	30.	5.
SEP	6.33	6.80	7.11	7.23	7.18	6.94	6.53	5.96	5.25	4.42	.722	26.	5.
OCT	4.78	5.42	5.93	6.29	6.49	6.52	6.38	6.09	5.63	5.05	.688	20.	4.
NOV	3.35	4.00	4.55	4.98	5.29	5.46	5.48	5.36	5.11	4.73	.630	13.	4.
DEC	2.77	3.39	3.93	4.37	4.70	4.91	4.99	4.94	4.76	4.46	.601	9.	4.
YRT	2121.	2262.	2347.	2373.	2343.	2258.	2117.	1926.	1697.	1439.			

DALLAS, TX

32.65 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.59	3.01	3.36	3.64	3.82	3.91	3.91	3.81	3.61	3.34	.488	7.	5.
FEB	3.38	3.78	4.10	4.33	4.45	4.46	4.37	4.18	3.88	3.51	.510	9.	5.
MAR	4.48	4.81	5.04	5.14	5.13	4.99	4.75	4.39	3.94	3.41	.540	13.	6.
APR	5.13	5.27	5.30	5.21	5.01	4.70	4.29	3.80	3.23	2.61	.517	19.	6.
MAY	5.95	5.95	5.82	5.56	5.20	4.73	4.17	3.52	2.88	2.21	.545	23.	5.
JUN	6.73	6.64	6.40	6.02	5.53	4.94	4.25	3.52	2.76	2.07	.593	28.	5.
JUL	6.69	6.64	6.43	6.09	5.63	5.06	4.38	3.65	2.90	2.18	.598	30.	5.
AUG	6.15	6.25	6.21	6.03	5.72	5.29	4.74	4.09	3.37	2.64	.592	29.	4.
SEP	5.00	5.28	5.44	5.47	5.38	5.16	4.82	4.38	3.85	3.24	.558	26.	4.
OCT	4.03	4.46	4.78	5.00	5.09	5.06	4.91	4.64	4.26	3.80	.555	20.	4.
NOV	2.95	3.40	3.77	4.06	4.24	4.32	4.30	4.17	3.94	3.62	.519	13.	5.
DEC	2.46	2.90	3.27	3.57	3.78	3.90	3.91	3.84	3.66	3.42	.495	9.	5.
YRT	1691.	1778.	1825.	1829.	1794.	1719.	1606.	1459.	1285.	1095.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

DILLON, MT

45.25 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.64	2.11	2.52	2.88	3.16	3.36	3.47	3.49	3.42	3.28	.510	-6.	5.
FEB	2.66	3.23	3.72	4.11	4.40	4.58	4.64	4.58	4.40	4.11	.573	-3.	5.
MAR	4.04	4.56	4.98	5.28	5.44	5.47	5.37	5.13	4.76	4.29	.599	-1.	5.
APR	5.17	5.49	5.69	5.75	5.68	5.48	5.16	4.72	4.18	3.55	.572	4.	5.
MAY	6.27	6.44	6.46	6.33	6.06	5.66	5.17	4.55	3.86	3.14	.587	10.	4.
JUN	6.76	6.82	6.74	6.52	6.15	5.66	5.08	4.40	3.66	2.92	.589	15.	4.
JUL	7.54	7.68	7.65	7.44	7.05	6.52	5.87	5.09	4.22	3.35	.676	19.	3.
AUG	6.38	6.69	6.85	6.84	6.66	6.34	5.88	5.29	4.57	3.79	.652	18.	4.
SEP	4.79	5.29	5.66	5.90	5.98	5.93	5.72	5.37	4.90	4.33	.626	12.	4.
OCT	3.22	3.80	4.28	4.66	4.92	5.06	5.07	4.94	4.69	4.36	.596	7.	4.
NOV	1.90	2.40	2.84	3.21	3.50	3.70	3.80	3.81	3.71	3.60	.527	0.	4.
DEC	1.42	1.86	2.25	2.59	2.86	3.06	3.18	3.22	3.16	3.11	.500	-5.	5.
YRT	1579.	1718.	1817.	1873.	1883.	1851.	1777.	1660.	1506.	1332.			

DODGE CITY, KA

37.77 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.61	3.20	3.71	4.13	4.44	4.64	4.72	4.68	4.51	4.31	.582	-2.	6.
FEB	3.53	4.11	4.59	4.95	5.19	5.30	5.28	5.12	4.83	4.45	.605	1.	6.
MAR	4.66	5.12	5.45	5.66	5.73	5.66	5.45	5.11	4.65	4.11	.604	5.	7.
APR	5.94	6.21	6.34	6.31	6.14	5.83	5.38	4.82	4.15	3.42	.619	12.	7.
MAY	6.58	6.66	6.58	6.35	5.98	5.50	4.90	4.21	3.46	2.70	.606	18.	7.
JUN	7.43	7.41	7.22	6.86	6.35	5.74	5.00	4.18	3.35	2.52	.650	23.	6.
JUL	7.24	7.26	7.11	6.80	6.34	5.77	5.07	4.27	3.46	2.61	.645	26.	6.
AUG	6.48	6.67	6.71	6.59	6.31	5.91	5.37	4.71	3.95	3.16	.635	25.	6.
SEP	5.31	5.72	5.99	6.12	6.10	5.93	5.62	5.17	4.61	3.95	.627	20.	6.
OCT	4.10	4.68	5.14	5.47	5.67	5.73	5.64	5.41	5.04	4.56	.627	14.	6.
NOV	2.81	3.39	3.88	4.28	4.57	4.74	4.79	4.71	4.51	4.35	.580	5.	6.
DEC	2.31	2.87	3.36	3.77	4.08	4.29	4.38	4.36	4.23	4.13	.561	0.	6.
YRT	1797.	1927.	2011.	2047.	2035.	1978.	1873.	1725.	1542.	1345.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

DULUTH, MN

46.83 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.22	1.55	1.84	2.09	2.29	2.43	2.51	2.52	2.47	2.50	.415	-14.	5.
FEB	2.11	2.54	2.90	3.20	3.42	3.55	3.60	3.55	3.42	3.34	.482	-11.	5.
MAR	3.26	3.66	3.97	4.19	4.31	4.33	4.25	4.06	3.78	3.43	.501	-5.	5.
APR	4.33	4.58	4.74	4.79	4.73	4.57	4.32	3.97	3.54	3.04	.487	3.	6.
MAY	5.18	5.31	5.33	5.23	5.02	4.71	4.33	3.86	3.31	2.74	.487	10.	5.
JUN	5.57	5.63	5.57	5.40	5.12	4.74	4.30	3.77	3.19	2.60	.486	15.	5.
JUL	5.85	5.95	5.92	5.78	5.50	5.12	4.65	4.10	3.47	2.84	.525	18.	4.
AUG	4.87	5.08	5.18	5.17	5.04	4.81	4.48	4.06	3.55	3.02	.503	17.	4.
SEP	3.45	3.76	3.98	4.12	4.16	4.11	3.96	3.72	3.41	3.05	.462	12.	5.
OCT	2.28	2.64	2.93	3.16	3.31	3.39	3.38	3.29	3.12	2.92	.442	7.	5.
NOV	1.20	1.46	1.68	1.87	2.01	2.10	2.15	2.14	2.07	2.03	.359	-2.	5.
DEC	.92	1.16	1.38	1.56	1.71	1.82	1.88	1.89	1.85	1.85	.356	-10.	5.
YRT	1227.	1319.	1384.	1418.	1419.	1390.	1332.	1244.	1130.	1014.			

EAGLE, CO

39.65 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.38	2.96	3.46	3.88	4.20	4.41	4.50	4.48	4.34	4.15	.572	-8.	2.
FEB	3.39	3.99	4.50	4.89	5.16	5.29	5.29	5.15	4.89	4.53	.612	-5.	2.
MAR	4.74	5.26	5.65	5.91	6.01	5.97	5.78	5.45	4.99	4.45	.634	0.	3.
APR	6.09	6.41	6.57	6.58	6.43	6.13	5.69	5.12	4.43	3.69	.643	5.	3.
MAY	7.11	7.23	7.17	6.95	6.56	6.06	5.42	4.67	3.84	3.00	.656	11.	3.
JUN	7.91	7.91	7.74	7.38	6.85	6.21	5.44	4.56	3.67	2.75	.690	16.	3.
JUL	7.52	7.57	7.45	7.15	6.68	6.11	5.40	4.58	3.73	2.83	.670	19.	2.
AUG	6.57	6.80	6.87	6.77	6.51	6.12	5.59	4.93	4.17	3.36	.650	17.	2.
SEP	5.57	6.05	6.39	6.57	6.59	6.44	6.14	5.68	5.09	4.39	.672	13.	2.
OCT	4.12	4.76	5.29	5.68	5.92	6.02	5.96	5.74	5.38	4.91	.658	6.	2.
NOV	2.74	3.36	3.90	4.34	4.66	4.87	4.95	4.90	4.72	4.55	.603	-2.	2.
DEC	2.18	2.76	3.28	3.71	4.05	4.28	4.40	4.40	4.28	4.19	.575	-8.	2.
YRT	1837.	1981.	2078.	2124.	2118.	2066.	1963.	1814.	1627.	1422.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

EL PASO, TX

31.80 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.54	4.22	4.80	5.25	5.57	5.75	5.77	5.64	5.36	4.97	.649	7.	4.
FEB	4.66	5.34	5.88	6.28	6.51	6.58	6.47	6.20	5.77	5.21	.692	9.	4.
MAR	6.02	6.55	6.92	7.11	7.13	6.96	6.62	6.11	5.45	4.68	.718	14.	5.
APR	7.44	7.71	7.79	7.67	7.36	6.88	6.23	5.42	4.50	3.50	.748	18.	5.
MAY	8.20	8.20	7.99	7.59	7.03	6.31	5.45	4.47	3.49	2.50	.751	23.	5.
JUN	8.46	8.32	7.98	7.44	6.77	5.95	5.00	4.02	3.00	2.08	.747	28.	4.
JUL	7.72	7.65	7.39	6.96	6.40	5.70	4.87	3.99	3.09	2.23	.692	28.	4.
AUG	7.20	7.33	7.27	7.05	6.66	6.13	5.45	4.65	3.77	2.88	.692	27.	4.
SEP	6.26	6.65	6.88	6.94	6.83	6.55	6.12	5.53	4.82	4.00	.693	24.	4.
OCT	5.17	5.80	6.29	6.61	6.77	6.76	6.57	6.22	5.70	5.06	.702	18.	4.
NOV	3.91	4.61	5.20	5.65	5.96	6.11	6.10	5.93	5.61	5.15	.673	11.	4.
DEC	3.25	3.92	4.50	4.96	5.30	5.49	5.55	5.45	5.22	4.87	.635	7.	4.
YRT	2187.	2322.	2400.	2419.	2381.	2285.	2133.	1934.	1694.	1430.			

EL TORO, CA

33.67 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.98	3.55	4.03	4.41	4.69	4.84	4.87	4.77	4.55	4.24	.578	12.	2.
FEB	3.89	4.44	4.88	5.21	5.40	5.46	5.38	5.16	4.82	4.37	.603	13.	3.
MAR	5.08	5.51	5.82	5.98	6.00	5.87	5.60	5.19	4.67	4.04	.621	13.	2.
APR	6.08	6.29	6.36	6.27	6.05	5.68	5.19	4.58	3.88	3.11	.617	12.	3.
MAY	6.53	6.54	6.41	6.13	5.73	5.22	4.59	3.88	3.15	2.39	.598	16.	3.
JUN	6.92	6.84	6.61	6.22	5.73	5.12	4.42	3.66	2.89	2.15	.608	18.	2.
JUL	7.45	7.41	7.19	6.80	6.29	5.64	4.88	4.04	3.18	2.34	.665	21.	2.
AUG	6.80	6.94	6.91	6.73	6.39	5.91	5.30	4.57	3.75	2.92	.656	21.	2.
SEP	5.47	5.82	6.03	6.09	6.01	5.78	5.42	4.94	4.34	3.65	.617	20.	2.
OCT	4.28	4.78	5.17	5.43	5.56	5.55	5.40	5.13	4.73	4.22	.601	18.	2.
NOV	3.23	3.79	4.27	4.63	4.88	5.01	5.01	4.88	4.63	4.27	.586	15.	2.
DEC	2.74	3.31	3.80	4.20	4.49	4.66	4.72	4.65	4.46	4.17	.571	13.	2.
YRT	1871.	1986.	2054.	2072.	2044.	1969.	1848.	1686.	1490.	1272.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

ELKO, NV

40.83 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.17	2.71	3.18	3.57	3.88	4.08	4.17	4.16	4.04	3.82	.548	-4.	2.
FEB	3.26	3.85	4.36	4.76	5.03	5.18	5.19	5.07	4.82	4.46	.608	-1.	3.
MAR	4.62	5.14	5.55	5.82	5.94	5.92	5.75	5.43	4.99	4.43	.630	2.	3.
APR	5.99	6.32	6.50	6.52	6.38	6.11	5.69	5.13	4.47	3.71	.638	6.	3.
MAY	7.26	7.40	7.37	7.16	6.77	6.27	5.63	4.87	4.02	3.15	.672	12.	3.
JUN	7.98	8.01	7.85	7.51	6.99	6.36	5.59	4.70	3.81	2.86	.697	17.	3.
JUL	8.26	8.36	8.24	7.93	7.42	6.79	6.00	5.08	4.11	3.11	.737	22.	3.
AUG	7.30	7.60	7.72	7.64	7.38	6.95	6.36	5.62	4.75	3.81	.726	20.	3.
SEP	5.96	6.55	6.97	7.21	7.27	7.14	6.83	6.34	5.70	4.93	.731	15.	2.
OCT	4.17	4.86	5.44	5.87	6.16	6.28	6.24	6.04	5.68	5.19	.685	8.	2.
NOV	2.56	3.16	3.69	4.12	4.44	4.65	4.74	4.70	4.54	4.39	.590	2.	2.
DEC	1.95	2.47	2.94	3.33	3.64	3.86	3.97	3.98	3.88	3.81	.543	-4.	2.
YRT	1874.	2024.	2126.	2175.	2170.	2117.	2012.	1859.	1666.	1449.			

EVANSVILLE, IN

38.05 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.81	2.14	2.42	2.64	2.80	2.89	2.92	2.87	2.75	2.70	.409	0.	4.
FEB	2.59	2.94	3.22	3.43	3.56	3.61	3.57	3.44	3.24	2.97	.447	2.	4.
MAR	3.63	3.93	4.15	4.27	4.30	4.23	4.06	3.80	3.46	3.07	.473	7.	5.
APR	4.73	4.91	4.99	4.95	4.81	4.57	4.23	3.80	3.30	2.75	.493	14.	5.
MAY	5.61	5.67	5.60	5.41	5.11	4.72	4.23	3.66	3.05	2.43	.517	19.	4.
JUN	6.25	6.23	6.08	5.79	5.38	4.90	4.31	3.65	2.99	2.31	.546	24.	3.
JUL	6.05	6.07	5.95	5.70	5.33	4.88	4.33	3.69	3.05	2.37	.540	25.	3.
AUG	5.47	5.62	5.64	5.53	5.30	4.97	4.53	4.00	3.39	2.76	.537	24.	3.
SEP	4.42	4.72	4.91	4.99	4.96	4.81	4.56	4.20	3.75	3.24	.523	20.	3.
OCT	3.43	3.86	4.20	4.44	4.58	4.60	4.52	4.32	4.02	3.65	.528	14.	3.
NOV	2.15	2.52	2.83	3.08	3.26	3.36	3.37	3.30	3.15	3.05	.448	7.	4.
DEC	1.57	1.87	2.13	2.34	2.49	2.59	2.62	2.59	2.49	2.46	.387	2.	4.
YRT	1454.	1538.	1587.	1601.	1579.	1525.	1437.	1318.	1175.	1027.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

FAIRBANKS, AK

64.82 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.10	.22	.33	.44	.53	.61	.68	.72	.74	1.51	.331	-26.	1.
FEB	.70	1.10	1.48	1.82	2.11	2.35	2.51	2.61	2.64	2.90	.491	-15.	2.
MAR	2.13	2.74	3.29	3.76	4.13	4.39	4.53	4.55	4.45	4.25	.574	-13.	2.
APR	3.76	4.26	4.65	4.93	5.10	5.14	5.05	4.85	4.54	4.12	.545	-1.	3.
MAY	5.05	5.36	5.55	5.63	5.61	5.46	5.18	4.81	4.36	3.81	.519	9.	3.
JUN	5.52	5.70	5.79	5.76	5.64	5.41	5.06	4.64	4.14	3.57	.488	16.	3.
JUL	4.86	5.06	5.17	5.17	5.09	4.90	4.61	4.25	3.82	3.32	.456	17.	3.
AUG	3.52	3.81	4.02	4.15	4.19	4.13	3.98	3.75	3.45	3.10	.432	13.	3.
SEP	2.24	2.64	2.99	3.26	3.46	3.57	3.60	3.53	3.38	3.21	.453	7.	3.
OCT	.92	1.27	1.58	1.86	2.08	2.26	2.37	2.42	2.41	2.53	.420	-4.	2.
NOV	.23	.48	.71	.92	1.11	1.26	1.38	1.46	1.50	2.14	.429	-16.	2.
DEC	.02	.02	.02	.02	.02	.01	.01	.01	.01	.86	.068	-23.	1.
YRT	887.	996.	1084.	1149.	1189.	1202.	1186.	1144.	1077.	1073.			

FARGO, ND

46.90 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.31	1.67	2.00	2.28	2.51	2.67	2.76	2.78	2.73	2.80	.444	-15.	6.
FEB	2.22	2.68	3.08	3.40	3.64	3.79	3.85	3.80	3.66	3.62	.507	-11.	6.
MAR	3.43	3.86	4.21	4.46	4.60	4.63	4.54	4.35	4.05	3.73	.527	-4.	6.
APR	4.65	4.94	5.13	5.19	5.14	4.97	4.69	4.31	3.84	3.35	.524	6.	6.
MAY	5.78	5.94	5.98	5.88	5.64	5.29	4.85	4.31	3.69	3.06	.544	13.	6.
JUN	6.29	6.36	6.30	6.11	5.79	5.35	4.83	4.22	3.55	2.89	.549	19.	5.
JUL	6.68	6.82	6.80	6.63	6.31	5.87	5.32	4.67	3.92	3.20	.601	22.	5.
AUG	5.75	6.04	6.19	6.19	6.05	5.77	5.38	4.86	4.25	3.59	.594	21.	5.
SEP	4.11	4.52	4.83	5.03	5.11	5.06	4.89	4.61	4.22	3.79	.551	14.	6.
OCT	2.75	3.24	3.65	3.97	4.19	4.31	4.33	4.23	4.03	3.79	.534	8.	6.
NOV	1.44	1.80	2.12	2.39	2.59	2.74	2.81	2.81	2.74	2.70	.433	-2.	6.
DEC	1.06	1.38	1.67	1.92	2.12	2.27	2.36	2.38	2.35	2.35	.414	-10.	6.
YRT	1386.	1502.	1583.	1628.	1635.	1605.	1540.	1440.	1308.	1182.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY) CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

FORT SMITH, AR

35.33 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.34	2.76	3.11	3.40	3.60	3.71	3.73	3.65	3.49	3.34	.480	3.	4.
FEB	3.14	3.56	3.89	4.13	4.27	4.31	4.25	4.08	3.82	3.53	.506	6.	4.
MAR	4.13	4.46	4.69	4.82	4.83	4.72	4.52	4.20	3.80	3.38	.517	10.	4.
APR	5.09	5.27	5.32	5.26	5.09	4.80	4.41	3.93	3.38	2.82	.522	16.	4.
MAY	6.03	6.06	5.96	5.72	5.37	4.92	4.37	3.73	3.07	2.43	.553	21.	3.
JUN	6.59	6.54	6.34	6.00	5.54	5.00	4.34	3.64	2.92	2.24	.578	25.	3.
JUL	6.51	6.49	6.33	6.03	5.60	5.08	4.45	3.75	3.03	2.33	.581	27.	3.
AUG	5.92	6.05	6.04	5.90	5.63	5.24	4.73	4.13	3.45	2.78	.575	27.	3.
SEP	4.73	5.02	5.20	5.26	5.20	5.02	4.72	4.32	3.83	3.28	.543	23.	3.
OCT	3.79	4.23	4.57	4.81	4.93	4.93	4.81	4.58	4.24	3.83	.550	16.	3.
NOV	2.68	3.13	3.51	3.80	4.01	4.11	4.11	4.01	3.81	3.56	.511	10.	3.
DEC	2.15	2.57	2.93	3.22	3.44	3.56	3.60	3.55	3.41	3.23	.475	5.	4.
YRT	1618.	1710.	1763.	1776.	1750.	1685.	1583.	1447.	1284.	1117.			

FRESNO, CA

36.77 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.07	2.44	2.76	3.02	3.20	3.31	3.33	3.27	3.13	2.96	.446	7.	2.
FEB	3.18	3.64	4.02	4.29	4.47	4.53	4.49	4.33	4.07	3.74	.532	10.	3.
MAR	4.94	5.42	5.77	5.99	6.05	5.97	5.74	5.37	4.87	4.29	.631	12.	3.
APR	6.59	6.90	7.04	7.00	6.80	6.44	5.93	5.28	4.51	3.68	.682	15.	3.
MAY	7.83	7.91	7.81	7.51	7.04	6.44	5.69	4.81	3.88	2.95	.719	20.	4.
JUN	8.61	8.57	8.32	7.86	7.24	6.48	5.58	4.58	3.57	2.60	.754	24.	4.
JUL	8.47	8.48	8.29	7.89	7.31	6.60	5.74	4.74	3.76	2.75	.755	27.	3.
AUG	7.64	7.88	7.93	7.77	7.43	6.93	6.25	5.43	4.49	3.53	.746	26.	3.
SEP	6.26	6.77	7.12	7.28	7.27	7.06	6.68	6.13	5.44	4.64	.729	23.	3.
OCT	4.51	5.15	5.66	6.03	6.25	6.31	6.21	5.94	5.53	5.01	.675	17.	2.
NOV	2.80	3.33	3.78	4.15	4.40	4.55	4.58	4.49	4.29	4.17	.558	11.	2.
DEC	1.81	2.16	2.46	2.71	2.89	2.99	3.03	2.99	2.88	2.88	.423	7.	2.
YRT	1972.	2092.	2161.	2178.	2142.	2058.	1924.	1745.	1533.	1313.			

TABLE I (Continued)
AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

GRAND JUNCTION, CO

39.12 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.50	3.10	3.63	4.06	4.39	4.61	4.70	4.67	4.52	4.44	.587	-4.	3.
FEB	3.52	4.14	4.66	5.07	5.34	5.48	5.47	5.33	5.05	4.67	.626	0.	3.
MAR	4.90	5.44	5.84	6.10	6.21	6.17	5.97	5.62	5.13	4.56	.650	5.	4.
APR	6.26	6.58	6.75	6.75	6.59	6.28	5.82	5.22	4.51	3.73	.658	11.	4.
MAY	7.50	7.62	7.56	7.31	6.89	6.35	5.67	4.85	3.97	3.09	.691	17.	4.
JUN	8.19	8.19	8.00	7.61	7.05	6.38	5.56	4.63	3.71	2.77	.715	22.	4.
JUL	7.77	7.82	7.69	7.37	6.87	6.27	5.53	4.66	3.78	2.87	.693	26.	4.
AUG	6.88	7.12	7.19	7.08	6.81	6.39	5.82	5.12	4.31	3.48	.679	24.	4.
SEP	5.78	6.28	6.63	6.82	6.83	6.67	6.35	5.87	5.25	4.54	.693	19.	4.
OCT	4.24	4.89	5.42	5.82	6.07	6.16	6.09	5.87	5.49	5.02	.668	12.	4.
NOV	2.90	3.55	4.13	4.59	4.94	5.16	5.24	5.18	4.99	4.83	.625	4.	3.
DEC	2.31	2.93	3.47	3.93	4.28	4.53	4.65	4.65	4.52	4.45	.595	-2.	3.
YRT	1911.	2061.	2160.	2207.	2199.	2143.	2033.	1875.	1678.	1472.			

GRAND RAPIDS, MI

42.90 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.17	1.37	1.55	1.69	1.80	1.86	1.88	1.86	1.80	1.86	.322	-4.	5.
FEB	2.04	2.35	2.61	2.81	2.94	3.00	3.00	2.92	2.77	2.60	.406	-4.	5.
MAR	3.20	3.51	3.75	3.90	3.97	3.94	3.82	3.62	3.33	3.02	.454	0.	5.
APR	4.45	4.67	4.79	4.80	4.70	4.51	4.22	3.84	3.39	2.90	.483	8.	5.
MAY	5.53	5.64	5.62	5.48	5.22	4.87	4.42	3.89	3.29	2.70	.514	14.	5.
JUN	6.17	6.20	6.10	5.87	5.51	5.07	4.53	3.91	3.25	2.60	.538	20.	4.
JUL	6.04	6.10	6.04	5.84	5.52	5.10	4.59	3.98	3.33	2.69	.539	22.	4.
AUG	5.28	5.48	5.55	5.50	5.32	5.04	4.65	4.16	3.59	3.01	.532	21.	4.
SEP	3.98	4.29	4.52	4.64	4.65	4.56	4.36	4.07	3.68	3.27	.502	17.	4.
OCT	2.70	3.08	3.38	3.61	3.75	3.80	3.76	3.63	3.42	3.18	.468	11.	4.
NOV	1.41	1.65	1.86	2.03	2.15	2.22	2.25	2.21	2.13	2.11	.351	4.	5.
DEC	.98	1.15	1.31	1.43	1.52	1.58	1.60	1.59	1.54	1.56	.302	-2.	5.
YRT	1309.	1387.	1434.	1450.	1433.	1387.	1311.	1207.	1080.	958.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

GUANTANAMO BAY, CU

19.90 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	4.42	4.96	5.37	5.66	5.80	5.80	5.66	5.38	4.97	4.49	.603	23.	3.
FEB	5.20	5.66	5.98	6.15	6.18	6.05	5.78	5.37	4.83	4.24	.624	24.	3.
MAR	6.07	6.35	6.47	6.44	6.26	5.92	5.45	4.86	4.16	3.43	.642	25.	4.
APR	6.68	6.70	6.57	6.29	5.86	5.30	4.62	3.85	3.03	2.23	.646	26.	4.
MAY	6.42	6.26	5.96	5.54	5.00	4.35	3.64	2.90	2.17	1.65	.599	27.	3.
JUN	6.18	5.95	5.59	5.12	4.55	3.89	3.21	2.50	1.88	1.63	.571	28.	3.
JUL	6.57	6.35	5.99	5.51	4.91	4.21	3.48	2.71	2.00	1.63	.608	28.	3.
AUG	6.31	6.25	6.05	5.71	5.25	4.68	4.01	3.28	2.53	1.86	.599	28.	3.
SEP	5.75	5.89	5.90	5.78	5.52	5.14	4.65	4.06	3.39	2.70	.584	28.	3.
OCT	5.00	5.33	5.53	5.61	5.55	5.36	5.05	4.63	4.10	3.54	.569	27.	3.
NOV	4.52	5.00	5.38	5.62	5.72	5.69	5.51	5.21	4.78	4.28	.592	26.	3.
DEC	4.14	4.67	5.09	5.39	5.56	5.59	5.48	5.23	4.86	4.42	.587	25.	3.
YRT	2046.	2110.	2125.	2092.	2011.	1883.	1718.	1518.	1296.	1095.			

GULKANA, AK

62.15 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.23	.43	.62	.79	.94	1.07	1.17	1.23	1.26	2.94	.380	-23.	2.
FEB	.90	1.32	1.71	2.05	2.34	2.56	2.72	2.80	2.80	2.94	.488	-16.	2.
MAR	2.39	3.00	3.53	3.98	4.32	4.55	4.66	4.65	4.52	4.31	.575	-10.	3.
APR	4.11	4.61	5.01	5.28	5.43	5.44	5.32	5.08	4.72	4.28	.568	0.	4.
MAY	5.09	5.37	5.54	5.60	5.54	5.36	5.06	4.68	4.21	3.67	.515	7.	4.
JUN	5.54	5.71	5.78	5.73	5.59	5.33	4.96	4.53	4.01	3.43	.491	13.	4.
JUL	5.08	5.28	5.38	5.37	5.26	5.05	4.72	4.33	3.86	3.32	.475	14.	4.
AUG	3.94	4.26	4.48	4.61	4.63	4.55	4.36	4.10	3.74	3.36	.469	12.	4.
SEP	2.51	2.92	3.27	3.54	3.72	3.82	3.82	3.73	3.55	3.35	.468	6.	3.
OCT	1.23	1.64	2.02	2.35	2.61	2.81	2.93	2.98	2.94	3.05	.466	-3.	3.
NOV	.37	.62	.86	1.08	1.26	1.42	1.53	1.60	1.63	1.96	.406	-14.	2.
DEC	.09	.16	.22	.27	.32	.36	.40	.42	.43	.79	.259	-20.	2.
YRT	961.	1077.	1171.	1238.	1278.	1288.	1268.	1220.	1145.	1138.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

HILO, HI

19.72 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	3.53	3.89	4.16	4.34	4.41	4.39	4.26	4.04	3.72	3.41	.479	21.	3.
FEB	3.94	4.21	4.40	4.48	4.47	4.36	4.15	3.85	3.46	3.09	.470	21.	4.
MAR	4.25	4.39	4.44	4.40	4.26	4.03	3.72	3.33	2.88	2.47	.448	21.	3.
APR	4.52	4.52	4.44	4.26	3.99	3.65	3.23	2.77	2.26	1.83	.437	22.	3.
MAY	4.90	4.79	4.58	4.29	3.91	3.46	2.96	2.44	1.92	1.57	.457	23.	3.
JUN	5.23	5.05	4.77	4.40	3.94	3.41	2.87	2.30	1.79	1.61	.483	23.	3.
JUL	5.12	4.97	4.72	4.38	3.95	3.45	2.92	2.36	1.84	1.59	.475	24.	3.
AUG	5.02	4.97	4.82	4.57	4.22	3.80	3.30	2.76	2.20	1.73	.477	24.	3.
SEP	4.87	4.97	4.97	4.86	4.64	4.33	3.92	3.44	2.90	2.39	.495	24.	3.
OCT	4.33	4.58	4.73	4.78	4.71	4.54	4.28	3.92	3.48	3.05	.492	24.	3.
NOV	3.49	3.80	4.03	4.16	4.21	4.16	4.01	3.78	3.46	3.14	.455	23.	3.
DEC	3.21	3.56	3.82	4.00	4.09	4.08	3.98	3.79	3.51	3.23	.454	22.	3.
YRT	1594.	1634.	1639.	1609.	1545.	1448.	1325.	1178.	1015.	884.			

HOMER, AK

59.63 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	.38	.64	.88	1.10	1.28	1.44	1.55	1.62	1.64	2.25	.409	-7.	3.
FEB	1.05	1.45	1.81	2.12	2.38	2.58	2.71	2.77	2.75	2.86	.464	-4.	3.
MAR	2.39	2.90	3.34	3.70	3.97	4.13	4.19	4.14	3.99	3.81	.524	-3.	3.
APR	3.93	4.34	4.66	4.86	4.95	4.92	4.77	4.53	4.18	3.78	.522	2.	3.
MAY	4.99	5.24	5.37	5.40	5.31	5.11	4.80	4.42	3.94	3.41	.498	6.	4.
JUN	5.52	5.67	5.72	5.65	5.49	5.21	4.83	4.38	3.86	3.27	.489	10.	3.
JUL	5.04	5.22	5.29	5.26	5.14	4.90	4.56	4.16	3.69	3.15	.467	12.	3.
AUG	3.75	4.00	4.18	4.26	4.26	4.15	3.96	3.70	3.36	2.99	.433	12.	3.
SEP	2.49	2.85	3.14	3.36	3.50	3.55	3.53	3.42	3.23	3.02	.435	9.	3.
OCT	1.38	1.77	2.12	2.42	2.66	2.84	2.93	2.96	2.90	2.97	.450	3.	3.
NOV	.55	.86	1.15	1.42	1.64	1.82	1.94	2.02	2.04	2.38	.436	-2.	3.
DEC	.20	.34	.47	.59	.69	.78	.84	.88	.90	1.38	.316	-5.	3.
YRT	966.	1076.	1162.	1223.	1257.	1261.	1236.	1186.	1109.	1072.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

HONOLULU, HI

21.33 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.72	4.14	4.47	4.69	4.81	4.80	4.69	4.46	4.13	3.77	.522	22.	4.
FEB	4.41	4.77	5.03	5.17	5.19	5.09	4.86	4.53	4.10	3.64	.540	22.	5.
MAR	5.11	5.33	5.43	5.41	5.26	5.00	4.62	4.15	3.59	3.03	.546	23.	5.
APR	5.66	5.69	5.59	5.38	5.04	4.60	4.06	3.45	2.78	2.16	.548	24.	5.
MAY	6.15	6.01	5.75	5.36	4.87	4.27	3.61	2.92	2.22	1.69	.571	25.	5.
JUN	6.32	6.10	5.74	5.28	4.71	4.04	3.35	2.62	1.96	1.66	.580	25.	6.
JUL	6.31	6.13	5.80	5.37	4.82	4.17	3.48	2.76	2.08	1.65	.581	26.	6.
AUG	6.20	6.15	5.97	5.66	5.23	4.68	4.04	3.33	2.61	1.95	.588	26.	6.
SEP	5.70	5.87	5.89	5.79	5.55	5.18	4.71	4.13	3.47	2.80	.584	26.	5.
OCT	4.86	5.20	5.41	5.50	5.46	5.30	5.01	4.60	4.10	3.57	.563	26.	5.
NOV	3.99	4.42	4.74	4.95	5.05	5.02	4.88	4.62	4.25	3.84	.538	24.	5.
DEC	3.57	4.01	4.36	4.61	4.74	4.77	4.68	4.47	4.16	3.82	.523	23	5.
YRT	1887.	1942.	1953.	1922.	1847.	1731.	1580.	1399.	1198.	1020.			

INDIANAPOLIS, IN

39.73 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.56	1.85	2.09	2.28	2.43	2.51	2.53	2.50	2.40	2.43	.377	-3.	5.
FEB	2.35	2.67	2.94	3.14	3.26	3.31	3.28	3.18	3.00	2.81	.425	-1.	5.
MAR	3.27	3.55	3.75	3.87	3.90	3.84	3.70	3.48	3.18	2.88	.438	4.	5.
APR	4.40	4.58	4.66	4.64	4.52	4.31	4.00	3.61	3.16	2.71	.465	11.	5.
MAY	5.32	5.39	5.34	5.17	4.90	4.54	4.10	3.57	3.00	2.46	.491	17.	4.
JUN	5.89	5.89	5.76	5.51	5.15	4.71	4.18	3.57	2.96	2.36	.514	22.	4.
JUL	5.69	5.72	5.63	5.41	5.08	4.68	4.18	3.60	3.00	2.41	.508	24.	3.
AUG	5.18	5.33	5.36	5.28	5.07	4.77	4.37	3.89	3.32	2.77	.513	23.	3.
SEP	4.17	4.47	4.66	4.75	4.73	4.61	4.38	4.05	3.64	3.20	.504	19.	4.
OCT	3.08	3.47	3.78	4.01	4.14	4.17	4.10	3.93	3.67	3.39	.493	13.	4.
NOV	1.83	2.14	2.41	2.62	2.77	2.86	2.87	2.82	2.70	2.66	.403	5.	5.
DEC	1.31	1.56	1.77	1.94	2.06	2.14	2.17	2.14	2.07	2.09	.348	0.	5.
YRT	1343.	1420.	1466.	1480.	1461.	1413.	1334.	1227.	1098.	977.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

KANSAS CITY, MO

39.12 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.04	2.47	2.84	3.14	3.37	3.51	3.56	3.52	3.40	3.33	.480	-2.	4.
FEB	2.82	3.24	3.58	3.84	4.01	4.09	4.06	3.93	3.71	3.46	.500	1.	5.
MAR	3.79	4.13	4.38	4.54	4.58	4.52	4.35	4.09	3.73	3.35	.503	6.	5.
APR	4.97	5.18	5.28	5.26	5.12	4.87	4.52	4.07	3.54	2.99	.522	14.	5.
MAY	5.90	5.97	5.92	5.73	5.41	5.01	4.50	3.90	3.25	2.62	.544	19.	5.
JUN	6.55	6.55	6.40	6.11	5.68	5.18	4.56	3.86	3.17	2.47	.572	24.	4.
JUL	6.63	6.66	6.55	6.28	5.88	5.38	4.77	4.07	3.34	2.62	.591	27.	4.
AUG	5.87	6.05	6.09	5.99	5.76	5.41	4.94	4.37	3.70	3.04	.579	26.	4.
SEP	4.58	4.91	5.14	5.24	5.23	5.09	4.83	4.46	4.00	3.49	.549	21.	4.
OCT	3.44	3.90	4.27	4.54	4.69	4.74	4.66	4.47	4.18	3.84	.543	15.	4.
NOV	2.32	2.77	3.16	3.47	3.70	3.83	3.87	3.81	3.65	3.56	.502	7.	4.
DEC	1.77	2.17	2.51	2.80	3.02	3.16	3.22	3.20	3.10	3.08	.456	1.	4.
YRT	1544.	1645.	1709.	1733.	1718.	1667.	1577.	1453.	1301.	1151.			

KINGSVILLE, TX

27.52 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.87	3.24	3.54	3.76	3.89	3.93	3.88	3.73	3.50	3.24	.467	14.	4.
FEB	3.66	4.02	4.29	4.46	4.52	4.49	4.34	4.10	3.77	3.40	.498	15.	4.
MAR	4.52	4.78	4.93	4.96	4.89	4.71	4.42	4.03	3.57	3.08	.513	19.	5.
APR	5.24	5.33	5.30	5.16	4.91	4.55	4.10	3.57	2.98	2.40	.516	23.	5.
MAY	5.88	5.82	5.64	5.34	4.93	4.43	3.83	3.20	2.54	1.96	.539	25.	5.
JUN	6.42	6.27	5.98	5.57	5.07	4.45	3.77	3.07	2.36	1.81	.573	28.	5.
JUL	6.66	6.54	6.27	5.87	5.36	4.74	4.02	3.29	2.53	1.90	.601	29.	4.
AUG	6.06	6.09	5.99	5.75	5.40	4.92	4.34	3.68	2.98	2.30	.577	29.	4.
SEP	5.12	5.33	5.42	5.39	5.24	4.97	4.59	4.11	3.55	2.96	.546	27.	3.
OCT	4.39	4.77	5.04	5.20	5.23	5.14	4.93	4.60	4.17	3.70	.554	23.	3.
NOV	3.26	3.66	3.98	4.21	4.34	4.37	4.29	4.11	3.83	3.52	.502	18.	4.
DEC	2.67	3.05	3.35	3.58	3.73	3.78	3.75	3.62	3.42	3.18	.459	14.	4.
YRT	1728.	1793.	1819.	1804.	1750.	1657.	1528.	1372.	1191.	1017.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

KOROR IS, PI

7.33 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	4.41	4.69	4.87	4.95	4.91	4.76	4.51	4.15	3.72	3.25	.486	27.	3.
FEB	4.92	5.12	5.22	5.19	5.06	4.81	4.45	4.01	3.48	2.94	.509	27.	4.
MAR	5.13	5.19	5.13	4.96	4.69	4.31	3.85	3.32	2.73	2.15	.505	27.	3.
APR	5.33	5.21	4.98	4.65	4.22	3.70	3.12	2.51	1.88	1.53	.518	27.	3.
MAY	4.94	4.71	4.39	3.98	3.49	2.96	2.40	1.86	1.52	1.48	.491	27.	3.
JUN	4.59	4.33	3.99	3.57	3.09	2.58	2.07	1.62	1.46	1.43	.464	27.	2.
JUL	4.54	4.32	4.00	3.60	3.14	2.66	2.14	1.68	1.46	1.43	.456	27.	3.
AUG	4.67	4.52	4.28	3.96	3.55	3.08	2.58	2.06	1.58	1.46	.458	27.	3.
SEP	4.80	4.79	4.67	4.46	4.15	3.77	3.31	2.79	2.23	1.70	.470	27.	3.
OCT	4.75	4.88	4.91	4.84	4.66	4.37	4.00	3.55	3.04	2.52	.481	27.	3.
NOV	4.57	4.83	4.99	5.04	4.98	4.80	4.52	4.14	3.67	3.19	.495	27.	3.
DEC	4.22	4.52	4.72	4.82	4.80	4.68	4.45	4.13	3.72	3.28	.476	27.	3.
YRT	1729.	1736.	1707.	1641.	1541.	1412.	1257.	1087.	925.	801.			

KWAJALEIN IS, PI

8.72 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	4.97	5.34	5.60	5.72	5.71	5.57	5.29	4.90	4.39	3.84	.558	27.	8.
FEB	5.53	5.81	5.95	5.96	5.82	5.56	5.16	4.65	4.05	3.41	.580	27.	8.
MAR	5.66	5.74	5.70	5.53	5.23	4.82	4.31	3.71	3.04	2.38	.560	27.	7.
APR	5.48	5.38	5.15	4.82	4.38	3.86	3.26	2.63	1.98	1.54	.531	27.	7.
MAY	5.12	4.90	4.58	4.16	3.66	3.11	2.53	1.97	1.54	1.51	.504	28.	7.
JUN	5.07	4.79	4.41	3.94	3.40	2.84	2.25	1.74	1.52	1.49	.507	28.	6.
JUL	5.07	4.82	4.46	4.02	3.49	2.94	2.35	1.82	1.53	1.50	.503	28.	5.
AUG	5.31	5.15	4.88	4.51	4.04	3.49	2.90	2.29	1.71	1.53	.518	28.	4.
SEP	5.08	5.08	4.97	4.76	4.44	4.03	3.55	3.00	2.40	1.83	.498	28.	4.
OCT	4.81	4.96	5.01	4.94	4.77	4.50	4.13	3.68	3.16	2.63	.492	28.	5.
NOV	4.60	4.89	5.07	5.14	5.09	4.92	4.65	4.27	3.81	3.31	.507	28.	6.
DEC	4.58	4.95	5.20	5.34	5.35	5.24	5.01	4.66	4.21	3.72	.527	27.	8.
YRT	1863.	1879.	1853.	1787.	1682.	1545.	1378.	1193.	1011.	871.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

LA CROSSE, WI

43.87 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.52	1.89	2.22	2.49	2.70	2.85	2.92	2.92	2.84	3.04	.440	-9.	4.
FEB	2.41	2.84	3.20	3.49	3.70	3.81	3.83	3.75	3.58	3.37	.494	-6.	3.
MAR	3.47	3.85	4.14	4.33	4.42	4.41	4.30	4.08	3.77	3.43	.501	-1.	4.
APR	4.50	4.73	4.86	4.88	4.80	4.61	4.32	3.94	3.49	3.01	.492	8.	5.
MAY	5.40	5.51	5.50	5.37	5.13	4.79	4.36	3.85	3.27	2.71	.503	15.	4.
JUN	6.01	6.04	5.96	5.75	5.41	4.98	4.47	3.87	3.24	2.62	.524	20.	4.
JUL	5.99	6.07	6.02	5.83	5.52	5.11	4.61	4.02	3.37	2.75	.536	22.	3.
AUG	5.25	5.46	5.54	5.50	5.33	5.06	4.68	4.20	3.64	3.07	.532	21.	3.
SEP	3.91	4.24	4.47	4.59	4.62	4.53	4.35	4.06	3.69	3.30	.500	16.	4.
OCT	2.72	3.12	3.45	3.69	3.85	3.92	3.89	3.77	3.55	3.32	.484	10.	4.
NOV	1.56	1.88	2.16	2.39	2.56	2.67	2.72	2.70	2.61	2.58	.405	2.	4.
DEC	1.16	1.44	1.69	1.90	2.06	2.17	2.23	2.24	2.18	2.20	.379	-6.	4.
YRT	1338.	1433.	1498.	1529.	1524.	1488.	1419.	1319.	1192.	1075.			

LAKE CHARLES, LA

30.12 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.29	2.59	2.82	3.00	3.11	3.14	3.10	3.00	2.82	2.65	.400	11.	4.
FEB	3.18	3.51	3.76	3.92	3.99	3.97	3.86	3.66	3.38	3.10	.456	12.	5.
MAR	4.14	4.39	4.55	4.60	4.55	4.40	4.16	3.82	3.41	2.99	.484	16.	5.
APR	4.95	5.06	5.06	4.94	4.73	4.41	4.01	3.53	2.98	2.45	.493	20.	5.
MAY	5.83	5.81	5.65	5.37	5.00	4.52	3.95	3.33	2.69	2.11	.534	24.	4.
JUN	6.21	6.10	5.86	5.48	5.03	4.47	3.82	3.16	2.48	1.93	.551	26.	3.
JUL	5.63	5.57	5.38	5.08	4.69	4.21	3.66	3.07	2.46	1.94	.506	27.	3.
AUG	5.23	5.28	5.21	5.03	4.76	4.38	3.92	3.38	2.80	2.27	.500	27.	3.
SEP	4.68	4.89	5.00	4.99	4.87	4.64	4.32	3.90	3.40	2.90	.510	25.	3.
OCT	4.12	4.51	4.80	4.97	5.03	4.97	4.80	4.51	4.11	3.69	.542	20.	3.
NOV	2.88	3.26	3.57	3.79	3.93	3.97	3.92	3.77	3.53	3.28	.474	15.	4.
DEC	2.22	2.54	2.80	3.00	3.13	3.19	3.17	3.08	2.92	2.75	.412	12.	4.
YRT	1564.	1628.	1657.	1649.	1607.	1530.	1419.	1283.	1124.	974.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

LIHUE KAUAI, HI

21.98 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.48	3.87	4.17	4.37	4.48	4.47	4.37	4.16	3.85	3.52	.495	22.	5.
FEB	4.10	4.43	4.67	4.79	4.81	4.71	4.51	4.21	3.81	3.40	.507	22.	5.
MAR	4.65	4.84	4.93	4.91	4.78	4.54	4.21	3.79	3.30	2.81	.500	22.	5.
APR	5.17	5.20	5.12	4.93	4.64	4.25	3.77	3.23	2.64	2.09	.501	23.	6.
MAY	5.75	5.64	5.40	5.06	4.61	4.07	3.46	2.84	2.20	1.70	.533	24.	5.
JUN	5.89	5.70	5.39	4.97	4.46	3.86	3.24	2.57	1.97	1.65	.538	25.	6.
JUL	5.87	5.71	5.43	5.04	4.55	3.97	3.34	2.69	2.06	1.64	.539	25.	6.
AUG	5.73	5.70	5.54	5.27	4.88	4.39	3.82	3.18	2.52	1.93	.544	26.	6.
SEP	5.49	5.65	5.68	5.59	5.36	5.02	4.57	4.02	3.39	2.76	.564	26.	5.
OCT	4.57	4.89	5.09	5.17	5.14	4.98	4.72	4.34	3.88	3.39	.534	25.	5.
NOV	3.64	4.01	4.29	4.48	4.56	4.53	4.40	4.16	3.83	3.48	.497	24.	5.
DEC	3.32	3.72	4.04	4.26	4.39	4.41	4.32	4.14	3.85	3.54	.494	22.	5.
YRT	1755.	1806.	1818.	1790.	1723.	1618.	1481.	1317.	1133.	970.			

LOVELOCK, NV

40.07 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.54	3.20	3.78	4.27	4.64	4.89	5.02	5.00	4.86	4.74	.620	-1.	2.
FEB	3.67	4.37	4.96	5.43	5.75	5.93	5.95	5.81	5.52	5.15	.670	2.	3.
MAR	5.23	5.85	6.33	6.66	6.81	6.79	6.59	6.22	5.70	5.10	.704	5.	3.
APR	6.83	7.22	7.44	7.47	7.32	6.99	6.49	5.84	5.05	4.20	.723	9.	4.
MAY	8.05	8.21	8.17	7.92	7.47	6.90	6.15	5.27	4.30	3.34	.744	15.	4.
JUN	8.66	8.68	8.50	8.10	7.51	6.80	5.94	4.94	3.94	2.93	.756	16.	4.
JUL	8.77	8.86	8.72	8.37	7.82	7.13	6.28	5.28	4.25	3.20	.782	25.	3.
AUG	7.83	8.16	8.27	8.18	7.88	7.41	6.76	5.95	5.00	4.01	.776	23.	3.
SEP	6.39	7.01	7.46	7.71	7.77	7.62	7.28	6.75	6.05	5.25	.775	18.	3.
OCT	4.57	5.36	6.01	6.50	6.83	6.97	6.93	6.70	6.29	5.77	.738	11.	3.
NOV	2.93	3.65	4.27	4.79	5.18	5.43	5.54	5.50	5.31	5.16	.655	3.	2.
DEC	2.25	2.89	3.45	3.93	4.31	4.56	4.70	4.71	4.60	4.54	.606	-1.	2.
YRT	2064.	2238.	2356.	2415.	2413.	2356.	2239.	2067.	1850.	1623.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

MEMPHIS, TN

35.05 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.15	2.51	2.81	3.04	3.21	3.30	3.30	3.23	3.08	3.04	.436	5.	5.
FEB	2.98	3.35	3.64	3.86	3.98	4.01	3.94	3.78	3.53	3.26	.476	7.	5.
MAR	4.03	4.34	4.55	4.66	4.67	4.56	4.36	4.05	3.66	3.24	.502	11.	5.
APR	5.16	5.34	5.40	5.33	5.15	4.86	4.46	3.97	3.41	2.82	.528	17.	5.
MAY	5.94	5.97	5.86	5.63	5.28	4.84	4.29	3.66	3.02	2.38	.545	22.	4.
JUN	6.44	6.39	6.20	5.86	5.42	4.88	4.25	3.56	2.86	2.21	.565	26.	4.
JUL	6.22	6.20	6.04	5.75	5.35	4.85	4.26	3.59	2.92	2.27	.555	27.	3.
AUG	5.75	5.87	5.86	5.72	5.45	5.07	4.58	4.00	3.34	2.71	.558	26.	3.
SEP	4.63	4.91	5.08	5.13	5.06	4.88	4.59	4.20	3.71	3.20	.530	23.	3.
OCT	3.80	4.24	4.58	4.81	4.93	4.93	4.80	4.57	4.22	3.82	.549	17.	3.
NOV	2.57	2.98	3.33	3.59	3.78	3.86	3.86	3.76	3.57	3.33	.486	11.	4.
DEC	1.98	2.34	2.65	2.90	3.08	3.18	3.21	3.15	3.02	2.87	.434	6.	4.
YRT	1573.	1658.	1705.	1713.	1684.	1619.	1518.	1385.	1226.	1068.			

MERIDIAN, MS

32.33 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.34	2.69	2.98	3.20	3.35	3.41	3.40	3.30	3.13	2.92	.436	8.	3.
FEB	3.19	3.55	3.84	4.03	4.14	4.14	4.05	3.86	3.59	3.28	.479	10.	3.
MAR	4.18	4.47	4.66	4.74	4.72	4.59	4.35	4.02	3.61	3.16	.503	14.	4.
APR	5.24	5.38	5.41	5.32	5.11	4.79	4.37	3.86	3.27	2.67	.527	19.	3.
MAY	5.86	5.86	5.73	5.47	5.11	4.65	4.09	3.46	2.83	2.21	.537	22.	3.
JUN	6.18	6.10	5.88	5.54	5.10	4.56	3.94	3.29	2.61	2.01	.546	26.	2.
JUL	5.74	5.70	5.53	5.24	4.86	4.39	3.83	3.23	2.61	2.04	.514	27.	2.
AUG	5.49	5.56	5.52	5.35	5.08	4.70	4.22	3.66	3.04	2.44	.527	26.	2.
SEP	4.58	4.81	4.94	4.96	4.86	4.66	4.35	3.95	3.47	2.96	.510	24.	2.
OCT	3.97	4.38	4.69	4.89	4.97	4.94	4.79	4.52	4.15	3.73	.544	18.	2.
NOV	2.82	3.23	3.57	3.82	3.99	4.05	4.02	3.89	3.67	3.40	.492	12.	3.
DEC	2.20	2.56	2.87	3.11	3.27	3.36	3.36	3.29	3.13	2.96	.438	9.	3.
YRT	1577.	1653.	1693.	1694.	1659.	1589.	1483.	1348.	1188.	1027.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

MILES CITY, MT

46.43 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.44	1.86	2.23	2.54	2.80	2.98	3.08	3.10	3.04	2.96	.478	-10.	4.
FEB	2.34	2.84	3.26	3.61	3.87	4.02	4.08	4.03	3.88	3.67	.527	-5.	4.
MAR	3.74	4.23	4.62	4.91	5.07	5.11	5.02	4.80	4.48	4.08	.569	0.	5.
APR	4.86	5.17	5.36	5.43	5.37	5.19	4.90	4.50	4.00	3.46	.545	7.	5.
MAY	5.97	6.14	6.17	6.06	5.82	5.45	4.99	4.43	3.77	3.13	.561	14.	5.
JUN	6.76	6.84	6.77	6.57	6.21	5.73	5.16	4.49	3.75	3.04	.590	19.	5.
JUL	7.23	7.37	7.36	7.17	6.82	6.32	5.72	4.99	4.16	3.38	.649	24.	4.
AUG	6.23	6.55	6.72	6.73	6.58	6.27	5.84	5.27	4.58	3.86	.642	23.	4.
SEP	4.55	5.03	5.39	5.63	5.72	5.67	5.49	5.17	4.73	4.24	.605	15.	4.
OCT	3.02	3.58	4.05	4.42	4.68	4.82	4.84	4.73	4.50	4.23	.579	9.	4.
NOV	1.74	2.21	2.63	2.98	3.25	3.45	3.55	3.56	3.48	3.42	.510	0.	4.
DEC	1.26	1.66	2.03	2.34	2.60	2.78	2.90	2.93	2.89	2.89	.476	-5.	4.
YRT	1499.	1630.	1725.	1778.	1790.	1760.	1691.	1582.	1438.	1288.			

MISSOULA, MT

46.92 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.98	1.20	1.39	1.55	1.68	1.76	1.80	1.80	1.76	1.78	.334	-5.	2.
FEB	1.80	2.13	2.41	2.64	2.80	2.90	2.92	2.88	2.76	2.69	.413	-2.	3.
MAR	3.10	3.46	3.75	3.95	4.06	4.08	3.99	3.82	3.56	3.28	.476	1.	3.
APR	4.36	4.62	4.78	4.83	4.77	4.61	4.36	4.00	3.57	3.13	.491	6.	3.
MAY	5.62	5.77	5.80	5.70	5.47	5.14	4.71	4.19	3.59	2.99	.529	11.	3.
JUN	6.09	6.16	6.10	5.92	5.61	5.19	4.69	4.10	3.45	2.83	.532	15.	3.
JUL	7.34	7.49	7.48	7.30	6.95	6.45	5.84	5.11	4.26	3.46	.659	20.	3.
AUG	5.92	6.23	6.39	6.39	6.25	5.97	5.56	5.03	4.38	3.71	.612	19.	3.
SEP	4.28	4.72	5.06	5.27	5.36	5.32	5.15	4.85	4.44	4.00	.574	13.	3.
OCT	2.56	2.99	3.35	3.63	3.82	3.92	3.92	3.83	3.64	3.43	.497	6.	2.
NOV	1.29	1.59	1.85	2.07	2.24	2.36	2.41	2.41	2.34	2.33	.389	0.	2.
DEC	.84	1.05	1.23	1.39	1.51	1.60	1.64	1.65	1.62	1.65	.329	-4.	2.
YRT	1348.	1446.	1512.	1544.	1540.	1501.	1432.	1330.	1199.	1074.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

NAKNEK, AK

58.68 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)									KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	.46	.75	1.02	1.26	1.47	1.64	1.76	1.84	1.86	1.95	.431	-12.	5.
FEB	1.19	1.63	2.02	2.37	2.65	2.87	3.01	3.06	3.04	3.04	.492	-10.	5.
MAR	2.52	3.04	3.49	3.85	4.12	4.28	4.33	4.28	4.11	3.91	.534	-7.	5.
APR	3.80	4.16	4.44	4.61	4.68	4.63	4.48	4.24	3.90	3.51	.497	-1.	5.
MAY	4.67	4.89	4.99	5.01	4.92	4.72	4.42	4.06	3.62	3.12	.464	6.	5.
JUN	4.85	4.97	5.00	4.93	4.77	4.52	4.18	3.79	3.34	2.84	.429	10.	5.
JUL	4.36	4.50	4.54	4.50	4.38	4.17	3.87	3.53	3.13	2.68	.404	12.	4.
AUG	3.30	3.49	3.62	3.67	3.64	3.54	3.37	3.13	2.84	2.52	.377	12.	5.
SEP	2.45	2.77	3.04	3.23	3.35	3.39	3.36	3.24	3.05	2.85	.417	8.	5.
OCT	1.49	1.91	2.27	2.59	2.84	3.01	3.11	3.13	3.06	3.10	.463	1.	5.
NOV	.64	.98	1.30	1.59	1.83	2.02	2.16	2.24	2.26	2.60	.454	-5.	5.
DEC	.28	.49	.69	.87	1.03	1.15	1.25	1.31	1.33	1.89	.376	-11.	5.
YRT	915.	1023.	1109.	1171.	1207.	1215.	1195.	1151.	1080.	1033.			

NOME, AK

64.50 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)									KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	.09	.18	.26	.34	.41	.47	.51	.54	.55	1.12	.286	-15.	5.
FEB	.70	1.09	1.46	1.79	2.07	2.29	2.45	2.54	2.56	2.91	.478	-16.	5.
MAR	1.99	2.53	3.00	3.40	3.72	3.94	4.05	4.06	3.96	3.82	.529	-14.	5.
APR	3.74	4.22	4.60	4.87	5.03	5.06	4.97	4.77	4.46	4.07	.538	-8.	5.
MAY	4.96	5.25	5.43	5.51	5.48	5.32	5.05	4.69	4.24	3.71	.508	2.	5.
JUN	5.53	5.71	5.79	5.76	5.64	5.40	5.05	4.63	4.13	3.55	.489	8.	4.
JUL	4.46	4.63	4.72	4.71	4.63	4.45	4.18	3.85	3.46	3.01	.418	10.	5.
AUG	3.13	3.36	3.52	3.62	3.63	3.57	3.43	3.23	2.97	2.66	.382	10.	5.
SEP	2.41	2.85	3.23	3.54	3.76	3.88	3.91	3.84	3.68	3.48	.482	6.	5.
OCT	.96	1.32	1.64	1.93	2.17	2.34	2.46	2.51	2.50	2.61	.428	-2.	5.
NOV	.20	.37	.53	.67	.80	.91	.99	1.04	1.06	1.73	.346	-9.	5.
DEC	.02	.02	.02	.02	.02	.02	.02	.02	.01	.86	.054	-15.	4.
YRT	860.	961.	1042.	1101.	1136.	1145.	1127.	1085.	1020.	1018.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

NORFOLK, VA

36.90 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.14	2.54	2.88	3.15	3.35	3.46	3.49	3.44	3.29	3.27	.463	5.	5.
FEB	2.93	3.33	3.66	3.89	4.04	4.09	4.04	3.90	3.66	3.40	.491	5.	5.
MAR	4.04	4.38	4.63	4.77	4.79	4.71	4.52	4.22	3.83	3.42	.517	9.	5.
APR	5.29	5.49	5.58	5.53	5.37	5.08	4.69	4.19	3.61	3.02	.547	14.	5.
MAY	5.95	6.00	5.91	5.69	5.36	4.93	4.40	3.78	3.13	2.51	.546	19.	5.
JUN	6.31	6.28	6.11	5.80	5.39	4.88	4.28	3.61	2.94	2.28	.552	23.	4.
JUL	5.84	5.84	5.72	5.47	5.11	4.66	4.13	3.52	2.90	2.28	.521	25.	4.
AUG	5.30	5.42	5.43	5.31	5.08	4.75	4.32	3.80	3.22	2.63	.518	25.	4.
SEP	4.40	4.67	4.85	4.91	4.87	4.71	4.45	4.08	3.64	3.15	.513	22.	4.
OCT	3.42	3.82	4.13	4.35	4.46	4.47	4.37	4.17	3.87	3.52	.513	16.	5.
NOV	2.55	3.01	3.40	3.71	3.93	4.05	4.06	3.98	3.80	3.67	.512	11.	5.
DEC	1.97	2.37	2.72	3.01	3.22	3.35	3.40	3.36	3.24	3.18	.462	6.	5.
YRT	1526.	1618.	1674.	1692.	1672.	1617.	1525.	1400.	1250.	1104.			

OAKLAND, CA

37.73 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.23	2.68	3.07	3.38	3.61	3.75	3.80	3.75	3.60	3.51	.497	9.	3.
FEB	3.20	3.69	4.09	4.40	4.59	4.67	4.64	4.49	4.23	3.90	.548	11.	3.
MAR	4.59	5.04	5.37	5.57	5.63	5.56	5.35	5.02	4.57	4.04	.596	12.	4.
APR	6.06	6.34	6.47	6.44	6.27	5.95	5.49	4.91	4.23	3.48	.631	13.	4.
MAY	6.97	7.05	6.97	6.72	6.33	5.81	5.17	4.42	3.62	2.82	.641	14.	5.
JUN	7.41	7.39	7.19	6.83	6.33	5.72	4.99	4.17	3.34	2.53	.648	16.	4.
JUL	7.32	7.34	7.19	6.87	6.41	5.83	5.12	4.31	3.49	2.65	.653	17.	4.
AUG	6.47	6.66	6.70	6.58	6.30	5.89	5.35	4.70	3.94	3.17	.634	17.	4.
SEP	5.36	5.77	6.05	6.18	6.16	5.99	5.67	5.22	4.65	4.01	.632	17.	4.
OCT	3.82	4.33	4.74	5.03	5.20	5.24	5.15	4.93	4.59	4.18	.584	16.	3.
NOV	2.59	3.09	3.51	3.85	4.10	4.24	4.27	4.20	4.01	3.89	.534	13.	3.
DEC	2.04	2.50	2.89	3.21	3.46	3.62	3.68	3.65	3.53	3.48	.496	9.	3.
YRT	1769.	1885.	1956.	1981.	1959.	1894.	1785.	1635.	1453.	1266.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

ORLANDO, FL

28.55 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	3.14	3.59	3.97	4.24	4.42	4.49	4.45	4.30	4.04	3.73	.524	15.	4.
FEB	3.92	4.35	4.68	4.89	4.99	4.98	4.84	4.58	4.22	3.80	.544	16.	5.
MAR	4.99	5.31	5.51	5.58	5.52	5.33	5.02	4.59	4.07	3.49	.572	18.	5.
APR	5.98	6.11	6.11	5.96	5.68	5.27	4.75	4.12	3.42	2.71	.592	22.	4.
MAY	6.27	6.23	6.04	5.72	5.29	4.75	4.11	3.43	2.72	2.06	.575	25.	4.
JUN	5.77	5.66	5.42	5.07	4.64	4.12	3.53	2.93	2.31	1.79	.514	26.	4.
JUL	5.68	5.60	5.39	5.07	4.67	4.17	3.60	3.01	2.38	1.84	.511	27.	3.
AUG	5.28	5.31	5.23	5.04	4.74	4.35	3.88	3.33	2.74	2.17	.503	27.	3.
SEP	4.71	4.91	5.00	4.97	4.84	4.60	4.26	3.83	3.32	2.79	.507	26.	4.
OCT	4.12	4.48	4.74	4.89	4.93	4.85	4.66	4.36	3.96	3.51	.529	23.	4.
NOV	3.45	3.93	4.31	4.59	4.76	4.81	4.75	4.56	4.27	3.91	.546	19.	4.
DEC	2.91	3.37	3.75	4.05	4.24	4.33	4.31	4.19	3.96	3.67	.516	16.	4.
YRT	1711.	1791.	1829.	1827.	1786.	1704.	1584.	1435.	1258.	1077.			

PENDLETON, OR

45.68 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.09	1.33	1.53	1.71	1.84	1.93	1.97	1.97	1.91	1.85	.346	1.	4.
FEB	1.93	2.27	2.55	2.78	2.95	3.04	3.06	3.00	2.87	2.71	.422	4.	4.
MAR	3.29	3.67	3.96	4.17	4.28	4.28	4.19	3.99	3.71	3.37	.493	6.	5.
APR	4.74	5.02	5.19	5.24	5.18	4.99	4.70	4.31	3.83	3.29	.527	10.	5.
MAY	6.07	6.23	6.25	6.13	5.88	5.50	5.02	4.44	3.78	3.10	.569	15.	5.
JUN	6.76	6.83	6.76	6.54	6.17	5.69	5.11	4.43	3.70	2.97	.590	19.	5.
JUL	7.55	7.70	7.67	7.47	7.08	6.56	5.91	5.14	4.27	3.41	.677	24.	4.
AUG	6.29	6.60	6.76	6.75	6.59	6.27	5.83	5.25	4.55	3.80	.644	22.	4.
SEP	4.73	5.23	5.60	5.84	5.93	5.88	5.68	5.34	4.88	4.34	.622	18.	4.
OCT	2.86	3.34	3.75	4.06	4.28	4.39	4.39	4.27	4.06	3.79	.535	11.	4.
NOV	1.38	1.69	1.95	2.17	2.34	2.45	2.50	2.49	2.41	2.38	.391	5.	4.
DEC	.92	1.14	1.33	1.49	1.61	1.70	1.74	1.75	1.71	1.72	.334	2.	4.
YRT	1453.	1557.	1626.	1657.	1649.	1605.	1526.	1412.	1268.	1118.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

PHILADELPHIA, PA

39.88 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.75	2.10	2.41	2.65	2.84	2.95	2.99	2.96	2.85	2.78	.425	0.	5.
FEB	2.50	2.86	3.16	3.39	3.53	3.60	3.57	3.46	3.27	3.05	.454	1.	5.
MAR	3.49	3.81	4.04	4.17	4.22	4.16	4.01	3.77	3.45	3.11	.470	5.	5.
APR	4.52	4.71	4.80	4.78	4.65	4.43	4.12	3.72	3.25	2.77	.478	12.	5.
MAY	5.23	5.29	5.25	5.09	4.82	4.47	4.04	3.52	2.97	2.42	.483	17.	4.
JUN	5.71	5.71	5.59	5.35	5.00	4.58	4.07	3.49	2.90	2.31	.498	22.	4.
JUL	5.54	5.57	5.48	5.27	4.95	4.56	4.08	3.52	2.94	2.36	.494	25.	4.
AUG	4.96	5.10	5.13	5.05	4.86	4.57	4.19	3.73	3.20	2.66	.492	24.	4.
SEP	4.04	4.32	4.50	4.59	4.57	4.44	4.22	3.91	3.51	3.08	.489	20.	4.
OCT	3.02	3.40	3.71	3.93	4.05	4.08	4.01	3.85	3.60	3.31	.485	14.	4.
NOV	1.95	2.31	2.61	2.86	3.03	3.14	3.16	3.11	2.98	2.91	.434	8.	4.
DEC	1.48	1.79	2.07	2.29	2.46	2.56	2.61	2.59	2.51	2.49	.396	2.	5.
YRT	1347.	1431.	1484.	1504.	1490.	1447.	1371.	1266.	1138.	1010.			

PHOENIX, AZ

33.43 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.21	3.85	4.39	4.83	5.14	5.31	5.35	5.25	5.01	4.77	.619	11.	2.
FEB	4.33	4.98	5.50	5.89	6.13	6.21	6.13	5.89	5.50	5.02	.667	13.	3.
MAR	5.72	6.25	6.62	6.83	6.86	6.72	6.42	5.95	5.34	4.65	.697	16.	3.
APR	7.42	7.72	7.83	7.74	7.46	7.00	6.37	5.59	4.68	3.70	.752	20.	3.
MAY	8.44	8.47	8.29	7.90	7.35	6.64	5.77	4.77	3.76	2.74	.773	26.	3.
JUN	8.64	8.53	8.21	7.69	7.02	6.21	5.26	4.26	3.22	2.28	.760	31.	3.
JUL	7.84	7.79	7.55	7.14	6.58	5.89	5.07	4.18	3.27	2.40	.700	34.	3.
AUG	7.23	7.38	7.36	7.15	6.79	6.27	5.61	4.82	3.93	3.06	.697	32.	3.
SEP	6.35	6.79	7.07	7.16	7.08	6.82	6.39	5.81	5.09	4.28	.714	29.	3.
OCT	4.97	5.61	6.11	6.46	6.64	6.65	6.49	6.16	5.68	5.09	.696	23.	3.
NOV	3.62	4.30	4.86	5.31	5.62	5.78	5.79	5.65	5.36	4.97	.652	15.	2.
DEC	2.94	3.57	4.11	4.55	4.88	5.07	5.14	5.07	4.86	4.57	.607	11.	2.
YRT	2153.	2290.	2371.	2393.	2358.	2268.	2121.	1926.	1692.	1443.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

POCATELLO, ID

42.92 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.70	2.12	2.48	2.79	3.02	3.18	3.26	3.26	3.17	3.04	.471	-4.	5.
FEB	2.77	3.29	3.74	4.09	4.33	4.47	4.50	4.41	4.21	3.93	.552	-2.	5.
MAR	4.33	4.85	5.26	5.54	5.69	5.69	5.55	5.27	4.87	4.38	.614	2.	5.
APR	5.74	6.08	6.28	6.33	6.23	5.98	5.60	5.09	4.47	3.77	.622	7.	5.
MAY	7.19	7.36	7.36	7.18	6.84	6.36	5.75	5.01	4.16	3.34	.668	13.	5.
JUN	7.82	7.87	7.75	7.45	6.97	6.37	5.65	4.81	3.93	3.04	.681	17.	5.
JUL	8.19	8.32	8.25	7.97	7.51	6.90	6.15	5.26	4.30	3.33	.732	22.	4.
AUG	7.06	7.39	7.53	7.49	7.27	6.88	6.34	5.64	4.82	3.94	.711	21.	4.
SEP	5.58	6.15	6.57	6.83	6.91	6.82	6.55	6.12	5.54	4.86	.703	15.	4.
OCT	3.79	4.46	5.01	5.44	5.73	5.87	5.86	5.69	5.38	4.97	.657	9.	4.
NOV	2.17	2.70	3.16	3.54	3.84	4.03	4.12	4.10	3.98	3.88	.543	2.	5.
DEC	1.50	1.91	2.26	2.57	2.80	2.97	3.06	3.07	3.00	2.99	.465	-3.	5.
YRT	1763.	1905.	2000.	2047.	2044.	1995.	1899.	1757.	1576.	1382.			

PORTLAND, ME

43.65 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.42	1.75	2.03	2.27	2.45	2.57	2.63	2.63	2.55	2.54	.407	-5.	4.
FEB	2.14	2.50	2.79	3.03	3.19	3.27	3.28	3.20	3.05	2.87	.437	-4.	4.
MAR	3.06	3.36	3.59	3.74	3.80	3.78	3.67	3.48	3.21	2.92	.440	0.	5.
APR	4.11	4.31	4.42	4.43	4.35	4.17	3.91	3.57	3.15	2.72	.449	6.	5.
MAY	4.94	5.03	5.02	4.90	4.67	4.37	3.98	3.52	3.00	2.49	.460	12.	4.
JUN	5.40	5.42	5.34	5.15	4.85	4.48	4.03	3.50	2.95	2.40	.470	17.	4.
JUL	5.23	5.29	5.24	5.07	4.80	4.45	4.03	3.53	2.98	2.44	.468	20.	3.
AUG	4.60	4.76	4.82	4.77	4.62	4.38	4.05	3.64	3.17	2.68	.465	19.	3.
SEP	3.65	3.93	4.13	4.24	4.26	4.17	4.00	3.73	3.39	3.01	.465	15.	4.
OCT	2.59	2.96	3.25	3.48	3.62	3.67	3.64	3.52	3.32	3.09	.458	9.	4.
NOV	1.45	1.73	1.97	2.16	2.31	2.40	2.43	2.40	2.32	2.29	.374	4.	4.
DEC	1.14	1.41	1.64	1.84	1.99	2.09	2.14	2.14	2.09	2.09	.367	-3.	4.
YRT	1211.	1293.	1347.	1372.	1367.	1333.	1271.	1182.	1069.	959.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

PRESCOTT, AZ

34.65 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	3.20	3.89	4.47	4.95	5.29	5.50	5.56	5.47	5.24	4.98	.641	3.	3.
FEB	4.20	4.86	5.40	5.80	6.05	6.15	6.09	5.87	5.50	5.04	.666	4.	4.
MAR	5.61	6.15	6.53	6.76	6.81	6.70	6.41	5.97	5.38	4.71	.694	7.	4.
APR	7.17	7.48	7.60	7.53	7.29	6.86	6.27	5.53	4.66	3.74	.732	11.	5.
MAY	8.29	8.35	8.19	7.83	7.31	6.63	5.79	4.82	3.83	2.83	.760	16.	5.
JUN	8.71	8.62	8.33	7.82	7.17	6.37	5.42	4.41	3.38	2.41	.764	22.	5.
JUL	7.28	7.25	7.06	6.70	6.20	5.59	4.86	4.04	3.22	2.41	.650	24.	4.
AUG	6.60	6.74	6.73	6.57	6.25	5.80	5.22	4.53	3.74	2.96	.639	22.	3.
SEP	6.16	6.60	6.89	7.00	6.94	6.70	6.30	5.75	5.06	4.28	.701	20.	4.
OCT	4.87	5.52	6.04	6.41	6.61	6.64	6.50	6.19	5.73	5.15	.697	14.	3.
NOV	3.59	4.31	4.91	5.40	5.74	5.93	5.96	5.84	5.56	5.17	.670	7.	3.
DEC	2.92	3.60	4.19	4.67	5.03	5.26	5.35	5.29	5.10	4.80	.630	3.	3.
YRT	2088.	2233.	2323.	2355.	2332.	2253.	2119.	1936.	1713.	1472.			

RED BLUFF, CA

40.15 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.80	2.17	2.50	2.76	2.96	3.09	3.13	3.10	3.00	2.85	.441	7.	4.
FEB	2.81	3.25	3.63	3.91	4.10	4.19	4.18	4.06	3.84	3.56	.514	10.	4.
MAR	4.27	4.72	5.06	5.27	5.36	5.32	5.15	4.85	4.45	3.96	.576	11.	5.
APR	6.02	6.34	6.51	6.52	6.38	6.09	5.66	5.10	4.43	3.69	.638	15.	4.
MAY	7.48	7.62	7.58	7.35	6.94	6.42	5.74	4.94	4.06	3.18	.691	20.	4.
JUN	8.19	8.21	8.04	7.67	7.12	6.46	5.66	4.73	3.81	2.85	.715	25.	4.
JUL	8.42	8.50	8.37	8.04	7.51	6.85	6.04	5.09	4.10	3.09	.751	28.	4.
AUG	7.29	7.57	7.67	7.58	7.31	6.87	6.28	5.53	4.66	3.75	.722	27.	4.
SEP	5.82	6.35	6.73	6.94	6.98	6.84	6.52	6.05	5.43	4.71	.706	23.	4.
OCT	3.87	4.46	4.94	5.30	5.53	5.62	5.56	5.36	5.03	4.61	.625	18.	4.
NOV	2.23	2.68	3.06	3.38	3.61	3.75	3.79	3.74	3.60	3.51	.500	11.	4.
DEC	1.61	1.98	2.30	2.56	2.76	2.90	2.96	2.95	2.86	2.85	.435	7.	4.
YRT	1823.	1946.	2023.	2050.	2027.	1960.	1847.	1689.	1498.	1295.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

REDMOND, OR

44.27 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.55	1.94	2.29	2.59	2.82	2.98	3.06	3.06	2.99	2.98	.458	0.	3.
FEB	2.44	2.89	3.27	3.58	3.80	3.92	3.95	3.88	3.71	3.48	.507	2.	3.
MAR	3.75	4.20	4.54	4.78	4.90	4.91	4.79	4.56	4.22	3.82	.547	3.	3.
APR	5.31	5.63	5.82	5.87	5.79	5.57	5.23	4.78	4.22	3.60	.582	6.	3.
MAY	6.55	6.72	6.73	6.59	6.29	5.87	5.34	4.69	3.94	3.21	.612	11.	3.
JUN	7.21	7.27	7.18	6.92	6.51	5.98	5.34	4.59	3.79	3.00	.629	15.	3.
JUL	7.71	7.84	7.79	7.56	7.15	6.60	5.92	5.11	4.22	3.34	.690	20.	3.
AUG	6.52	6.83	6.97	6.95	6.76	6.42	5.94	5.32	4.58	3.79	.662	18.	3.
SEP	4.99	5.50	5.88	6.11	6.19	6.12	5.89	5.52	5.02	4.44	.642	14.	3.
OCT	3.15	3.67	4.11	4.45	4.67	4.78	4.77	4.64	4.39	4.08	.566	9.	3.
NOV	1.81	2.23	2.60	2.91	3.15	3.31	3.38	3.37	3.27	3.20	.479	4.	3.
DEC	1.34	1.71	2.04	2.32	2.54	2.70	2.78	2.80	2.75	2.73	.445	1.	3.
YRT	1596.	1720.	1805.	1847.	1844.	1801.	1717.	1592.	1433.	1267.			

RICHMOND, VA

37.50 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	1.99	2.36	2.68	2.93	3.11	3.22	3.25	3.19	3.06	2.97	.440	3.	4.
FEB	2.76	3.13	3.44	3.66	3.80	3.85	3.80	3.67	3.45	3.20	.469	4.	4.
MAR	3.82	4.14	4.36	4.49	4.52	4.44	4.26	3.99	3.62	3.23	.493	8.	4.
APR	4.94	5.13	5.21	5.17	5.01	4.75	4.39	3.94	3.41	2.86	.513	14.	4.
MAY	5.55	5.60	5.52	5.33	5.03	4.64	4.15	3.59	2.99	2.42	.511	19.	4.
JUN	5.90	5.88	5.73	5.46	5.08	4.62	4.07	3.46	2.84	2.23	.516	23.	3.
JUL	5.59	5.60	5.48	5.25	4.92	4.50	4.00	3.42	2.84	2.25	.499	25.	3.
AUG	5.05	5.17	5.17	5.06	4.85	4.54	4.14	3.66	3.11	2.56	.494	24.	3.
SEP	4.24	4.51	4.68	4.75	4.71	4.56	4.31	3.96	3.54	3.07	.499	21.	3.
OCT	3.26	3.64	3.93	4.14	4.25	4.26	4.17	3.98	3.70	3.37	.495	14.	3.
NOV	2.31	2.71	3.05	3.32	3.51	3.62	3.63	3.56	3.40	3.29	.472	9.	3.
DEC	1.79	2.15	2.46	2.71	2.90	3.02	3.06	3.02	2.92	2.88	.430	4.	3.
YRT	1437.	1523.	1574.	1591.	1573.	1521.	1437.	1321.	1182.	1043.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

ROCHESTER, NY

43.12 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.15	1.35	1.53	1.67	1.78	1.84	1.87	1.84	1.78	1.81	.321	-4.	6.
FEB	1.76	2.00	2.19	2.34	2.44	2.48	2.46	2.39	2.27	2.13	.353	-4.	6.
MAR	2.85	3.11	3.30	3.43	3.47	3.44	3.33	3.15	2.91	2.63	.406	0.	5.
APR	4.22	4.43	4.53	4.54	4.45	4.27	4.00	3.64	3.21	2.76	.459	8.	5.
MAY	5.06	5.16	5.14	5.01	4.77	4.46	4.06	3.58	3.04	2.52	.471	14.	5.
JUN	5.73	5.75	5.66	5.46	5.13	4.72	4.24	3.67	3.08	2.48	.499	19.	4.
JUL	5.61	5.67	5.61	5.43	5.14	4.76	4.29	3.74	3.15	2.56	.502	22.	4.
AUG	4.79	4.95	5.01	4.96	4.80	4.54	4.20	3.77	3.27	2.75	.483	21.	4.
SEP	3.65	3.93	4.13	4.23	4.24	4.15	3.97	3.70	3.35	2.98	.462	17.	4.
OCT	2.46	2.79	3.05	3.24	3.36	3.40	3.36	3.25	3.05	2.84	.429	11.	4.
NOV	1.27	1.48	1.65	1.79	1.88	1.94	1.95	1.92	1.84	1.83	.321	5.	5.
DEC	.88	1.02	1.14	1.23	1.30	1.34	1.35	1.33	1.29	1.32	.276	-2.	5.
YRT	1203.	1269.	1309.	1320.	1303.	1259.	1190.	1095.	981.	870.			

ROCK SPRINGS, WY

41.60 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.32	2.95	3.51	3.98	4.35	4.60	4.73	4.73	4.61	4.46	.604	-6.	6.
FEB	3.43	4.11	4.70	5.16	5.49	5.68	5.72	5.60	5.34	4.99	.655	-5.	6.
MAR	4.83	5.42	5.88	6.19	6.35	6.35	6.18	5.86	5.39	4.84	.668	-2.	6.
APR	6.13	6.48	6.69	6.72	6.60	6.33	5.90	5.34	4.66	3.92	.657	4.	6.
MAY	7.39	7.55	7.53	7.33	6.95	6.44	5.79	5.02	4.15	3.29	.685	10.	5.
JUN	8.11	8.15	8.01	7.67	7.15	6.51	5.74	4.84	3.92	2.98	.708	16.	5.
JUL	8.03	8.13	8.03	7.74	7.26	6.66	5.91	5.04	4.10	3.16	.717	20.	4.
AUG	7.06	7.36	7.48	7.42	7.17	6.77	6.21	5.51	4.68	3.80	.706	19.	4.
SEP	5.77	6.35	6.76	7.00	7.07	6.95	6.66	6.20	5.59	4.88	.715	13.	5.
OCT	4.11	4.82	5.41	5.86	6.16	6.30	6.27	6.08	5.73	5.27	.689	7.	5.
NOV	2.61	3.26	3.83	4.31	4.67	4.91	5.02	4.99	4.83	4.69	.618	-1.	5.
DEC	2.05	2.66	3.20	3.66	4.03	4.29	4.43	4.46	4.36	4.30	.593	-5.	5.
YRT	1884.	2048.	2162.	2223.	2229.	2184.	2085.	1936.	1743.	1537.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

ROSWELL, NM

33.30 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.30	3.96	4.52	4.97	5.29	5.47	5.51	5.41	5.16	4.82	.632	4.	4.
FEB	4.33	4.97	5.49	5.87	6.11	6.19	6.10	5.87	5.48	4.99	.664	7.	5.
MAR	5.70	6.22	6.59	6.79	6.82	6.68	6.37	5.91	5.30	4.61	.693	11.	5.
APR	6.99	7.25	7.34	7.25	6.99	6.56	5.97	5.24	4.40	3.51	.708	17.	6.
MAY	7.76	7.78	7.61	7.26	6.76	6.12	5.33	4.43	3.53	2.61	.710	22.	5.
JUN	8.23	8.13	7.82	7.33	6.71	5.94	5.05	4.10	3.13	2.24	.724	27.	5.
JUL	7.69	7.64	7.41	7.00	6.46	5.78	4.98	4.11	3.22	2.37	.687	28.	4.
AUG	7.07	7.21	7.18	6.98	6.63	6.12	5.48	4.71	3.85	3.00	.682	27.	4.
SEP	6.03	6.43	6.67	6.75	6.67	6.42	6.01	5.46	4.79	4.03	.677	23.	4.
OCT	4.82	5.42	5.89	6.21	6.38	6.38	6.22	5.91	5.44	4.87	.672	17.	4.
NOV	3.56	4.21	4.76	5.19	5.48	5.63	5.64	5.50	5.22	4.83	.639	9.	4.
DEC	3.00	3.65	4.21	4.66	4.99	5.19	5.26	5.19	4.98	4.68	.617	4.	4.
YRT	2085.	2218.	2297.	2320.	2289.	2204.	2065.	1879.	1655.	1414.			

SALEM, OR

44.92 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.05	1.25	1.42	1.57	1.68	1.75	1.78	1.76	1.71	1.65	.320	4.	4.
FEB	1.85	2.15	2.40	2.60	2.73	2.81	2.81	2.75	2.63	2.47	.394	6.	3.
MAR	2.99	3.30	3.54	3.70	3.77	3.76	3.66	3.48	3.23	2.93	.441	7.	4.
APR	4.32	4.55	4.69	4.71	4.64	4.46	4.20	3.84	3.40	2.93	.477	9.	3.
MAY	5.48	5.60	5.61	5.49	5.25	4.91	4.48	3.97	3.38	2.79	.512	13.	3.
JUN	5.83	5.87	5.80	5.60	5.29	4.88	4.39	3.83	3.22	2.61	.508	16.	3.
JUL	6.75	6.86	6.82	6.63	6.28	5.82	5.25	4.57	3.81	3.07	.605	19.	3.
AUG	5.59	5.84	5.95	5.92	5.76	5.47	5.08	4.57	3.96	3.33	.570	19.	3.
SEP	4.19	4.57	4.86	5.03	5.08	5.01	4.82	4.52	4.11	3.66	.544	16.	3.
OCT	2.42	2.77	3.06	3.28	3.42	3.48	3.46	3.35	3.17	2.96	.444	11.	3.
NOV	1.30	1.54	1.76	1.94	2.07	2.15	2.18	2.16	2.09	2.06	.353	7.	3.
DEC	.87	1.05	1.20	1.32	1.42	1.48	1.51	1.50	1.46	1.48	.302	5.	4.
YRT	1301.	1383.	1436.	1456.	1443.	1400.	1328.	1227.	1100.	972.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

SALT LAKE CITY, UT

40.77 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.02	2.49	2.90	3.24	3.50	3.67	3.74	3.72	3.61	3.50	.508	-2.	4.
FEB	3.11	3.66	4.13	4.49	4.74	4.87	4.88	4.76	4.52	4.22	.580	1.	4.
MAR	4.59	5.11	5.51	5.77	5.89	5.87	5.70	5.38	4.94	4.43	.626	5.	4.
APR	5.97	6.30	6.47	6.50	6.36	6.08	5.66	5.11	4.45	3.74	.636	9.	4.
MAY	7.45	7.59	7.56	7.34	6.95	6.43	5.77	4.98	4.10	3.23	.689	15.	4.
JUN	8.07	8.09	7.94	7.58	7.05	6.42	5.64	4.74	3.83	2.89	.704	20.	4.
JUL	8.16	8.25	8.14	7.83	7.33	6.70	5.93	5.02	4.07	3.10	.728	25.	4.
AUG	7.11	7.39	7.50	7.42	7.16	6.74	6.17	5.46	4.62	3.74	.707	24.	4.
SEP	5.81	6.36	6.76	6.98	7.03	6.90	6.60	6.13	5.51	4.79	.711	18.	4.
OCT	4.07	4.74	5.29	5.71	5.98	6.10	6.05	5.86	5.50	5.05	.669	11.	4.
NOV	2.48	3.05	3.55	3.95	4.26	4.45	4.53	4.49	4.33	4.22	.570	4.	4.
DEC	1.80	2.25	2.65	2.99	3.25	3.43	3.52	3.52	3.42	3.39	.499	-1.	3.
YRT	1848.	1989.	2083.	2125.	2115.	2059.	1953.	1799.	1609.	1407.			

SAN ANGELO, TX

31.37 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	3.03	3.53	3.96	4.28	4.51	4.61	4.61	4.49	4.25	3.95	.547	8.	5.
FEB	3.81	4.28	4.65	4.91	5.05	5.06	4.96	4.73	4.39	3.98	.560	10.	5.
MAR	5.07	5.45	5.70	5.82	5.80	5.65	5.35	4.94	4.41	3.82	.601	14.	6.
APR	5.83	6.00	6.02	5.91	5.67	5.30	4.81	4.23	3.55	2.86	.584	19.	5.
MAY	6.40	6.39	6.23	5.93	5.52	4.99	4.37	3.66	2.95	2.25	.586	23.	5.
JUN	6.89	6.78	6.52	6.11	5.59	4.97	4.24	3.49	2.70	2.01	.609	27.	5.
JUL	6.69	6.62	6.40	6.04	5.57	4.98	4.30	3.57	2.81	2.11	.599	28.	4.
AUG	6.20	6.28	6.23	6.03	5.70	5.25	4.69	4.03	3.30	2.58	.594	28.	4.
SEP	5.06	5.33	5.47	5.49	5.38	5.15	4.80	4.34	3.79	3.19	.558	24.	4.
OCT	4.22	4.65	4.98	5.19	5.27	5.23	5.06	4.77	4.37	3.90	.563	19.	4.
NOV	3.28	3.79	4.21	4.53	4.73	4.82	4.78	4.63	4.37	4.02	.558	12.	4.
DEC	2.81	3.33	3.77	4.11	4.36	4.49	4.51	4.42	4.21	3.95	.543	8.	5.
YRT	1805.	1901.	1952.	1958.	1921.	1840.	1717.	1559.	1370.	1173.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

SAN JUAN, PR

18.43 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	4.18	4.63	4.98	5.20	5.30	5.28	5.12	4.85	4.46	3.99	.553	24.	4.
FEB	4.85	5.22	5.47	5.60	5.59	5.45	5.18	4.79	4.30	3.73	.569	24.	4.
MAR	5.63	5.85	5.93	5.88	5.69	5.36	4.92	4.37	3.73	3.05	.589	25.	4.
APR	5.96	5.96	5.82	5.56	5.17	4.68	4.08	3.41	2.70	1.99	.575	26.	4.
MAY	5.72	5.57	5.30	4.92	4.44	3.88	3.26	2.62	2.00	1.57	.536	26.	4.
JUN	5.73	5.51	5.17	4.74	4.21	3.60	2.98	2.34	1.78	1.58	.534	27.	4.
JUL	5.91	5.70	5.38	4.95	4.42	3.80	3.16	2.47	1.87	1.58	.551	27.	5.
AUG	5.79	5.72	5.52	5.21	4.78	4.25	3.65	2.99	2.32	1.71	.551	27.	4.
SEP	5.27	5.38	5.37	5.23	4.99	4.63	4.18	3.64	3.04	2.41	.532	27.	4.
OCT	4.78	5.06	5.23	5.27	5.20	5.00	4.70	4.29	3.79	3.23	.535	27.	3.
NOV	4.31	4.74	5.05	5.24	5.31	5.25	5.07	4.77	4.36	3.87	.551	26.	4.
DEC	3.90	4.34	4.69	4.93	5.04	5.04	4.92	4.68	4.33	3.90	.535	25.	4.
YRT	1887.	1937.	1943.	1907.	1828.	1708.	1556.	1373.	1173.	990.			

SCOTTSBLUFF, NE

41.87 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.13	2.69	3.19	3.60	3.93	4.15	4.26	4.26	4.15	4.12	.563	-4.	5.
FEB	2.99	3.54	4.01	4.38	4.64	4.78	4.80	4.70	4.47	4.16	.576	-1.	5.
MAR	4.12	4.58	4.93	5.17	5.28	5.26	5.11	4.84	4.45	3.99	.574	2.	6.
APR	5.26	5.54	5.69	5.71	5.59	5.36	5.00	4.54	3.97	3.35	.565	8.	6.
MAY	6.09	6.21	6.18	6.02	5.72	5.32	4.81	4.20	3.52	2.85	.565	14.	5.
JUN	7.05	7.08	6.96	6.67	6.24	5.71	5.06	4.32	3.55	2.76	.615	19.	5.
JUL	7.20	7.28	7.20	6.94	6.53	6.00	5.35	4.59	3.78	2.97	.643	23.	4.
AUG	6.30	6.55	6.65	6.59	6.37	6.01	5.53	4.92	4.20	3.45	.631	22.	4.
SEP	5.04	5.49	5.82	6.01	6.04	5.94	5.68	5.29	4.77	4.19	.626	16.	4.
OCT	3.61	4.19	4.66	5.02	5.26	5.36	5.32	5.15	4.85	4.47	.609	9.	4.
NOV	2.28	2.81	3.28	3.66	3.95	4.14	4.22	4.19	4.05	3.94	.547	2.	5.
DEC	1.81	2.32	2.77	3.15	3.45	3.66	3.78	3.79	3.71	3.66	.532	-3.	5.
YRT	1642.	1775.	1868.	1915.	1917.	1877.	1792.	1666.	1504.	1335.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

Table I

SEATTLE/TACOMA, WA

47.45 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.83	.98	1.12	1.23	1.32	1.37	1.40	1.39	1.35	1.41	.290	4.	5.
FEB	1.55	1.81	2.04	2.21	2.34	2.41	2.42	2.38	2.28	2.26	.363	6.	4.
MAR	2.69	2.99	3.23	3.39	3.47	3.48	3.41	3.25	3.03	2.79	.419	6.	5.
APR	4.09	4.33	4.47	4.52	4.47	4.32	4.08	3.76	3.36	2.93	.462	9.	4.
MAY	5.42	5.57	5.60	5.51	5.30	4.98	4.57	4.08	3.50	2.92	.511	12.	4.
JUN	5.66	5.73	5.67	5.51	5.23	4.85	4.39	3.86	3.27	2.69	.495	15.	4.
JUL	6.24	6.37	6.35	6.20	5.91	5.50	5.01	4.41	3.72	3.06	.562	18.	4.
AUG	5.06	5.30	5.42	5.42	5.29	5.05	4.71	4.28	3.75	3.17	.525	17.	4.
SEP	3.64	3.98	4.24	4.40	4.45	4.41	4.26	4.01	3.68	3.29	.492	15.	4.
OCT	2.05	2.36	2.61	2.81	2.94	3.00	2.99	2.91	2.76	2.58	.404	11.	4.
NOV	1.07	1.28	1.47	1.62	1.74	1.82	1.85	1.84	1.79	1.74	.330	7.	4.
DEC	.67	.79	.90	.99	1.06	1.11	1.13	1.12	1.09	1.10	.270	5.	4.
YRT	1189.	1265.	1315.	1335.	1326.	1288.	1225.	1135.	1022.	911.			

SHERIDAN, WY

44.77 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.63	2.07	2.47	2.80	3.07	3.25	3.35	3.37	3.29	3.19	.495	-6.	3.
FEB	2.48	2.96	3.38	3.71	3.95	4.09	4.13	4.06	3.89	3.65	.525	-3.	4.
MAR	3.80	4.26	4.63	4.88	5.02	5.03	4.92	4.69	4.35	3.94	.559	0.	4.
APR	4.85	5.13	5.29	5.34	5.26	5.07	4.76	4.36	3.85	3.30	.534	6.	4.
MAY	5.93	6.08	6.09	5.96	5.70	5.33	4.85	4.28	3.63	2.98	.555	12.	4.
JUN	6.80	6.86	6.77	6.54	6.16	5.67	5.08	4.39	3.65	2.91	.593	17.	4.
JUL	7.34	7.47	7.43	7.21	6.83	6.31	5.68	4.93	4.09	3.26	.658	22.	3.
AUG	6.32	6.63	6.77	6.75	6.57	6.25	5.79	5.20	4.49	3.73	.644	21.	3.
SEP	4.73	5.21	5.56	5.77	5.85	5.78	5.57	5.23	4.76	4.22	.613	14.	3.
OCT	3.17	3.71	4.17	4.52	4.76	4.88	4.88	4.75	4.51	4.20	.577	8.	3.
NOV	1.86	2.33	2.73	3.07	3.34	3.52	3.60	3.60	3.50	3.42	.505	0.	3.
DEC	1.39	1.80	2.17	2.48	2.73	2.91	3.02	3.04	2.99	2.97	.476	-4.	3.
YRT	1534.	1661.	1751.	1799.	1804.	1769.	1694.	1579.	1429.	1270.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

SHREVEPORT, LA

32.47 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)									KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.40	2.76	3.07	3.30	3.46	3.53	3.52	3.42	3.24	3.04	.448	8.	4.
FEB	3.27	3.65	3.95	4.16	4.27	4.28	4.19	4.00	3.71	3.40	.493	10.	5.
MAR	4.23	4.52	4.72	4.81	4.78	4.65	4.42	4.08	3.66	3.22	.509	14.	5.
APR	5.08	5.22	5.25	5.16	4.95	4.65	4.24	3.75	3.19	2.62	.512	19.	5.
MAY	5.95	5.95	5.81	5.55	5.18	4.72	4.15	3.51	2.86	2.24	.544	22.	4.
JUN	6.51	6.42	6.19	5.82	5.35	4.78	4.12	3.42	2.70	2.05	.574	26.	4.
JUL	6.34	6.29	6.10	5.77	5.34	4.81	4.17	3.49	2.79	2.13	.568	28.	3.
AUG	5.92	6.01	5.97	5.79	5.49	5.08	4.55	3.94	3.25	2.58	.569	27.	3.
SEP	4.89	5.16	5.31	5.33	5.24	5.02	4.69	4.26	3.74	3.17	.545	24.	3.
OCT	4.11	4.55	4.89	5.11	5.20	5.17	5.02	4.74	4.36	3.90	.565	19.	3.
NOV	2.92	3.36	3.73	4.00	4.18	4.25	4.23	4.10	3.87	3.57	.512	13.	4.
DEC	2.30	2.69	3.02	3.28	3.47	3.57	3.58	3.50	3.34	3.14	.460	9.	4.
YRT	1642.	1724.	1766.	1768.	1732.	1658.	1547.	1405.	1237.	1065.			

SIOUX CITY, IA

42.40 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)									KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	1.79	2.23	2.61	2.93	3.18	3.34	3.42	3.41	3.32	3.18	.485	-8.	5.
FEB	2.65	3.11	3.50	3.81	4.02	4.13	4.14	4.05	3.86	3.60	.519	-4.	5.
MAR	3.69	4.08	4.38	4.57	4.66	4.63	4.50	4.26	3.93	3.53	.519	1.	6.
APR	4.97	5.23	5.37	5.39	5.29	5.07	4.74	4.30	3.78	3.21	.537	10.	6.
MAY	5.99	6.11	6.09	5.93	5.64	5.25	4.76	4.17	3.50	2.85	.556	16.	5.
JUN	6.69	6.73	6.61	6.36	5.95	5.46	4.86	4.16	3.44	2.71	.584	22.	5.
JUL	6.69	6.77	6.69	6.47	6.09	5.62	5.03	4.34	3.60	2.86	.598	24.	4.
AUG	5.82	6.04	6.13	6.07	5.87	5.55	5.12	4.57	3.92	3.25	.584	23.	4.
SEP	4.48	4.86	5.13	5.28	5.31	5.21	4.99	4.65	4.20	3.70	.561	17.	4.
OCT	3.27	3.77	4.19	4.50	4.70	4.79	4.75	4.60	4.33	4.01	.559	11.	5.
NOV	2.03	2.47	2.86	3.19	3.43	3.58	3.65	3.62	3.50	3.41	.496	2.	5.
DEC	1.48	1.86	2.19	2.47	2.69	2.84	2.92	2.92	2.85	2.83	.446	-5.	5.
YRT	1510.	1623.	1698.	1734.	1730.	1688.	1609.	1492.	1345.	1190.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

SPOKANE, WA

47.63 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	.99	1.23	1.45	1.63	1.77	1.87	1.93	1.93	1.89	1.92	.353	-3.	4.
FEB	1.90	2.28	2.61	2.88	3.07	3.19	3.23	3.19	3.07	3.00	.448	0.	4.
MAR	3.28	3.70	4.03	4.27	4.41	4.44	4.37	4.19	3.91	3.59	.513	3.	4.
APR	4.72	5.03	5.22	5.30	5.26	5.09	4.82	4.44	3.96	3.44	.535	7.	4.
MAY	6.04	6.23	6.28	6.18	5.95	5.58	5.13	4.56	3.90	3.23	.570	13.	4.
JUN	6.56	6.65	6.60	6.41	6.08	5.62	5.09	4.44	3.73	3.04	.573	17.	4.
JUL	7.43	7.60	7.60	7.43	7.09	6.58	5.98	5.23	4.38	3.55	.669	21.	4.
AUG	6.12	6.46	6.64	6.66	6.53	6.24	5.83	5.28	4.61	3.86	.636	20.	4.
SEP	4.52	5.03	5.42	5.67	5.79	5.76	5.59	5.29	4.85	4.33	.614	15.	4.
OCT	2.65	3.12	3.53	3.84	4.07	4.19	4.21	4.12	3.93	3.67	.526	8.	4.
NOV	1.25	1.55	1.82	2.04	2.21	2.33	2.39	2.39	2.33	2.27	.391	2.	4.
DEC	.80	1.01	1.19	1.35	1.47	1.56	1.61	1.62	1.60	1.59	.329	-1.	4.
YRT	1412.	1522.	1597.	1636.	1636.	1598.	1527.	1421.	1283.	1140.			

SPRINGFIELD, MO

37.23 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.15	2.57	2.92	3.20	3.41	3.53	3.57	3.51	3.37	3.21	.472	0.	5.
FEB	2.91	3.32	3.64	3.88	4.03	4.09	4.04	3.90	3.66	3.37	.492	2.	6.
MAR	3.90	4.22	4.45	4.58	4.61	4.53	4.34	4.06	3.69	3.27	.501	7.	6.
APR	5.06	5.25	5.33	5.29	5.13	4.87	4.49	4.03	3.48	2.89	.525	13.	6.
MAY	5.93	5.98	5.90	5.69	5.36	4.93	4.41	3.79	3.14	2.49	.545	18.	5.
JUN	6.54	6.52	6.34	6.03	5.59	5.07	4.44	3.74	3.03	2.34	.572	23.	4.
JUL	6.50	6.51	6.37	6.09	5.69	5.18	4.57	3.87	3.16	2.45	.580	25.	4.
AUG	5.91	6.06	6.08	5.96	5.70	5.33	4.85	4.26	3.58	2.90	.578	24.	4.
SEP	4.66	4.98	5.18	5.26	5.22	5.06	4.79	4.40	3.92	3.39	.547	20.	4.
OCT	3.61	4.05	4.41	4.66	4.80	4.82	4.72	4.51	4.20	3.82	.545	14.	5.
NOV	2.44	2.87	3.24	3.53	3.74	3.85	3.87	3.79	3.61	3.50	.495	7.	5.
DEC	1.90	2.29	2.63	2.91	3.11	3.24	3.29	3.25	3.14	3.09	.452	2.	5.
YRT	1569.	1664.	1721.	1738.	1716.	1658.	1563.	1433.	1277.	1116.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

TALLAHASSEE, FL

30.38 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	2.76	3.16	3.50	3.75	3.91	3.98	3.96	3.83	3.62	3.35	.485	11.	3.
FEB	3.59	3.99	4.30	4.51	4.61	4.61	4.49	4.27	3.95	3.57	.516	12.	3.
MAR	4.66	4.98	5.18	5.27	5.23	5.06	4.79	4.40	3.92	3.39	.547	15.	4.
APR	5.75	5.89	5.91	5.78	5.53	5.16	4.68	4.09	3.43	2.75	.573	19.	3.
MAY	6.10	6.08	5.92	5.62	5.23	4.73	4.13	3.46	2.79	2.14	.559	23.	3.
JUN	5.93	5.83	5.61	5.26	4.83	4.31	3.70	3.08	2.43	1.88	.526	26.	3.
JUL	5.51	5.45	5.27	4.98	4.60	4.14	3.60	3.03	2.43	1.90	.494	26.	2.
AUG	5.28	5.34	5.27	5.10	4.82	4.44	3.97	3.43	2.84	2.27	.505	26.	2.
SEP	4.70	4.92	5.03	5.03	4.91	4.69	4.36	3.94	3.44	2.90	.514	25.	3.
OCT	4.16	4.56	4.86	5.05	5.11	5.06	4.88	4.59	4.19	3.73	.550	20.	3.
NOV	3.17	3.63	3.99	4.27	4.44	4.50	4.45	4.30	4.04	3.71	.526	14.	3.
DEC	2.55	2.97	3.31	3.57	3.75	3.84	3.84	3.74	3.55	3.31	.478	11.	3.
YRT	1649.	1728.	1769.	1770.	1733.	1657.	1545.	1403.	1234.	1060.			

TAMPA, FL

27.97 N LATITUDE

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
	SURFACE TILT (DEGREES UP FROM HORIZONTAL)												
JAN	3.18	3.63	4.00	4.28	4.45	4.51	4.46	4.31	4.05	3.72	.523	15.	4.
FEB	3.97	4.40	4.72	4.93	5.03	5.00	4.86	4.60	4.23	3.80	.545	16.	4.
MAR	5.02	5.34	5.53	5.60	5.53	5.33	5.01	4.58	4.05	3.46	.573	19.	5.
APR	6.01	6.14	6.12	5.97	5.68	5.26	4.73	4.10	3.39	2.68	.594	22.	5.
MAY	6.30	6.25	6.05	5.72	5.29	4.74	4.09	3.40	2.68	2.03	.578	25.	4.
JUN	5.82	5.70	5.46	5.10	4.66	4.13	3.52	2.91	2.29	1.77	.520	26.	4.
JUL	5.53	5.44	5.24	4.93	4.53	4.05	3.49	2.92	2.31	1.81	.498	27.	3.
AUG	5.21	5.24	5.16	4.96	4.67	4.28	3.80	3.26	2.68	2.12	.497	27.	3.
SEP	4.70	4.89	4.97	4.94	4.80	4.55	4.21	3.78	3.28	2.74	.504	26.	4.
OCT	4.25	4.62	4.89	5.04	5.07	4.99	4.79	4.47	4.06	3.59	.541	23.	4.
NOV	3.49	3.96	4.33	4.61	4.77	4.81	4.74	4.55	4.26	3.89	.543	19.	4.
DEC	2.94	3.39	3.76	4.05	4.23	4.31	4.29	4.16	3.93	3.64	.512	16.	4.
YRT	1717.	1795.	1832.	1828.	1785.	1701.	1580.	1429.	1252.	1070.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

TONOPAH, NV

38.07 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.90	3.62	4.24	4.76	5.16	5.42	5.53	5.49	5.31	5.03	.654	-1.	4.
FEB	4.01	4.73	5.34	5.81	6.13	6.29	6.29	6.12	5.78	5.34	.692	2.	4.
MAR	5.61	6.25	6.73	7.05	7.18	7.13	6.89	6.48	5.90	5.21	.731	5.	5.
APR	7.09	7.47	7.66	7.66	7.47	7.10	6.56	5.85	5.01	4.09	.740	9.	5.
MAY	8.13	8.25	8.16	7.87	7.40	6.79	6.01	5.10	4.12	3.13	.748	15.	5.
JUN	8.79	8.77	8.54	8.10	7.47	6.72	5.82	4.80	3.78	2.76	.768	20.	5.
JUL	8.52	8.56	8.39	8.01	7.45	6.75	5.90	4.92	3.92	2.89	.759	24.	4.
AUG	7.69	7.96	8.03	7.90	7.58	7.09	6.42	5.61	4.66	3.69	.755	22.	4.
SEP	6.44	7.01	7.41	7.62	7.63	7.45	7.07	6.52	5.80	4.97	.762	18.	4.
OCT	4.79	5.56	6.18	6.65	6.94	7.05	6.97	6.70	6.27	5.69	.738	11.	4.
NOV	3.25	3.99	4.64	5.17	5.56	5.80	5.89	5.82	5.59	5.40	.676	4.	4.
DEC	2.61	3.31	3.94	4.46	4.86	5.14	5.27	5.27	5.12	5.02	.642	0.	4.
YRT	2126.	2299.	2413.	2467.	2459.	2394.	2269.	2087.	1862.	1617.			

TULSA, OK

36.20 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.30	2.73	3.10	3.40	3.61	3.73	3.76	3.69	3.54	3.48	.486	2.	5.
FEB	3.08	3.50	3.84	4.08	4.24	4.28	4.23	4.07	3.82	3.51	.507	5.	5.
MAR	4.12	4.46	4.70	4.83	4.85	4.76	4.56	4.26	3.85	3.40	.522	9.	6.
APR	5.05	5.23	5.30	5.25	5.08	4.80	4.43	3.95	3.41	2.82	.520	16.	6.
MAY	5.74	5.78	5.69	5.48	5.15	4.73	4.22	3.63	3.00	2.38	.527	20.	5.
JUN	6.37	6.34	6.16	5.84	5.41	4.89	4.28	3.60	2.91	2.25	.558	25.	5.
JUL	6.40	6.40	6.25	5.96	5.55	5.05	4.44	3.75	3.06	2.36	.571	28.	4.
AUG	5.88	6.02	6.03	5.89	5.63	5.25	4.76	4.17	3.49	2.82	.573	27.	4.
SEP	4.64	4.93	5.12	5.19	5.13	4.96	4.68	4.29	3.81	3.28	.537	23.	4.
OCT	3.67	4.11	4.45	4.69	4.82	4.82	4.72	4.50	4.17	3.78	.542	17.	4.
NOV	2.60	3.06	3.44	3.74	3.95	4.06	4.07	3.98	3.79	3.54	.510	9.	5.
DEC	2.08	2.50	2.87	3.16	3.38	3.52	3.56	3.52	3.39	3.21	.475	4.	5.
YRT	1582.	1677.	1733.	1750.	1729.	1669.	1572.	1441.	1284.	1120.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

WAKE ISLAND, PI

19.28 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	4.26	4.74	5.11	5.36	5.48	5.47	5.33	5.05	4.66	4.19	.573	25.	6.
FEB	4.96	5.37	5.64	5.79	5.80	5.66	5.40	5.00	4.50	3.92	.589	25.	6.
MAR	5.71	5.95	6.04	6.00	5.82	5.50	5.05	4.50	3.85	3.16	.600	25.	7.
APR	6.16	6.17	6.04	5.78	5.38	4.87	4.26	3.56	2.82	2.09	.595	25.	7.
MAY	6.48	6.31	5.99	5.56	5.00	4.34	3.62	2.87	2.14	1.60	.605	26.	7.
JUN	6.45	6.20	5.80	5.30	4.69	3.98	3.26	2.51	1.86	1.61	.598	27.	6.
JUL	6.07	5.87	5.54	5.10	4.56	3.93	3.26	2.56	1.92	1.60	.564	28.	6.
AUG	5.90	5.83	5.64	5.33	4.90	4.37	3.75	3.08	2.39	1.77	.560	28.	5.
SEP	5.47	5.60	5.60	5.47	5.22	4.86	4.39	3.83	3.20	2.54	.555	28.	6.
OCT	4.96	5.27	5.46	5.52	5.46	5.27	4.96	4.53	4.01	3.43	.560	28.	6.
NOV	4.53	5.01	5.37	5.60	5.70	5.65	5.47	5.16	4.72	4.21	.587	27.	7.
DEC	4.13	4.64	5.05	5.33	5.49	5.51	5.39	5.14	4.77	4.31	.578	25.	7.
YRT	1980.	2036.	2046.	2011.	1930.	1805.	1645.	1452.	1240.	1045.			

WICHITA, KA

37.63 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL)										KT	TM	WS
	HOR	10	20	30	40	50	60	70	80	VERT			
JAN	2.47	3.01	3.47	3.85	4.13	4.30	4.36	4.31	4.15	4.09	.549	-1.	6.
FEB	3.33	3.85	4.27	4.60	4.81	4.90	4.87	4.71	4.44	4.09	.568	2.	6.
MAR	4.43	4.85	5.16	5.34	5.40	5.32	5.12	4.80	4.36	3.86	.574	6.	7.
APR	5.62	5.86	5.97	5.94	5.77	5.47	5.06	4.53	3.90	3.23	.584	14.	7.
MAY	6.41	6.48	6.40	6.17	5.82	5.35	4.77	4.10	3.38	2.66	.590	19.	6.
JUN	7.14	7.11	6.93	6.58	6.10	5.52	4.82	4.04	3.25	2.48	.624	24.	6.
JUL	7.06	7.07	6.93	6.62	6.18	5.62	4.95	4.17	3.39	2.59	.629	27.	5.
AUG	6.41	6.59	6.62	6.50	6.23	5.83	5.29	4.64	3.90	3.14	.628	26.	5.
SEP	5.09	5.47	5.71	5.83	5.80	5.63	5.33	4.91	4.37	3.77	.600	21.	5.
OCT	3.94	4.47	4.90	5.20	5.38	5.42	5.33	5.11	4.76	4.33	.601	15.	6.
NOV	2.74	3.29	3.75	4.13	4.40	4.56	4.60	4.52	4.33	4.19	.563	7.	6.
DEC	2.18	2.68	3.12	3.48	3.75	3.93	4.01	3.98	3.85	3.79	.526	1.	5.
YRT	1731.	1849.	1925.	1955.	1940.	1882.	1779.	1636.	1462.	1283.			

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

WICHITA FALLS, TX

33.97 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	2.71	3.21	3.63	3.96	4.19	4.32	4.34	4.25	4.05	3.92	.532	5.	5.
FEB	3.54	4.01	4.39	4.66	4.82	4.87	4.79	4.60	4.29	3.92	.551	7.	5.
MAR	4.64	5.02	5.28	5.41	5.42	5.30	5.06	4.69	4.22	3.70	.569	12.	6.
APR	5.55	5.74	5.79	5.72	5.51	5.19	4.75	4.21	3.58	2.92	.564	18.	6.
MAY	6.36	6.38	6.25	5.99	5.60	5.11	4.50	3.81	3.11	2.40	.583	22.	5.
JUN	7.00	6.93	6.70	6.31	5.81	5.20	4.48	3.72	2.93	2.20	.615	27.	5.
JUL	6.83	6.79	6.60	6.26	5.80	5.23	4.55	3.80	3.04	2.30	.610	29.	5.
AUG	6.21	6.33	6.31	6.14	5.84	5.42	4.87	4.22	3.50	2.78	.600	29.	5.
SEP	5.04	5.35	5.53	5.58	5.50	5.30	4.97	4.53	3.99	3.39	.571	24.	5.
OCT	4.07	4.54	4.90	5.15	5.27	5.26	5.12	4.86	4.48	4.03	.576	18.	5.
NOV	3.01	3.52	3.95	4.28	4.51	4.62	4.61	4.49	4.26	3.95	.551	11.	5.
DEC	2.52	3.02	3.45	3.80	4.05	4.20	4.24	4.18	4.01	3.77	.530	6.	5.
YRT	1751.	1852.	1911.	1925.	1896.	1825.	1712.	1561.	1382.	1193.			

WILKES-BARRE, PA

41.33 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.44	1.71	1.95	2.14	2.28	2.37	2.40	2.38	2.29	2.19	.370	-4.	4.
FEB	2.17	2.48	2.73	2.93	3.05	3.11	3.09	3.00	2.84	2.64	.411	-2.	4.
MAR	3.13	3.40	3.61	3.74	3.78	3.73	3.61	3.40	3.12	2.80	.431	2.	4.
APR	4.22	4.41	4.50	4.49	4.38	4.19	3.90	3.54	3.11	2.65	.452	9.	4.
MAY	5.01	5.09	5.05	4.91	4.66	4.34	3.94	3.46	2.92	2.40	.464	15.	4.
JUN	5.55	5.56	5.46	5.24	4.91	4.51	4.03	3.48	2.91	2.33	.484	20.	3.
JUL	5.50	5.54	5.47	5.28	4.97	4.59	4.12	3.58	3.00	2.42	.491	22.	3.
AUG	4.77	4.92	4.96	4.89	4.71	4.45	4.09	3.66	3.15	2.64	.476	21.	3.
SEP	3.77	4.05	4.23	4.32	4.31	4.20	4.00	3.72	3.35	2.96	.466	17.	3.
OCT	2.73	3.08	3.37	3.57	3.69	3.73	3.67	3.53	3.31	3.06	.455	11.	3.
NOV	1.54	1.80	2.02	2.20	2.32	2.40	2.41	2.37	2.27	2.24	.362	5.	4.
DEC	1.16	1.38	1.56	1.72	1.83	1.91	1.93	1.91	1.85	1.86	.331	-1.	4.
YRT	1249.	1323.	1368.	1383.	1367.	1325.	1254.	1157.	1038.	918.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY), CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C), AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

WINSLOW, AZ

35.02 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	3.10	3.76	4.33	4.79	5.13	5.33	5.39	5.31	5.10	4.86	.629	0.	3.
FEB	4.18	4.84	5.38	5.79	6.05	6.15	6.10	5.88	5.52	5.06	.668	3.	4.
MAR	5.62	6.17	6.57	6.80	6.86	6.75	6.47	6.03	5.44	4.76	.699	7.	4.
APR	7.19	7.51	7.64	7.59	7.34	6.92	6.33	5.59	4.72	3.79	.736	12.	5.
MAY	8.18	8.24	8.10	7.75	7.24	6.57	5.75	4.80	3.82	2.83	.750	17.	5.
JUN	8.55	8.47	8.19	7.70	7.06	6.29	5.37	4.37	3.36	2.41	.750	23.	5.
JUL	7.40	7.38	7.18	6.82	6.32	5.70	4.96	4.12	3.28	2.46	.660	25.	4.
AUG	6.75	6.91	6.91	6.74	6.42	5.96	5.37	4.66	3.85	3.05	.655	24.	4.
SEP	6.07	6.52	6.80	6.92	6.86	6.63	6.24	5.70	5.03	4.26	.694	20.	4.
OCT	4.77	5.41	5.93	6.29	6.49	6.52	6.39	6.09	5.64	5.08	.689	13.	3.
NOV	3.53	4.23	4.84	5.32	5.66	5.85	5.89	5.77	5.50	5.12	.665	6.	3.
DEC	2.82	3.48	4.04	4.51	4.86	5.08	5.17	5.12	4.93	4.65	.617	0.	3.
YRT	2075.	2219.	2310.	2343.	2320.	2243.	2110.	1928.	1707.	1467.			

YAKIMA, WA

46.57 N LATITUDE

SURFACE TILT (DEGREES UP FROM HORIZONTAL)

MONTH	HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	1.15	1.44	1.69	1.91	2.08	2.20	2.26	2.27	2.22	2.14	.385	-2.	3.
FEB	2.09	2.50	2.86	3.14	3.35	3.48	3.52	3.47	3.33	3.14	.473	2.	3.
MAR	3.54	3.99	4.35	4.61	4.75	4.78	4.69	4.49	4.19	3.81	.540	5.	4.
APR	5.04	5.37	5.58	5.65	5.60	5.42	5.11	4.70	4.18	3.59	.565	10.	4.
MAY	6.33	6.52	6.56	6.45	6.19	5.80	5.31	4.70	4.00	3.29	.595	15.	4.
JUN	6.84	6.92	6.85	6.64	6.28	5.80	5.22	4.54	3.79	3.06	.597	19.	4.
JUL	7.43	7.59	7.58	7.39	7.02	6.52	5.89	5.14	4.28	3.45	.668	22.	3.
AUG	6.22	6.55	6.72	6.73	6.57	6.27	5.84	5.27	4.59	3.85	.641	21.	3.
SEP	4.67	5.18	5.57	5.82	5.92	5.88	5.70	5.37	4.92	4.39	.623	16.	3.
OCT	2.80	3.30	3.71	4.04	4.26	4.38	4.39	4.29	4.08	3.83	.539	9.	3.
NOV	1.40	1.73	2.03	2.27	2.46	2.59	2.66	2.66	2.59	2.55	.414	3.	3.
DEC	.93	1.17	1.38	1.56	1.71	1.81	1.87	1.88	1.85	1.86	.354	0.	2.
YRT	1478.	1593.	1672.	1713.	1712.	1673.	1597.	1485.	1339.	1185.			

TABLE I (Continued)

AVERAGE DAILY ARRAY INSOLATION (KWH/SQ.M./DAY),
CLEARNESS NUMBER (KT), MEAN MONTHLY TEMPERATURE (TM, DEG C),
AND MONTHLY AVERAGE WIND SPEED (WS, M/S)

YAKUTAT, AK

59.52 N LATITUDE

MONTH	SURFACE TILT (DEGREES UP FROM HORIZONTAL) HOR	10	20	30	40	50	60	70	80	VERT	KT	TM	WS
JAN	.32	.49	.65	.80	.92	1.02	1.09	1.14	1.15	1.24	.332	-5.	3.
FEB	.84	1.10	1.34	1.54	1.71	1.84	1.91	1.94	1.92	1.94	.367	-2.	4.
MAR	1.97	2.33	2.64	2.89	3.07	3.18	3.21	3.16	3.03	2.88	.429	-1.	3.
APR	3.31	3.61	3.84	3.98	4.04	4.00	3.87	3.66	3.37	3.03	.438	2.	3.
MAY	4.00	4.16	4.25	4.25	4.17	4.00	3.76	3.46	3.09	2.69	.399	6.	4.
JUN	4.24	4.33	4.35	4.28	4.15	3.94	3.65	3.32	2.94	2.51	.375	10.	3.
JUL	3.81	3.91	3.94	3.90	3.79	3.61	3.37	3.08	2.74	2.36	.353	12.	3.
AUG	2.97	3.14	3.24	3.28	3.25	3.16	3.00	2.80	2.54	2.27	.343	12.	3.
SEP	2.00	2.23	2.42	2.55	2.63	2.65	2.62	2.52	2.37	2.23	.348	9.	3.
OCT	1.08	1.34	1.56	1.75	1.90	2.00	2.05	2.05	2.00	2.07	.352	5.	4.
NOV	.43	.62	.79	.94	1.08	1.18	1.25	1.29	1.30	1.56	.332	0.	4.
DEC	.16	.23	.29	.35	.40	.44	.47	.48	.49	.85	.246	-2.	4.
YRT	766.	838.	893.	930.	947.	944.	920.	879.	819.	780.			

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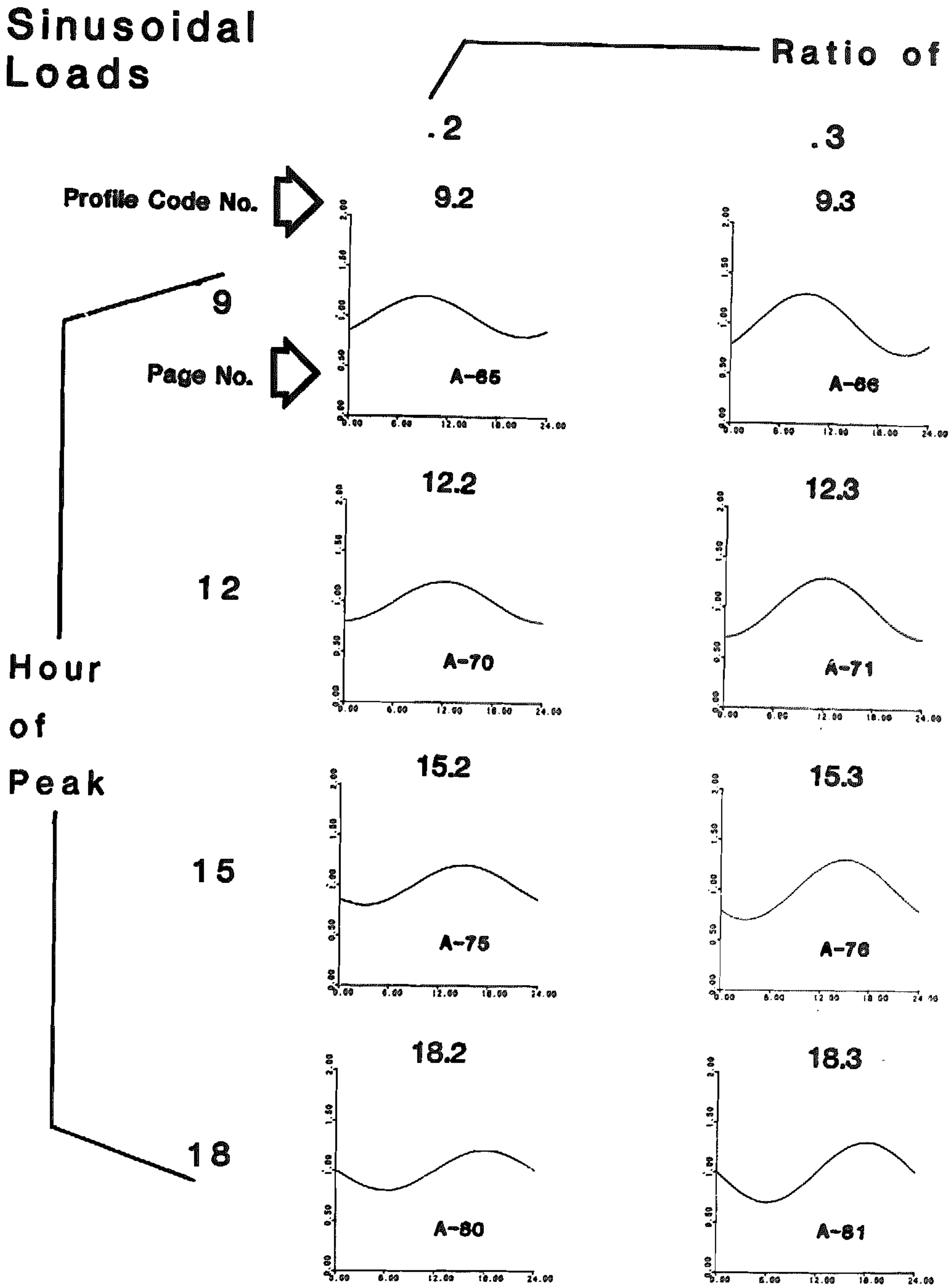
TABLF II

--Monthly Optimum Tilts--
Tilt Angle (s_M) between the Plane of the
Flat Array and Horizontal for Optimum Incident Energy*

Month	s_M(Degrees)**
January	$\phi + 29$
February	$\phi + 18$
March	$\phi + 3$
April	$\phi - 10$
May	$\phi - 22$
June	$\phi - 25$
July	$\phi - 24$
August	$\phi - 10$
September	$\phi - 2$
October	$\phi + 10$
November	$\phi + 23$
December	$\phi + 30$

*Array is assumed to be south facing

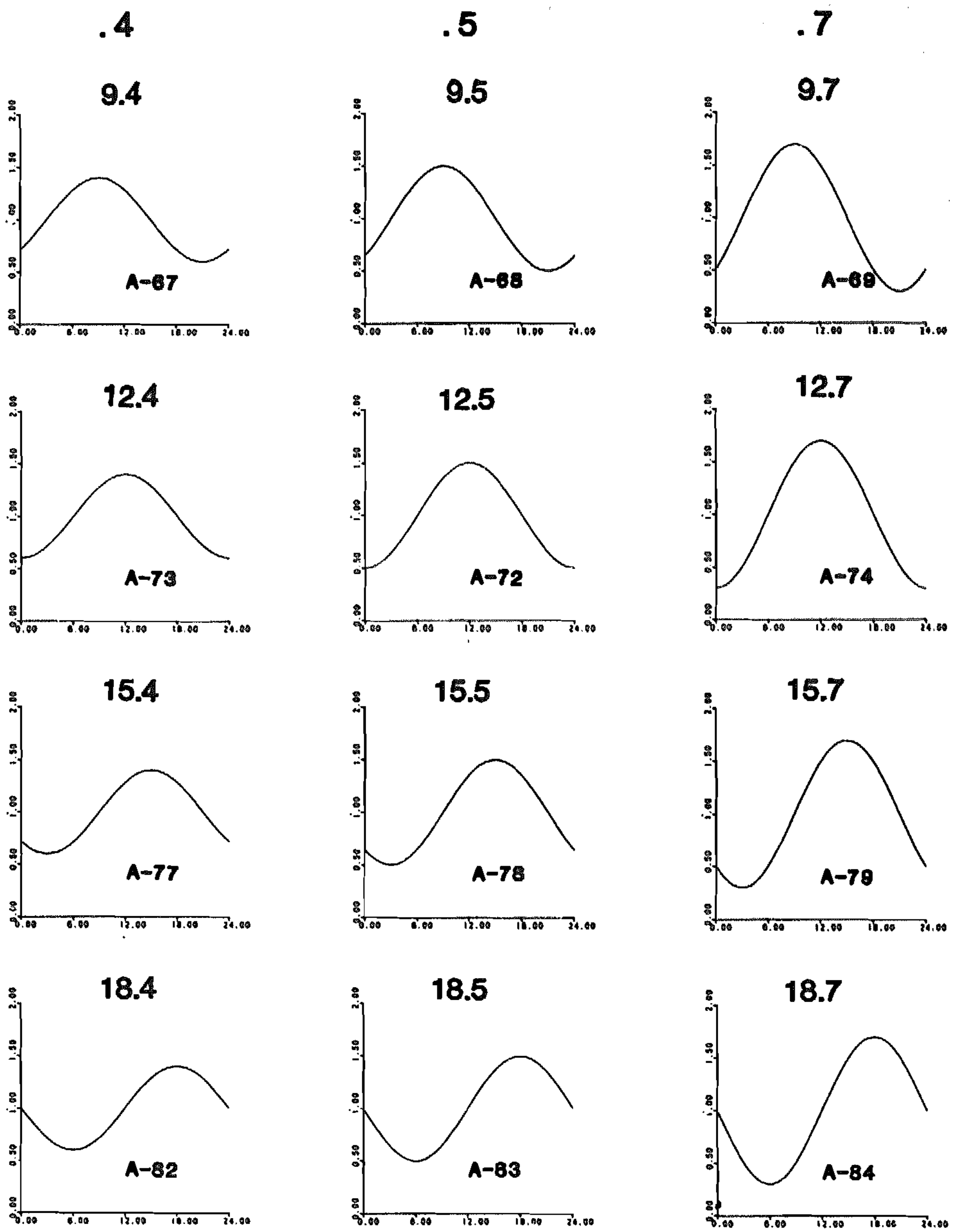
**ϕ is latitude in degrees



Monthly Average Daily Load Shapes for Which Data Are Given in Table III. (The number A-xx shown for each shape is the page number in this appendix on which the corresponding system performance graphs can be found)

TABLE III KEY

Amplitude to Mean



Only the load shape is important in selecting the proper graph. The magnitude of the load enters through the parameter QE/L. These shapes encompass all the two-digit SIC applications listed in Ref. 7.

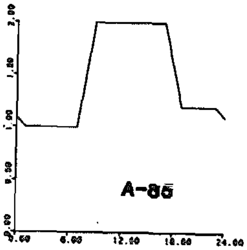
Table III Key

Unimodal Loads

Profile Code No. ⇨

Page No. ⇨

#1



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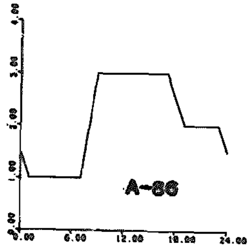

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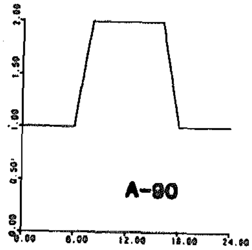

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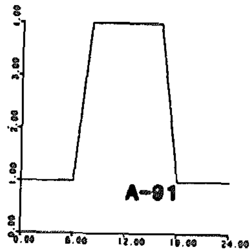

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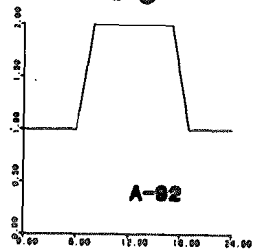

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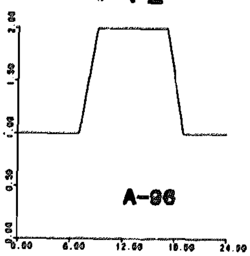

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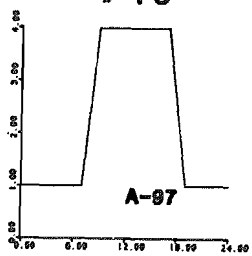

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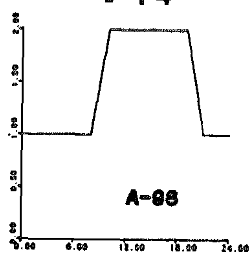

Bimodal Loads

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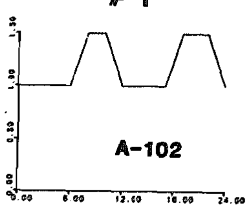

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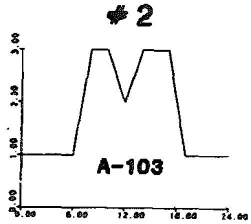
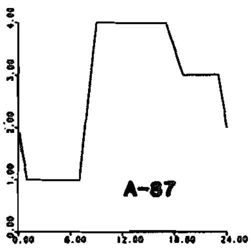


Monthly Average Daily Load Shapes for Which Data Are Given in Table III. (The number A-xx shown for each shape is the page number in this appendix on which the corresponding system performance graphs can be found)

TABLE III KEY

#3



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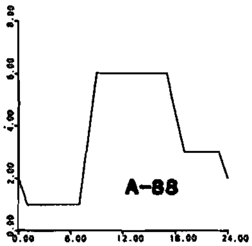

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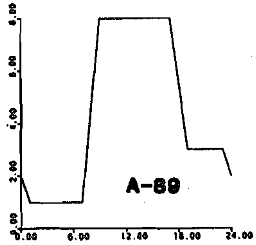

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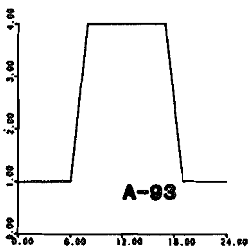

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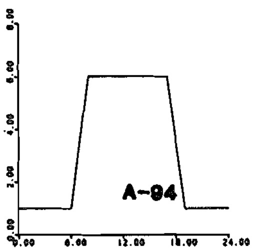

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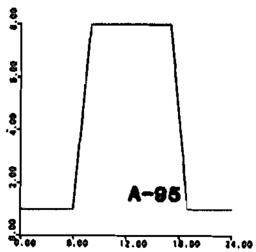

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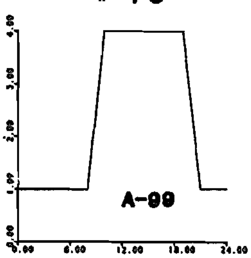

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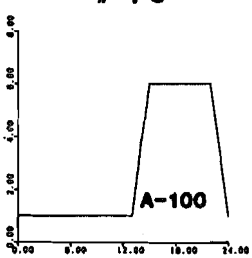

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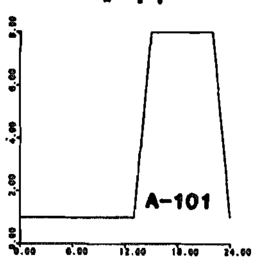

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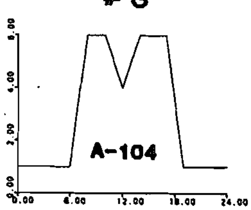
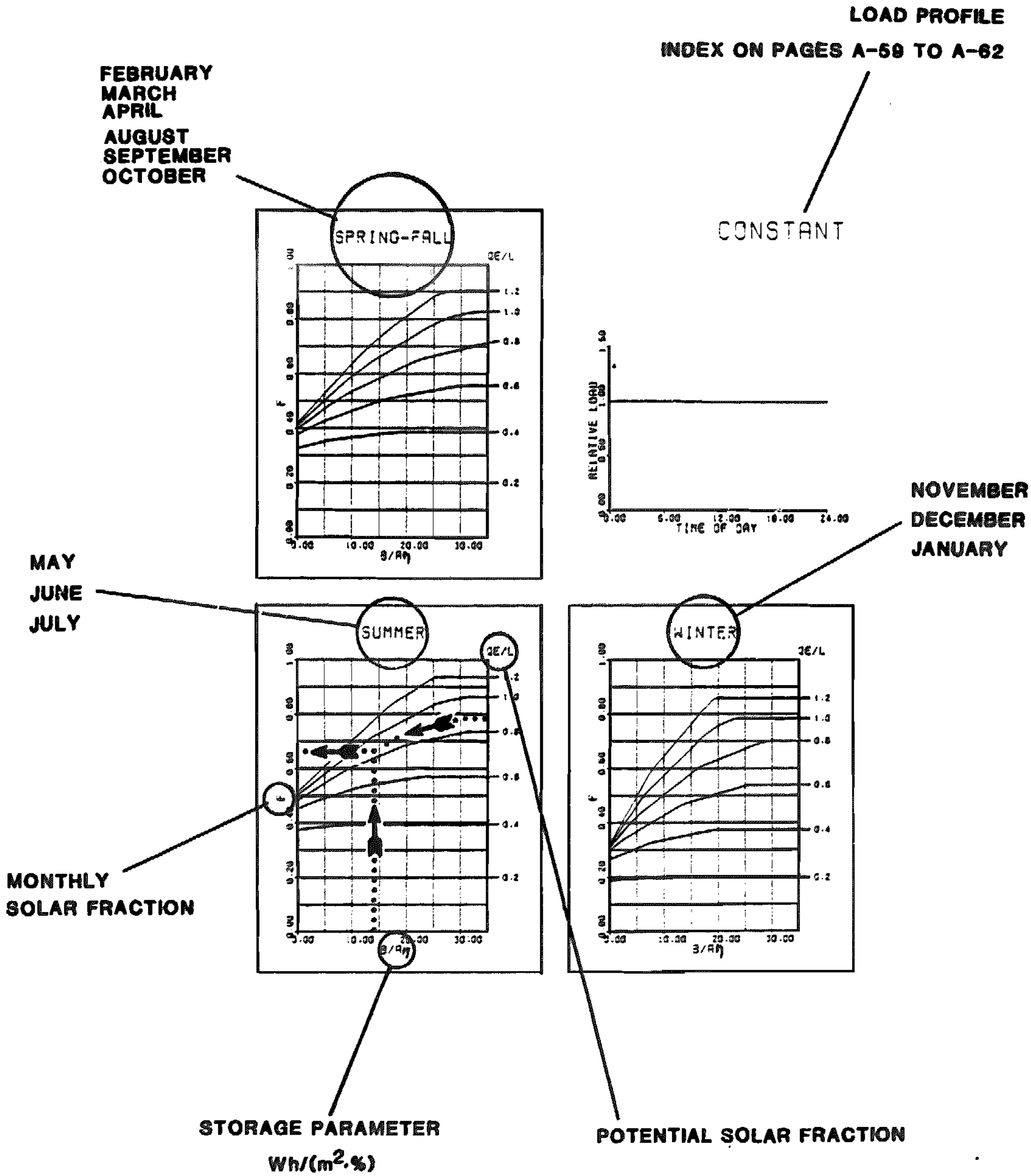


Only the load shape is important in selecting the proper graph. The magnitude of the load enters through the parameter QE/L. These shapes encompass all the two-digit SIC applications listed in Ref. 7.



KEY for reading TABLE III

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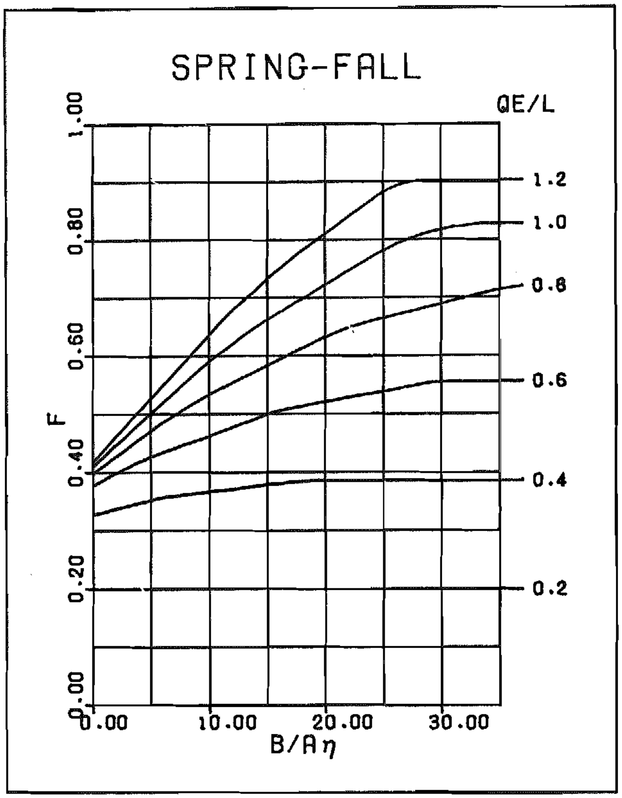


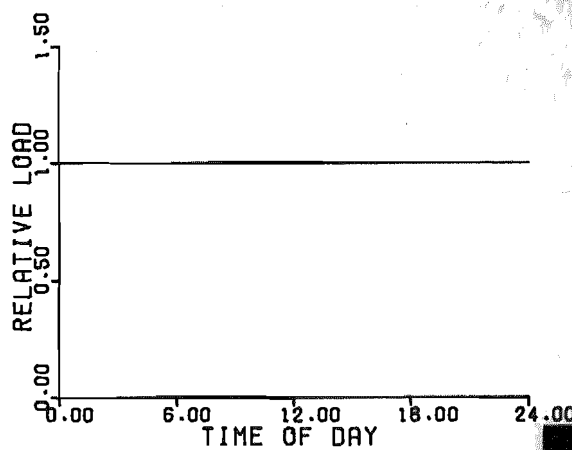
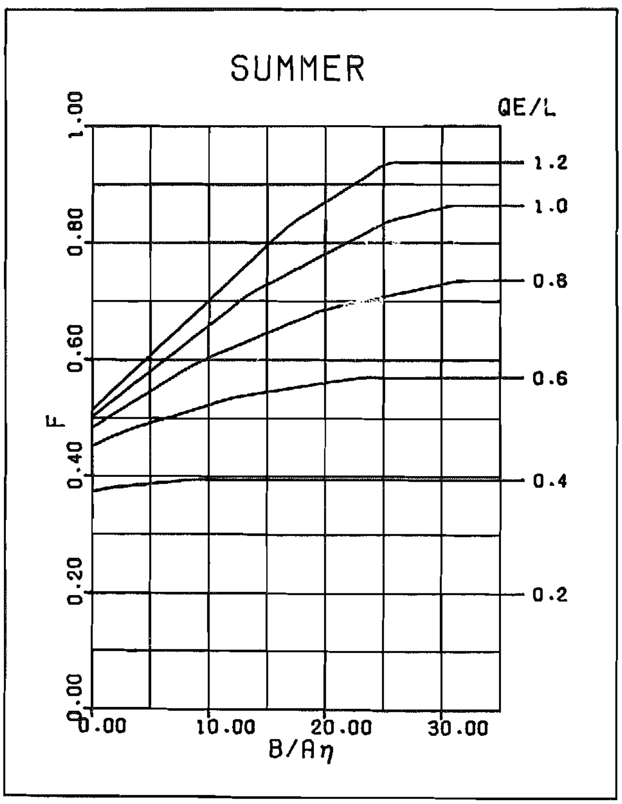
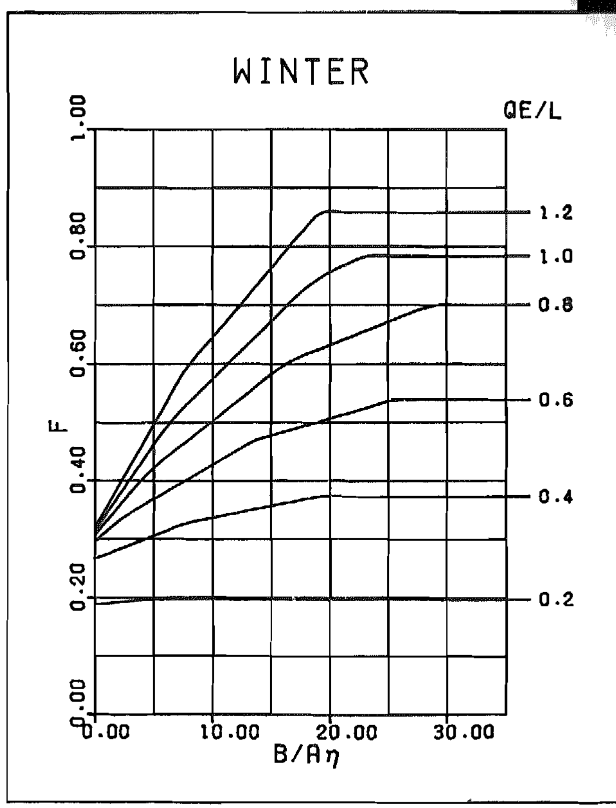


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





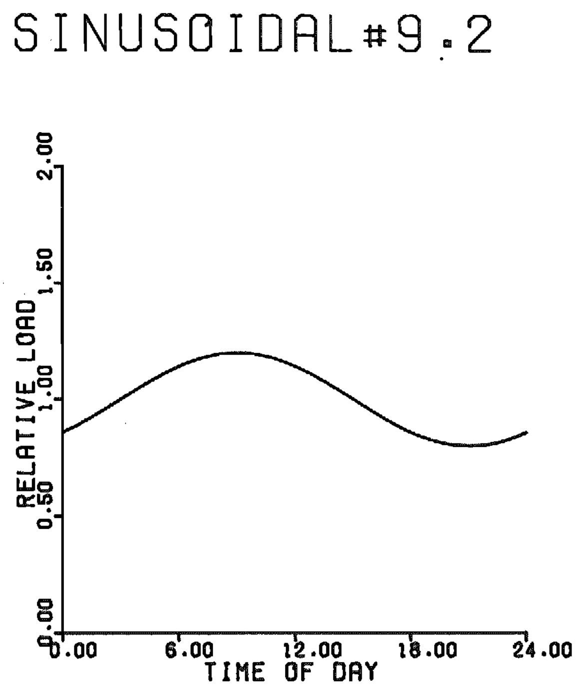
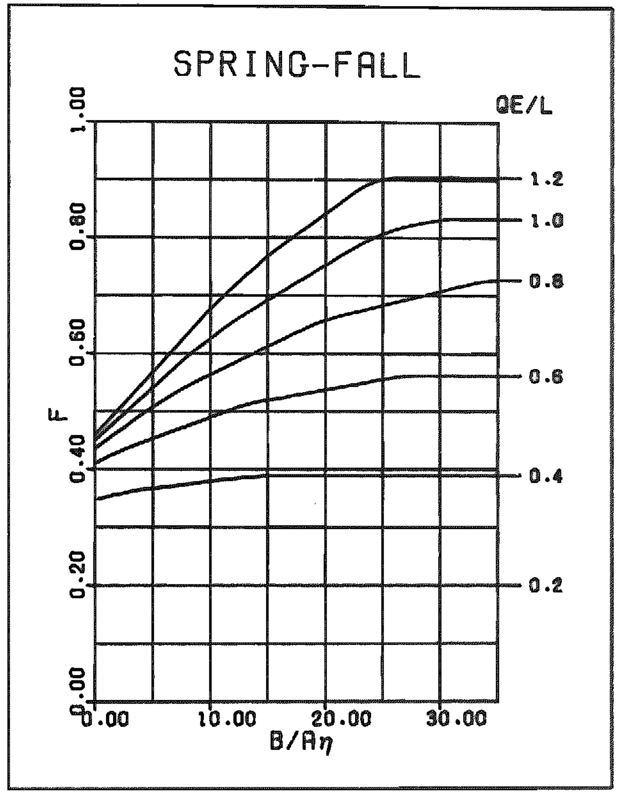
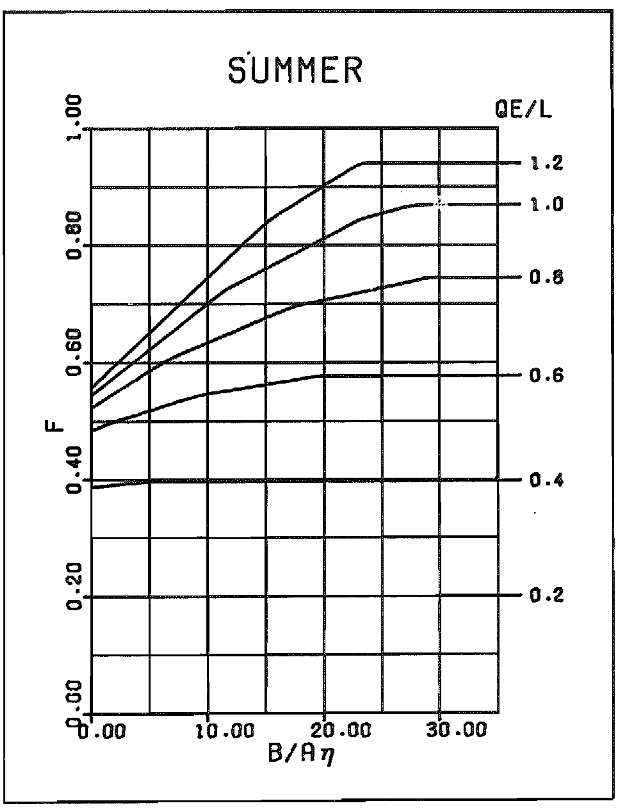
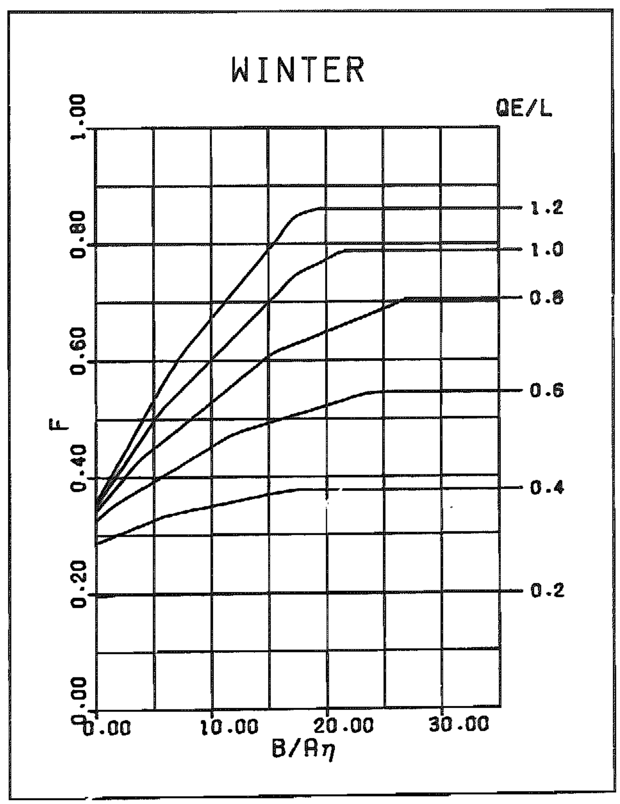


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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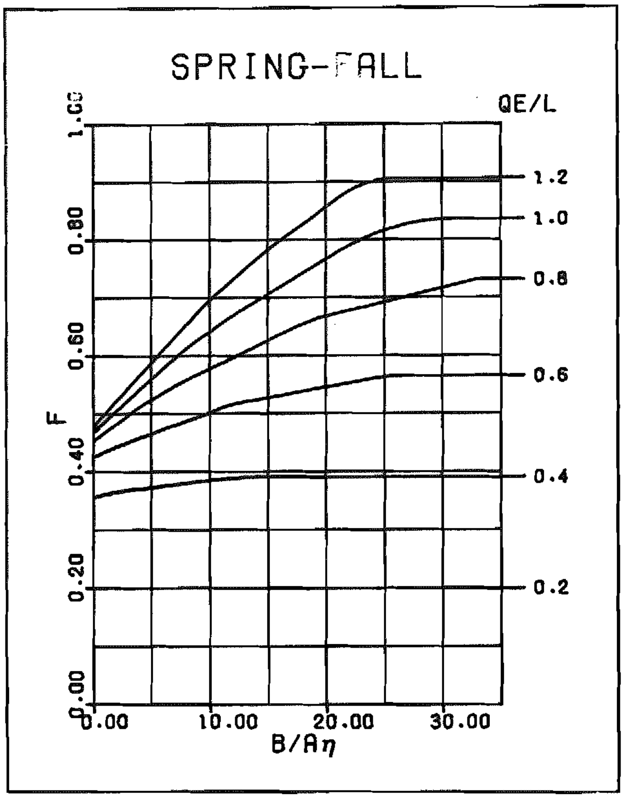


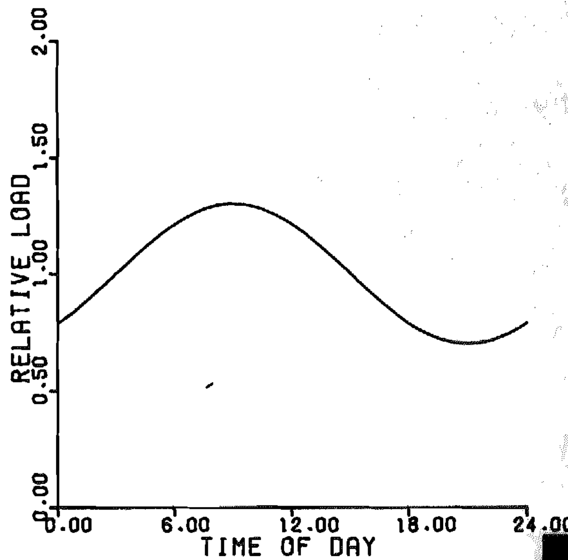
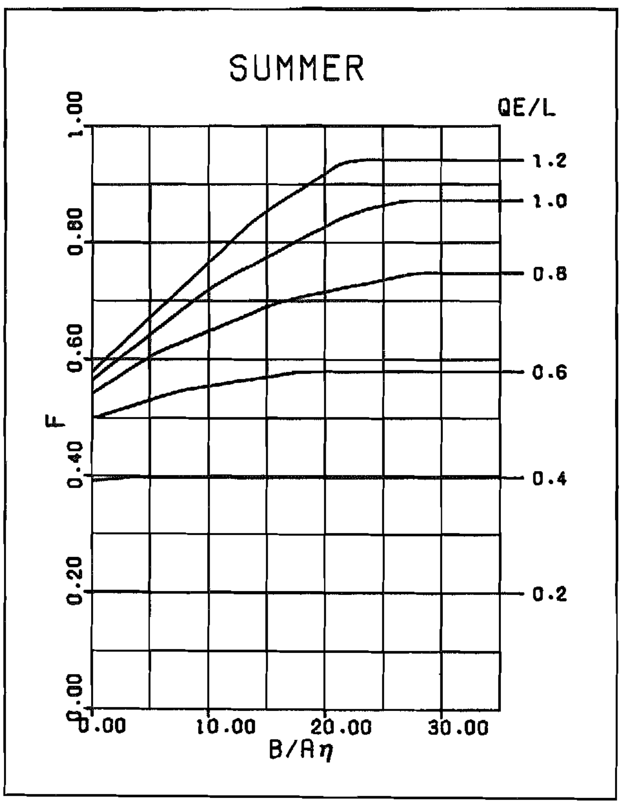


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63



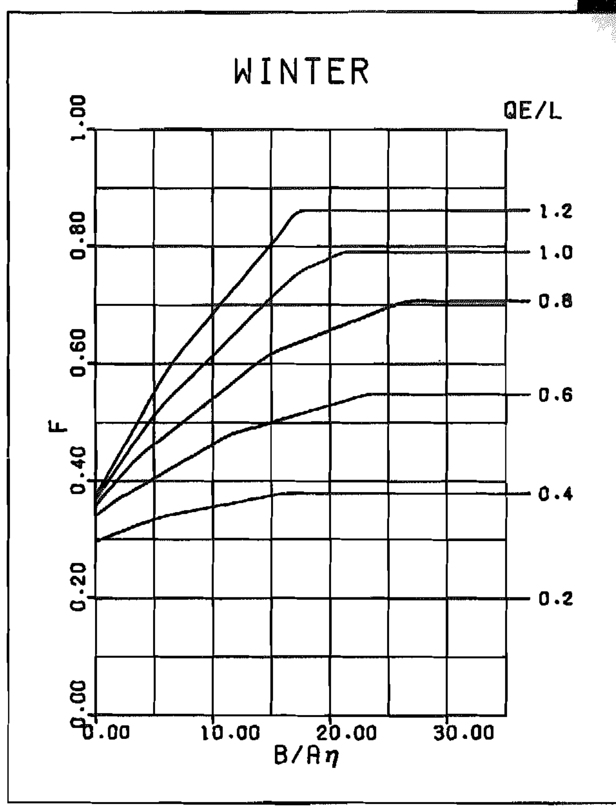


Table III

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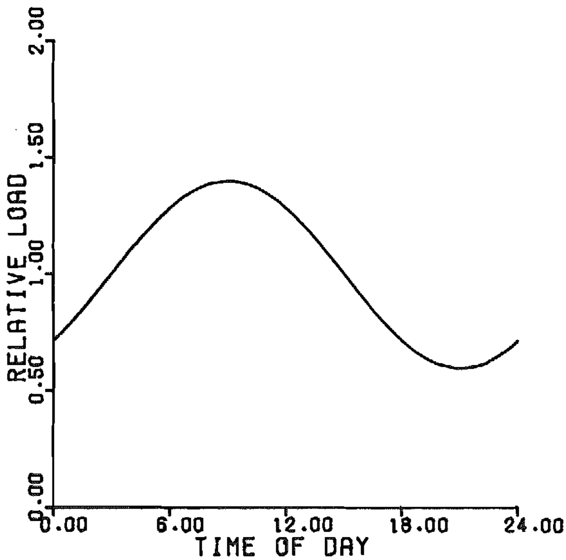
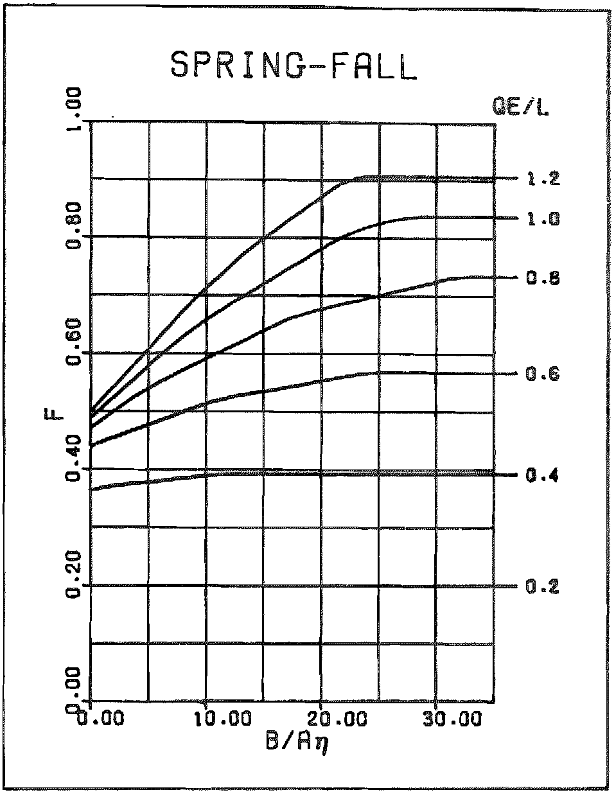
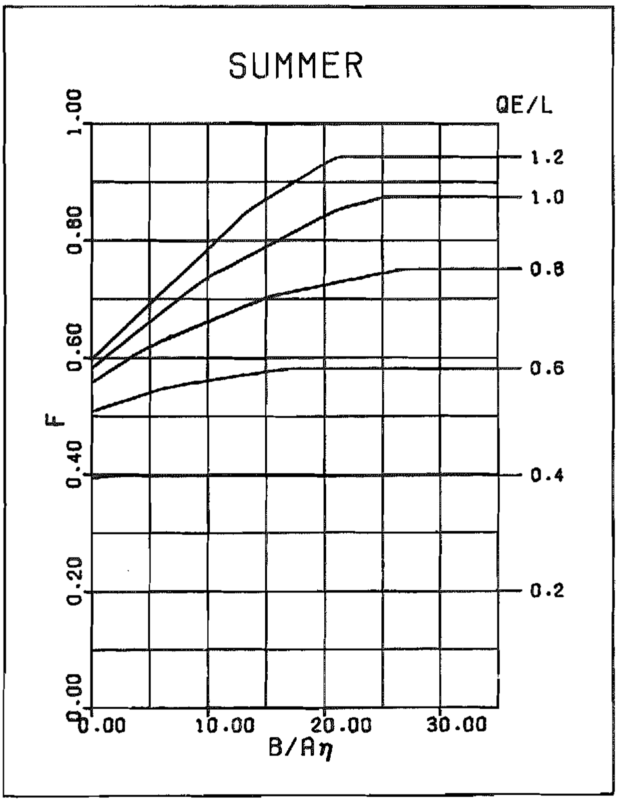
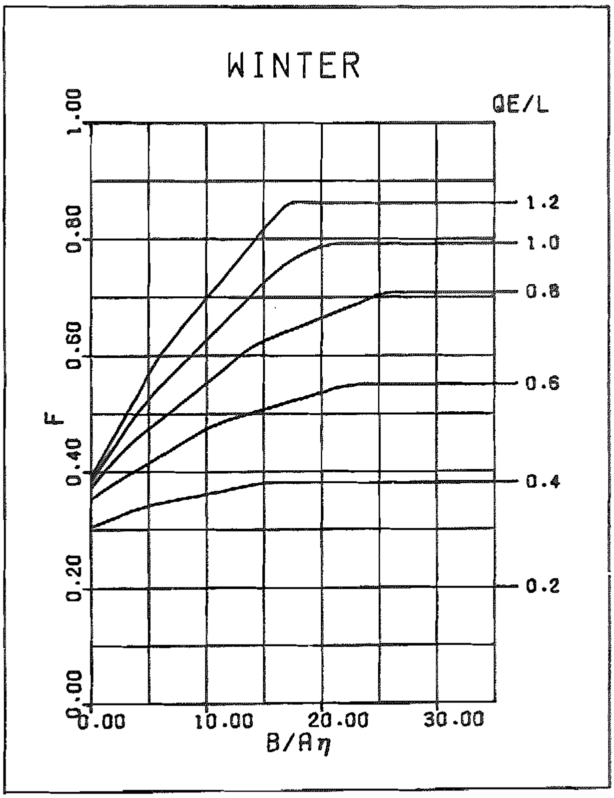


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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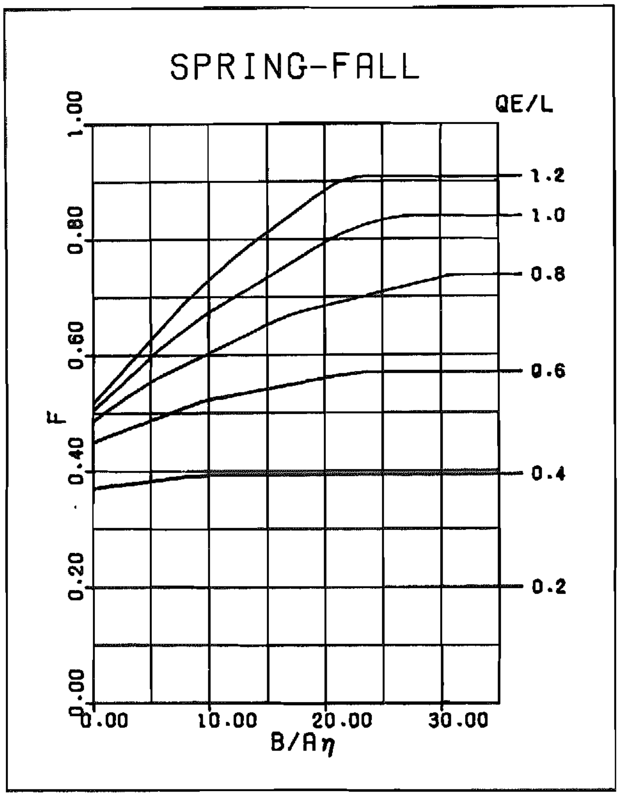


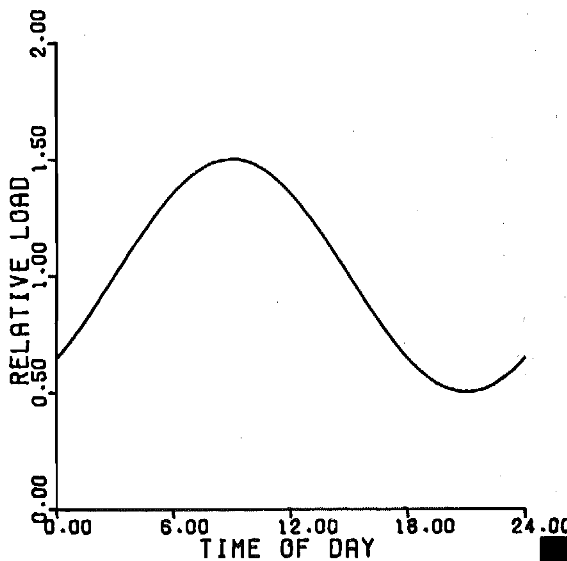
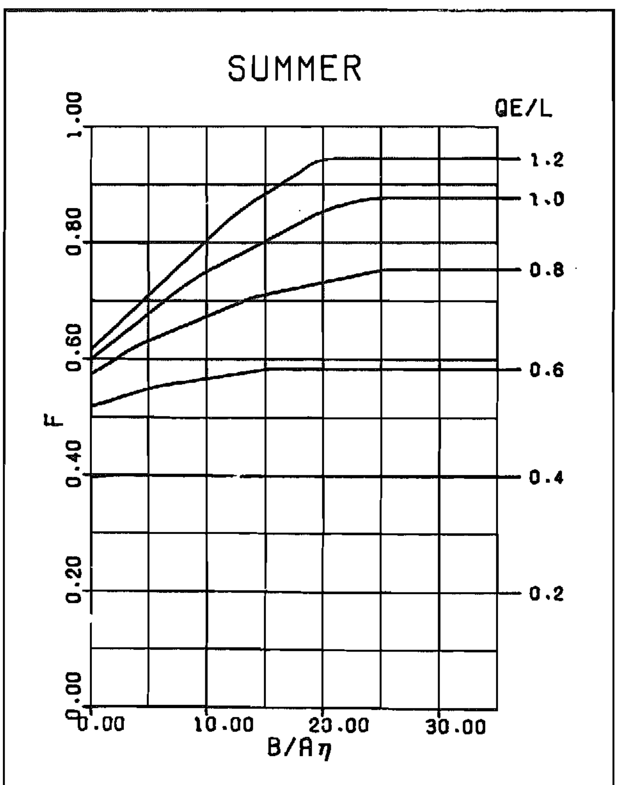
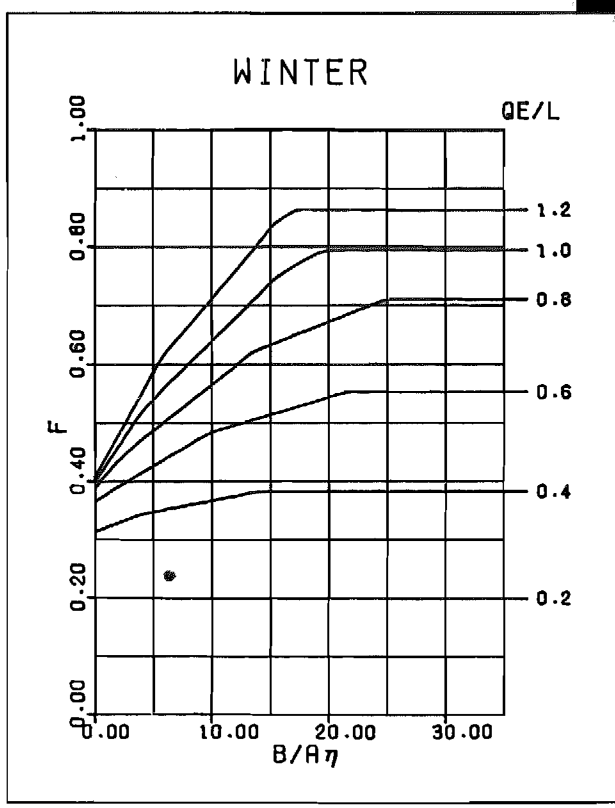


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





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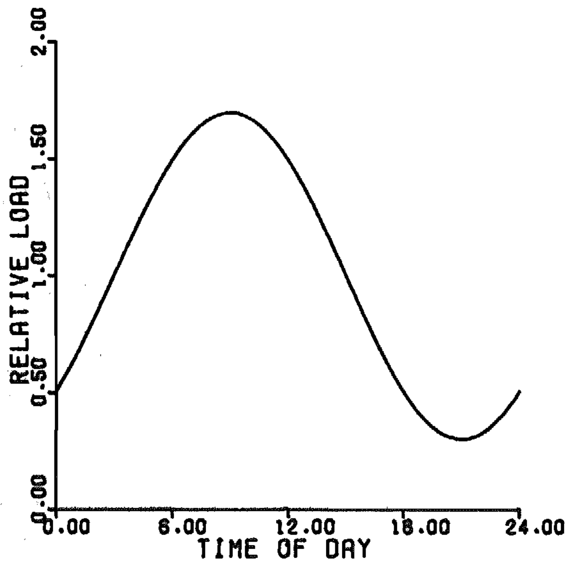


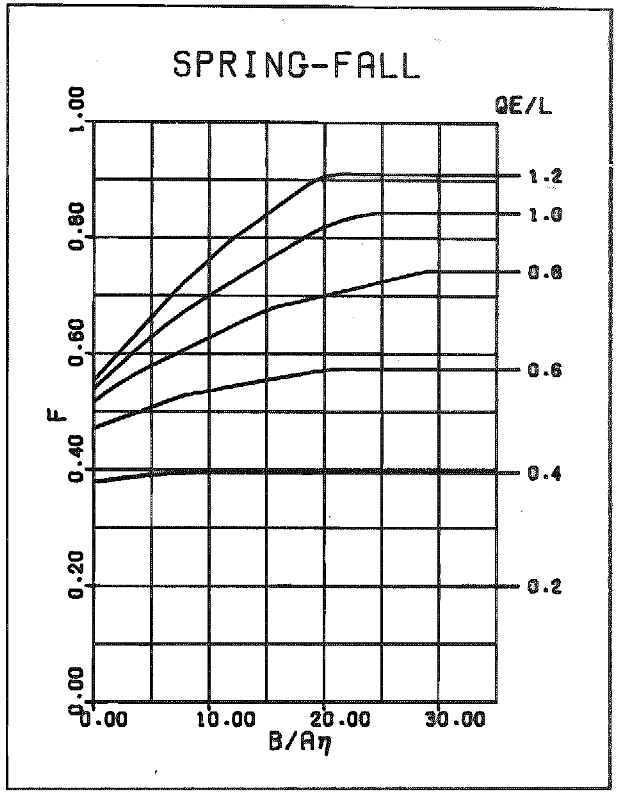
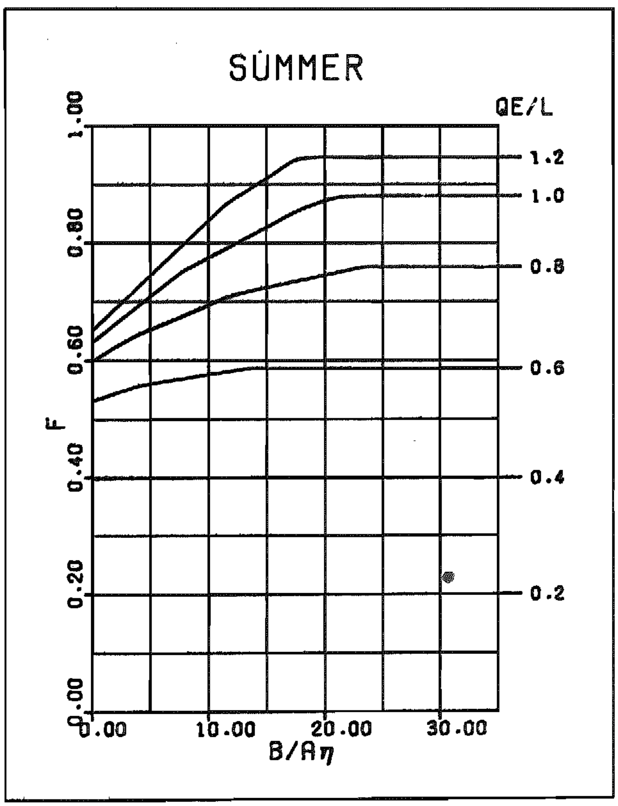
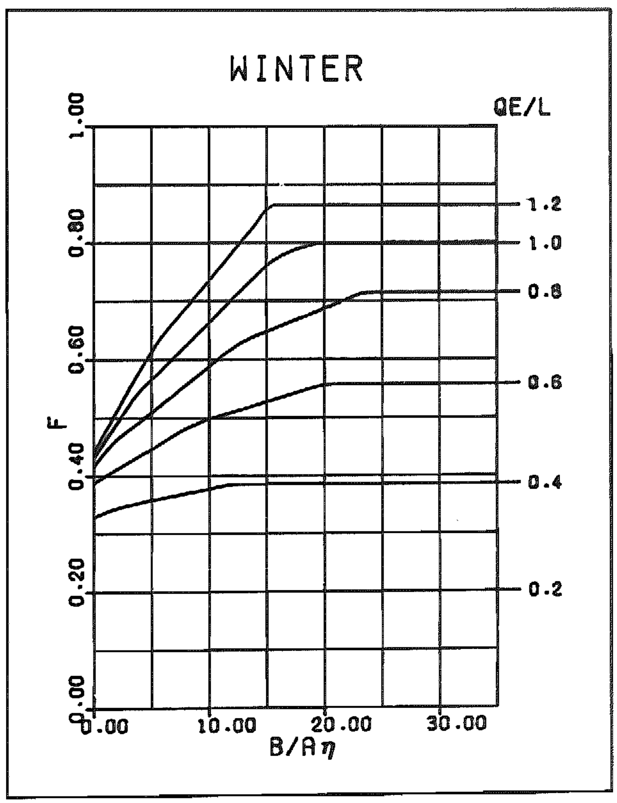


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





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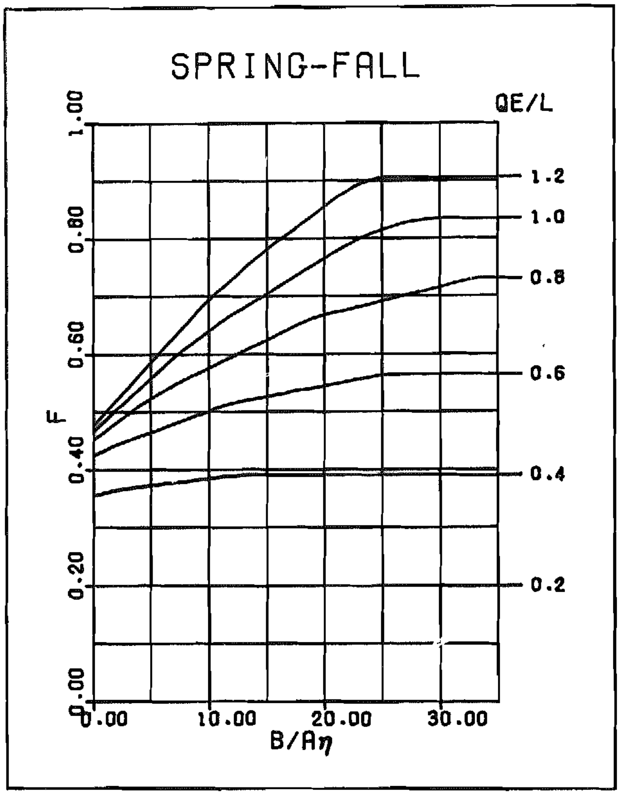


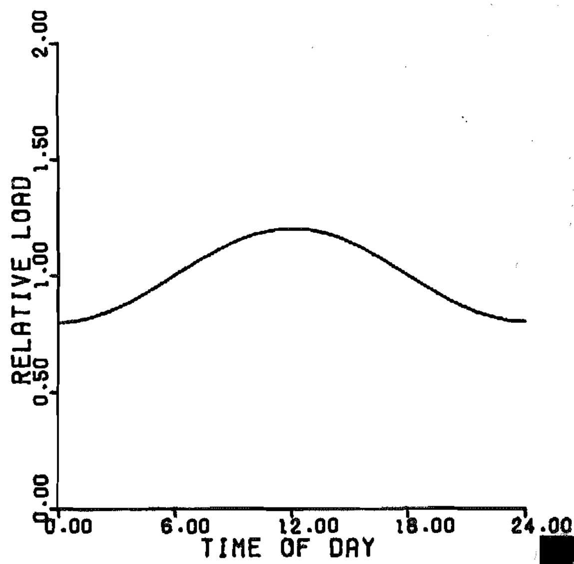
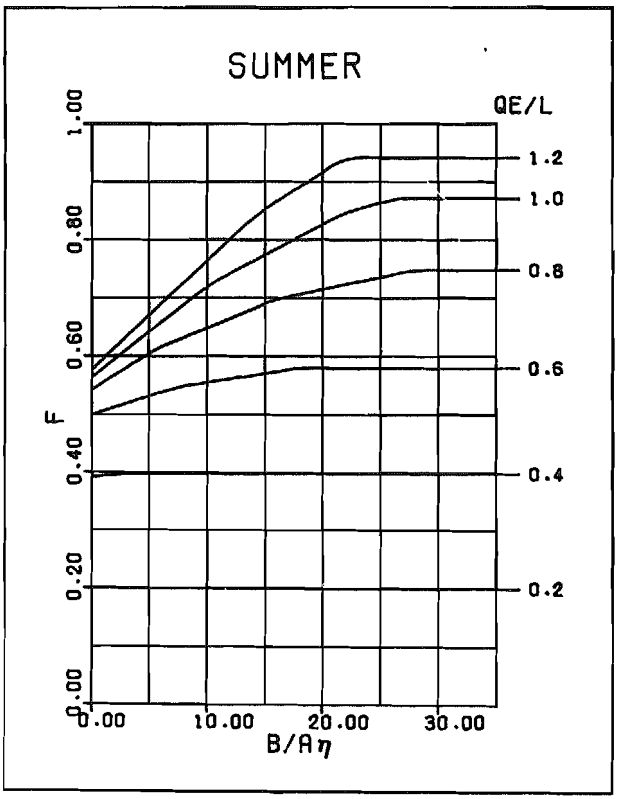
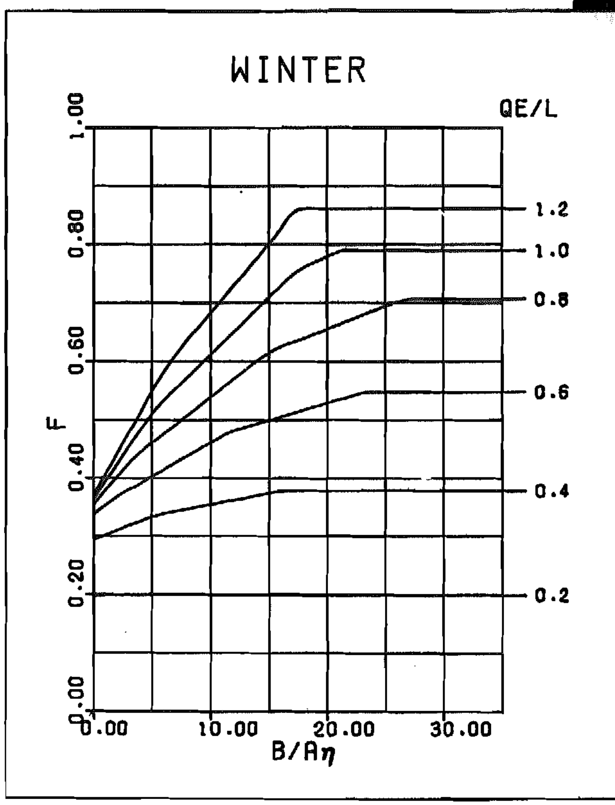


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





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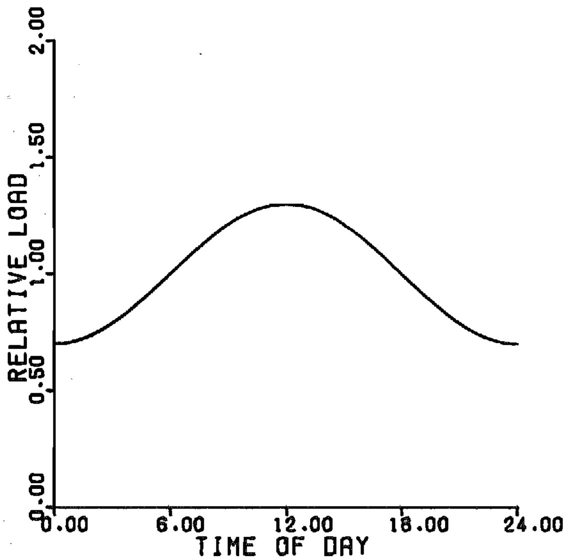
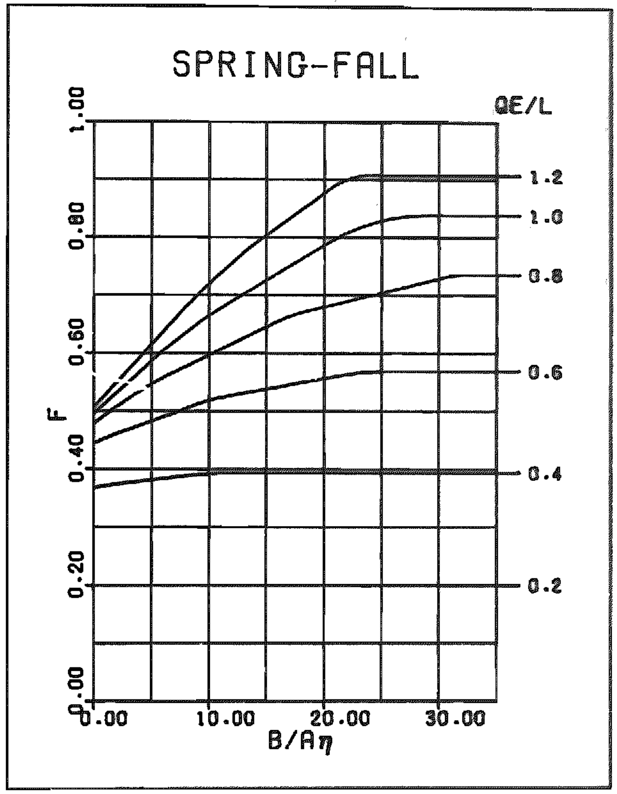
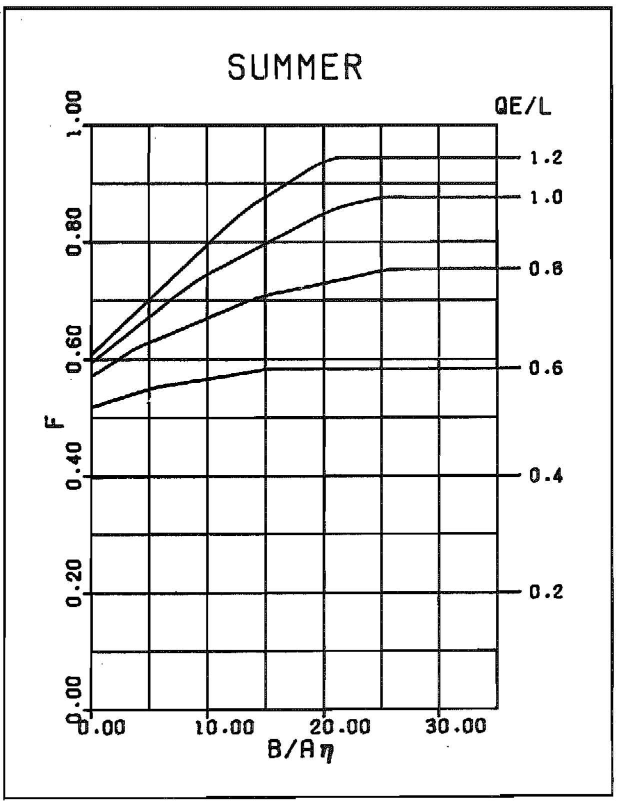
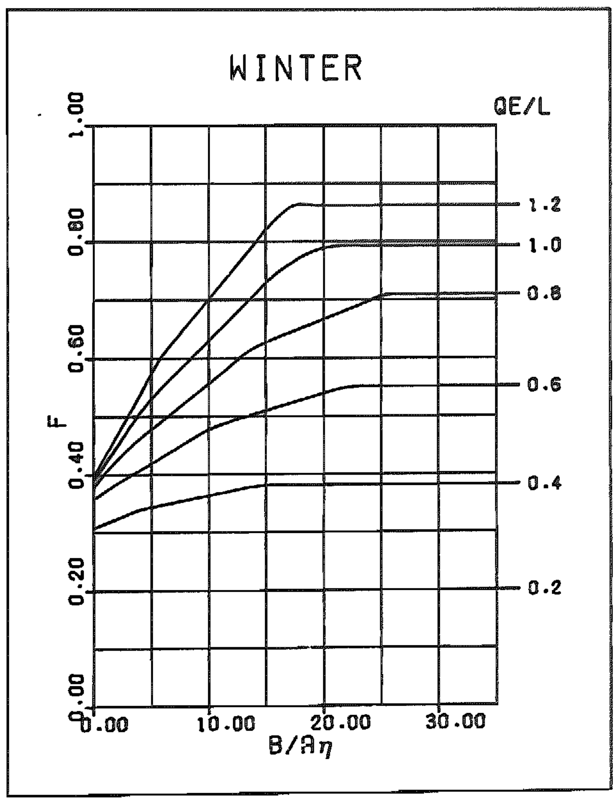


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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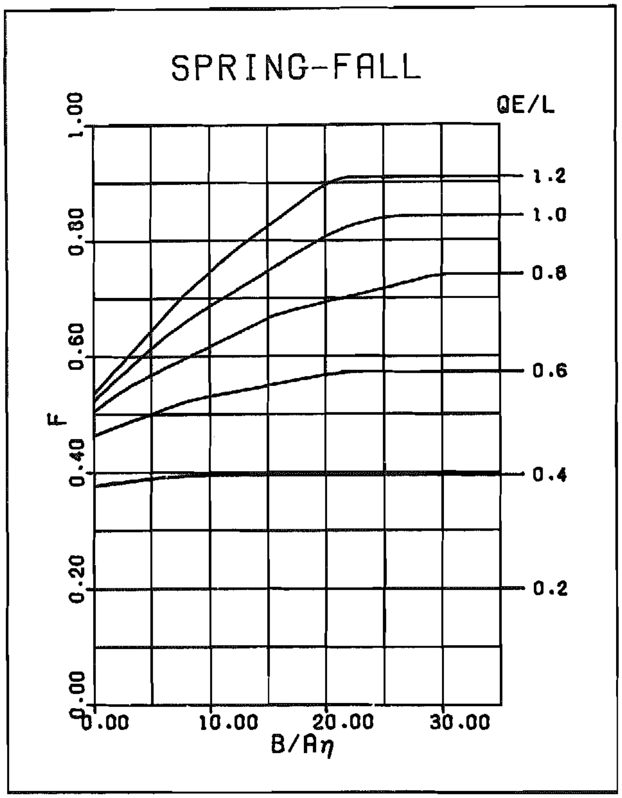

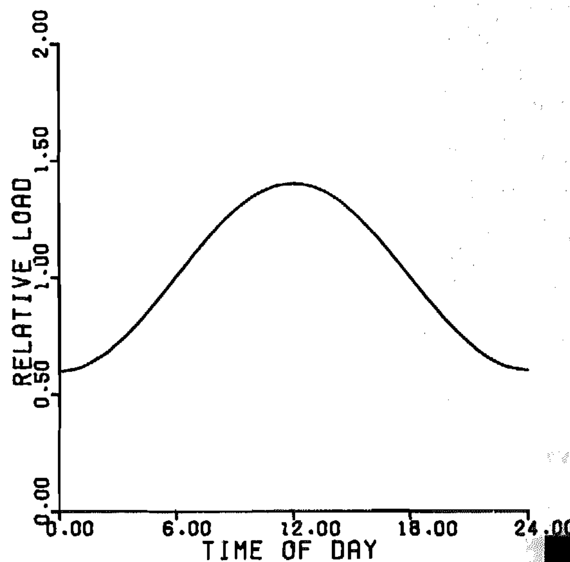

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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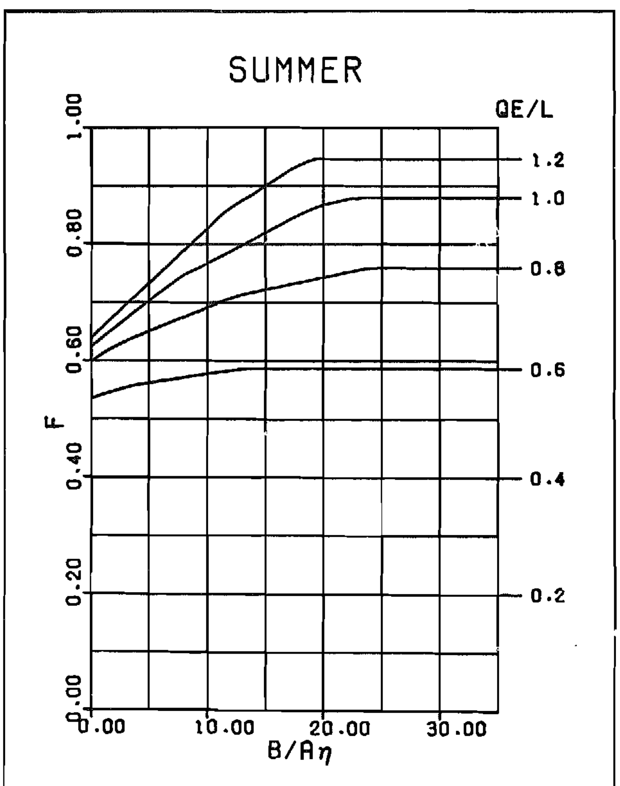

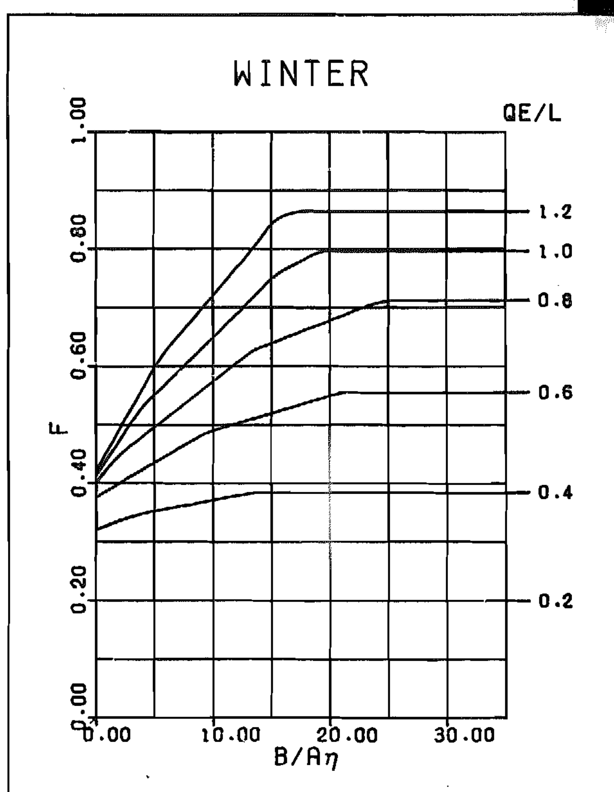

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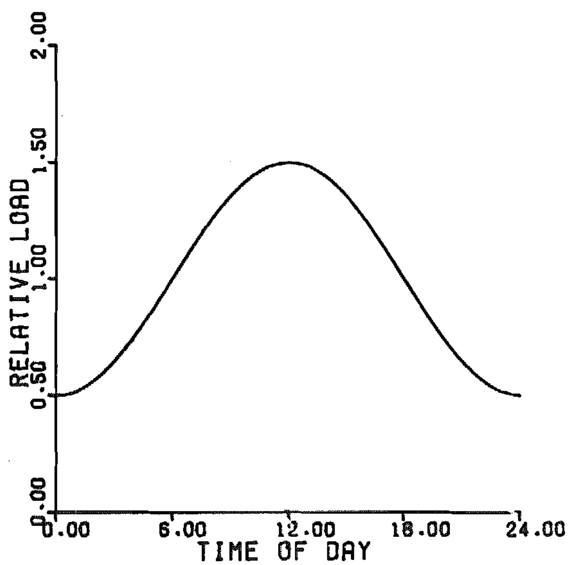
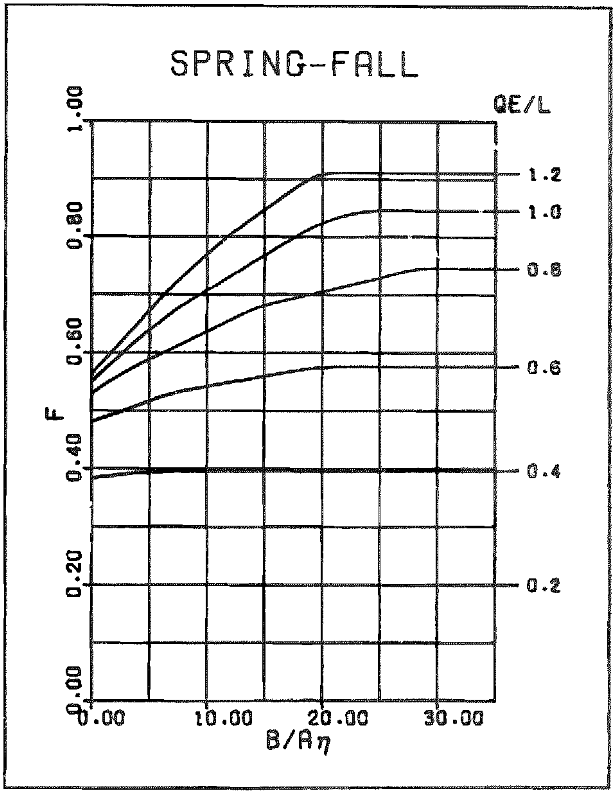
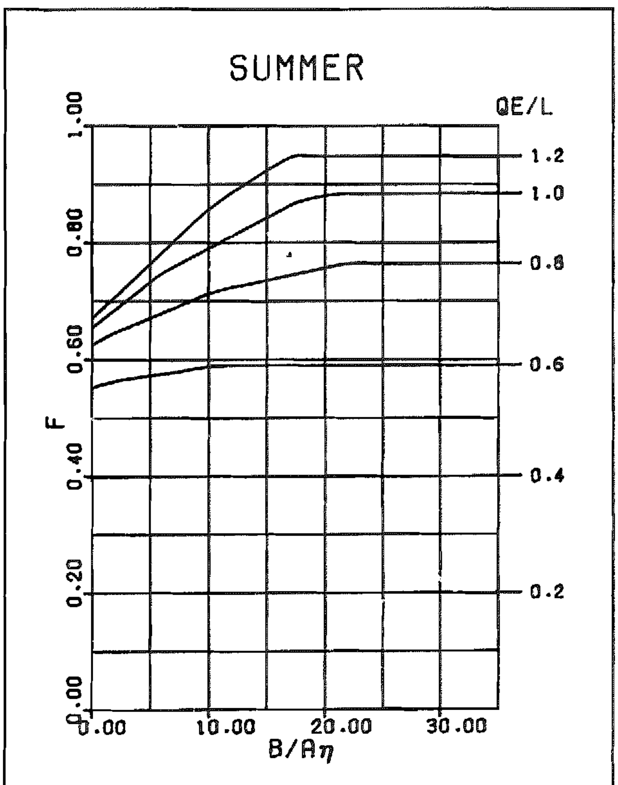
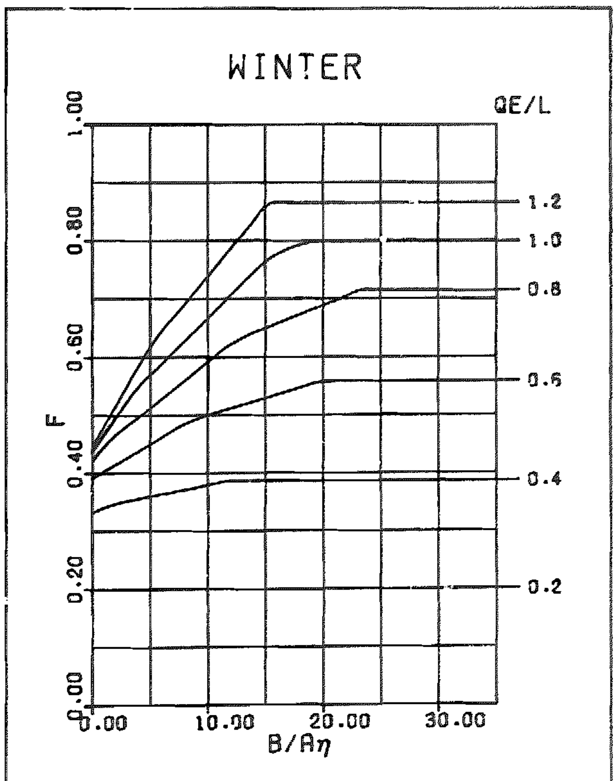
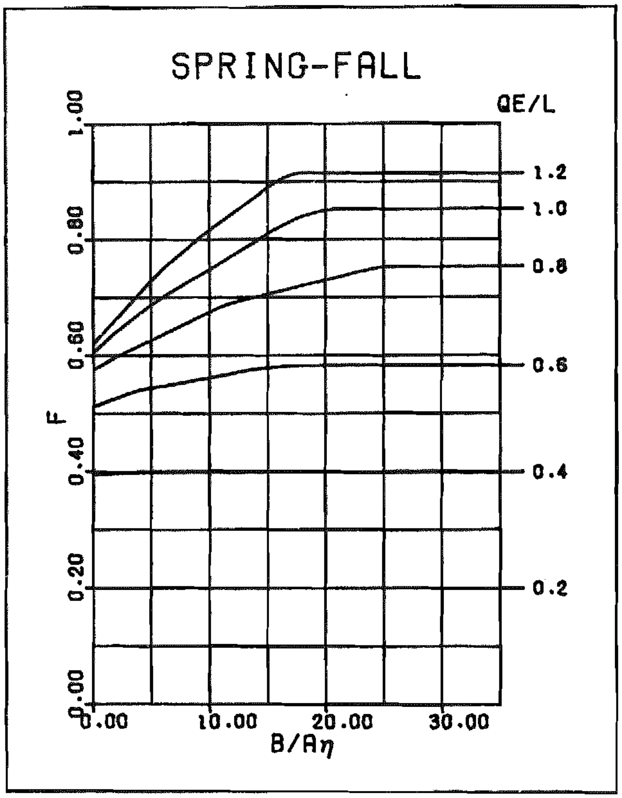


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63









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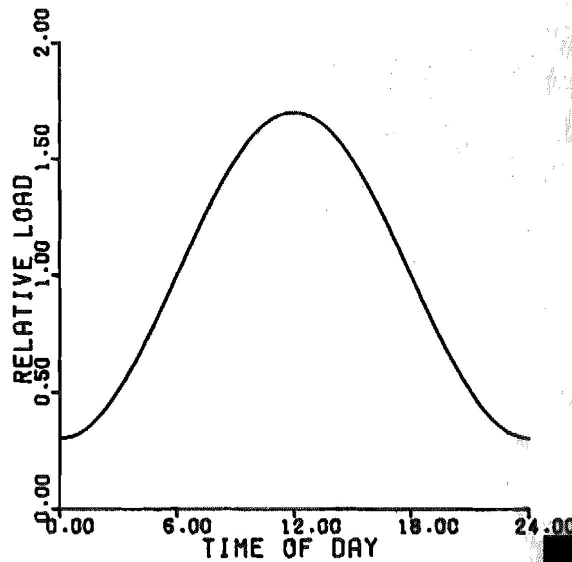
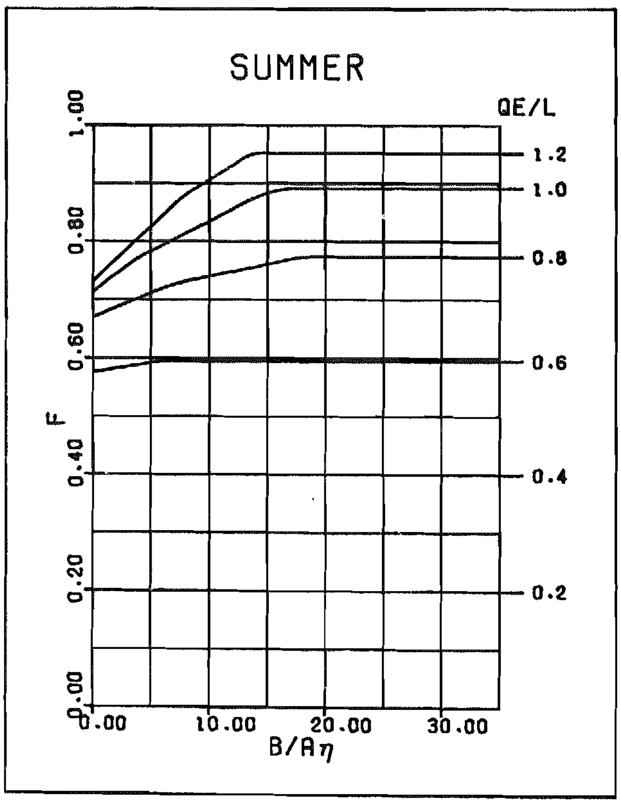
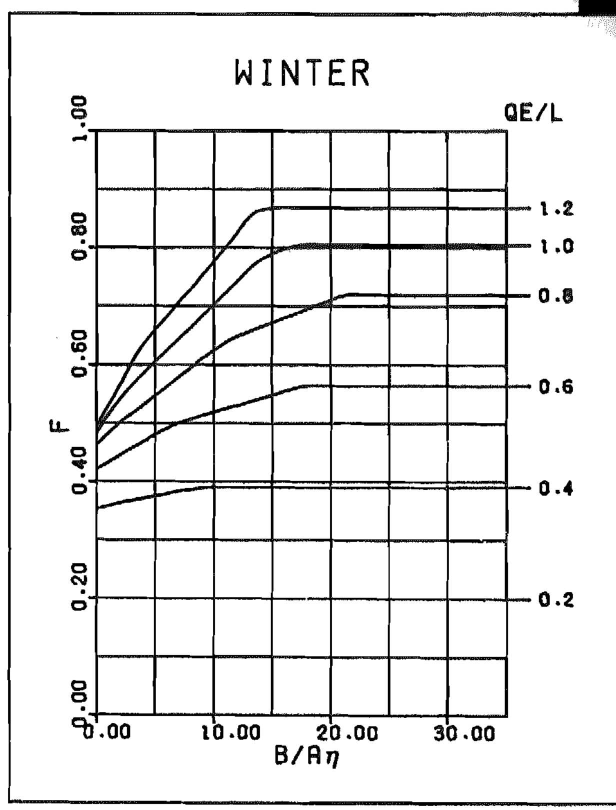


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





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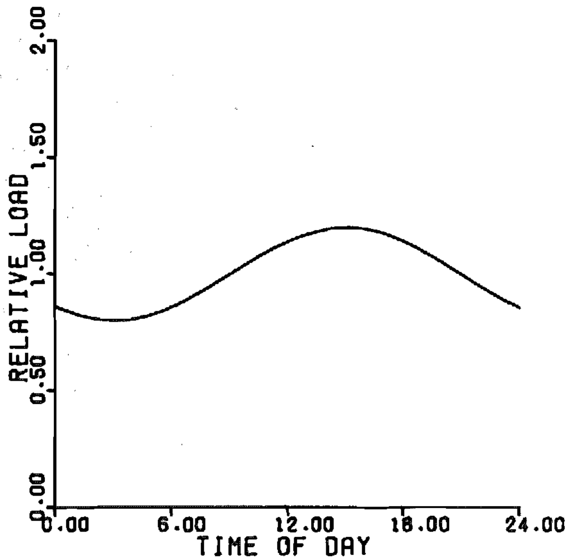
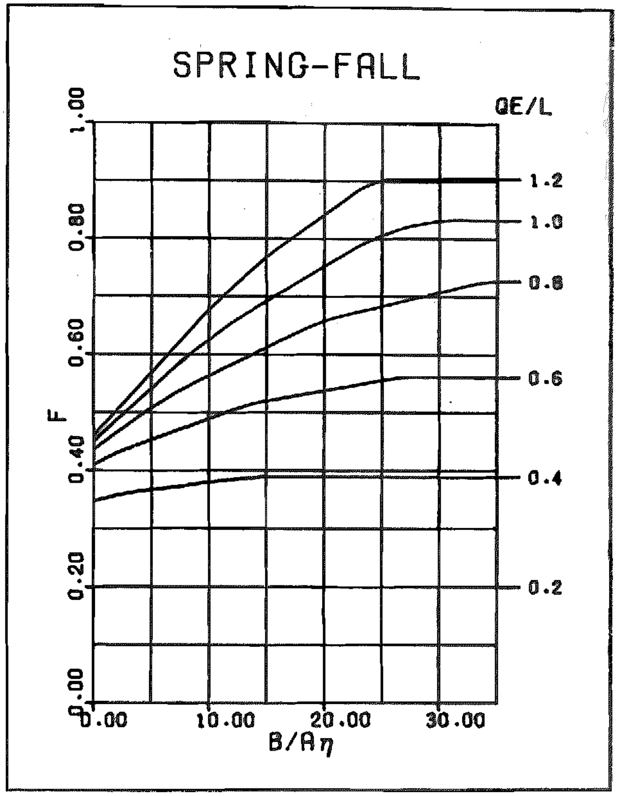
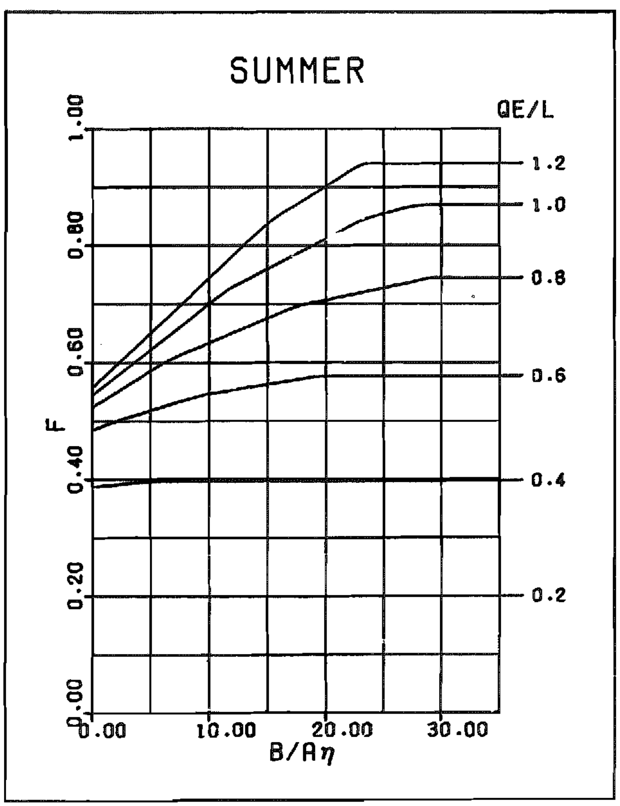
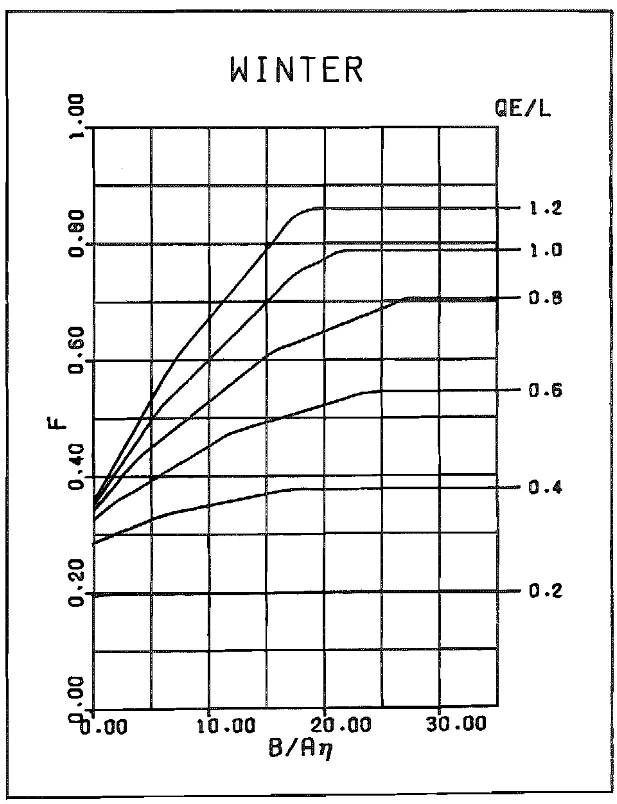


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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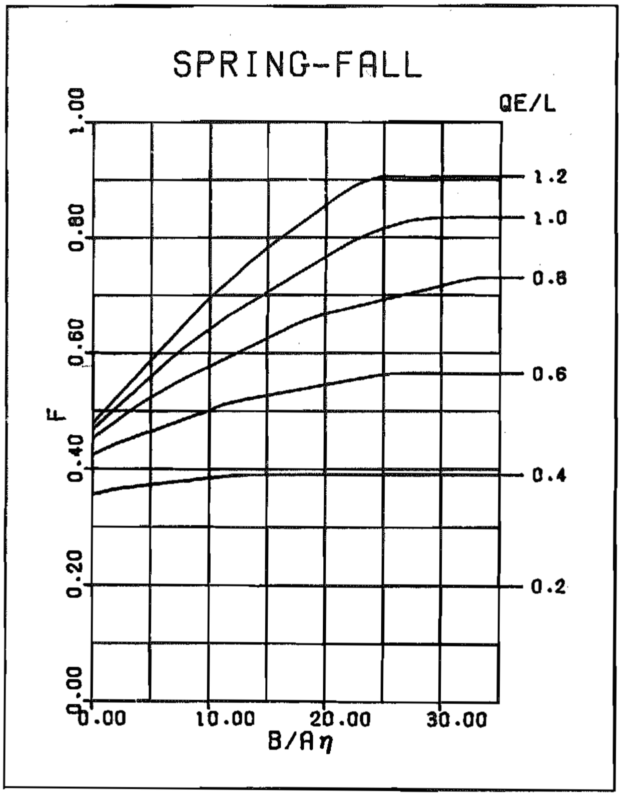

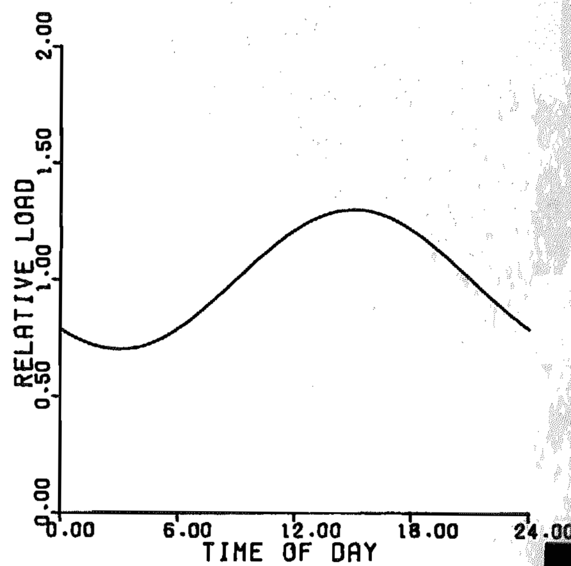

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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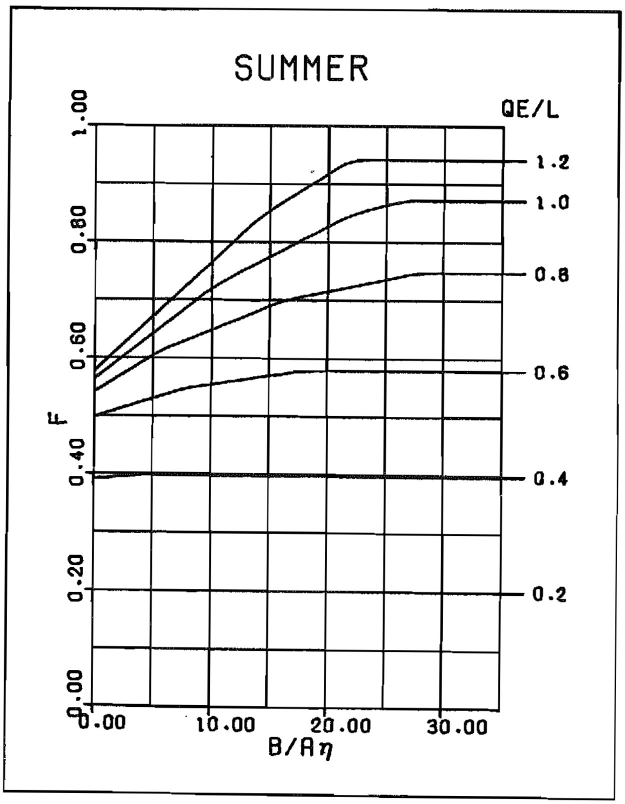

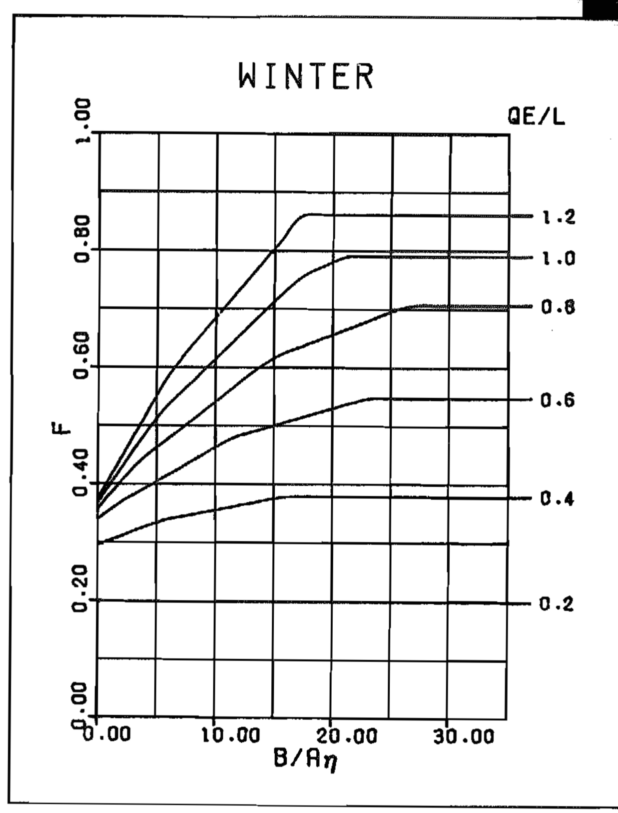

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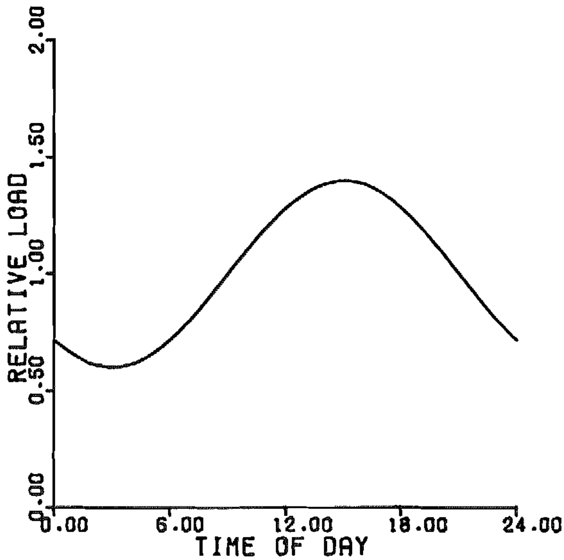


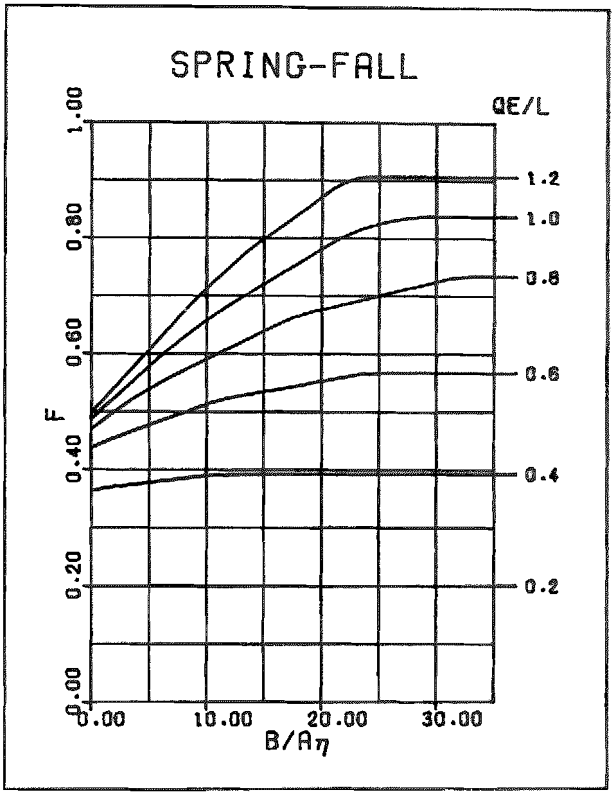
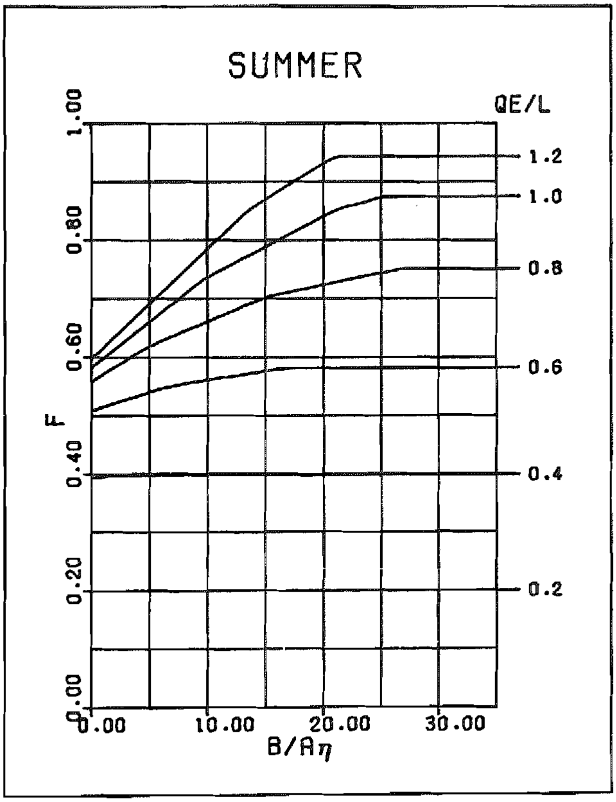
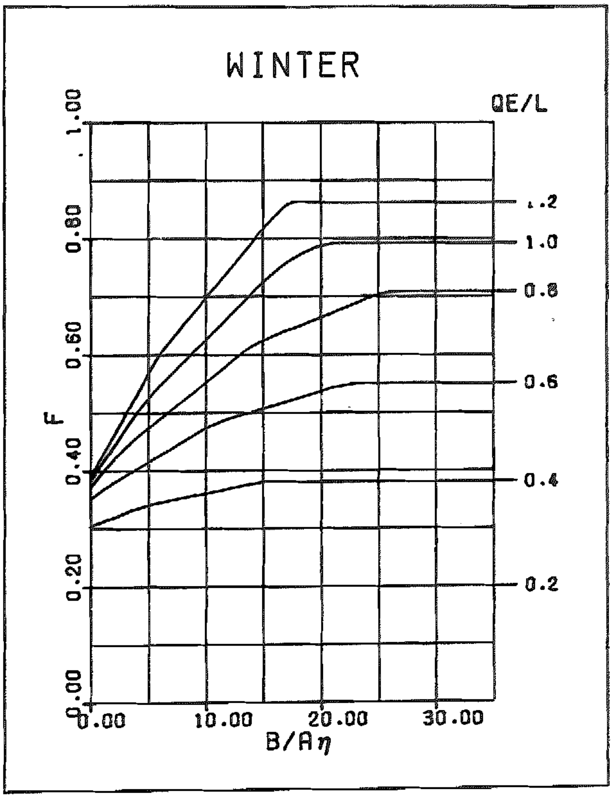


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





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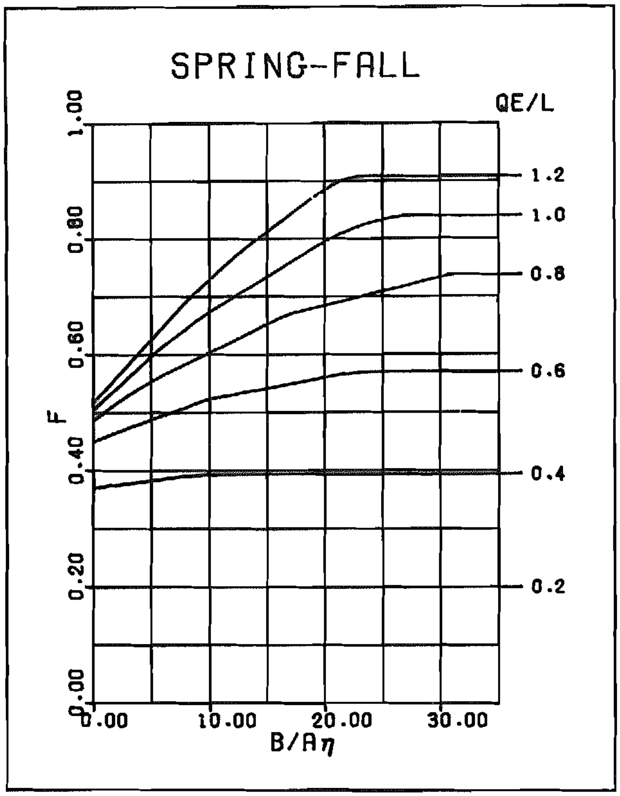

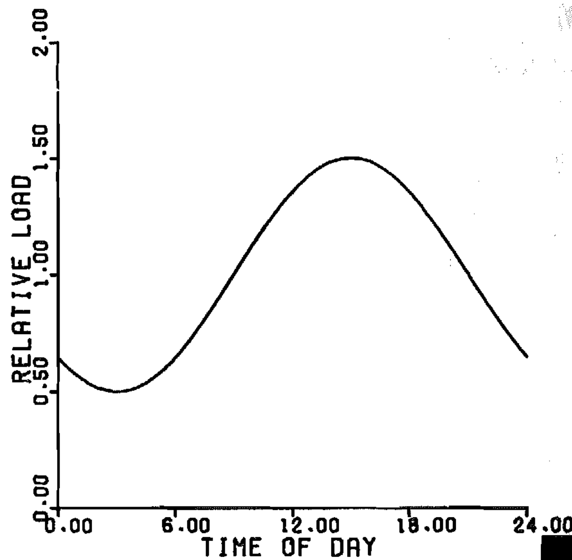

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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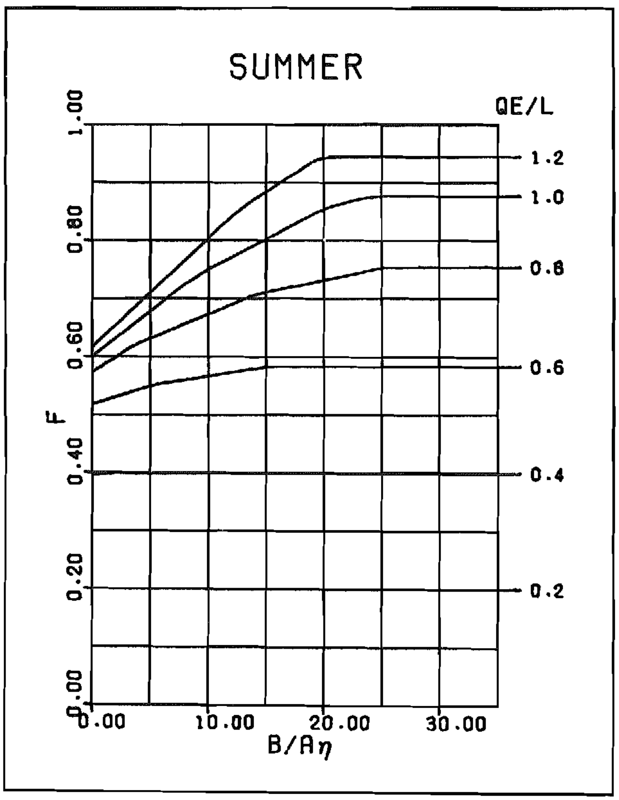

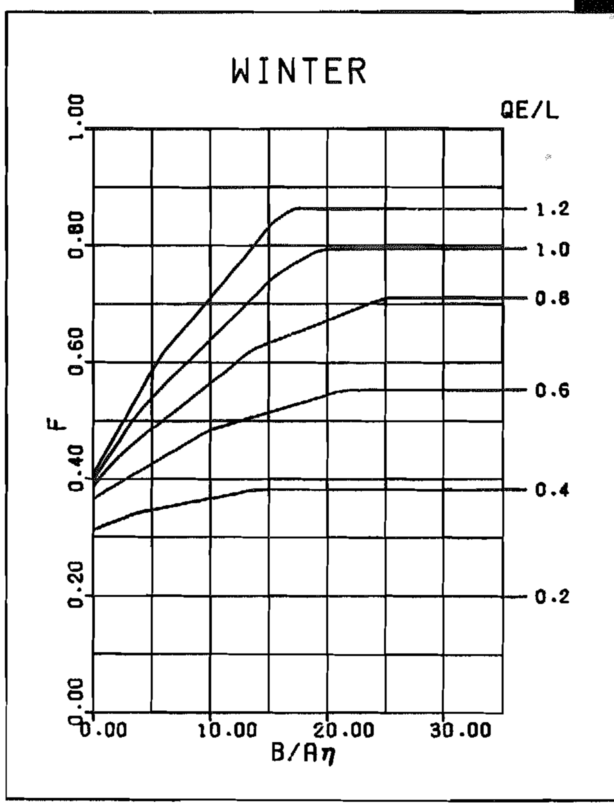

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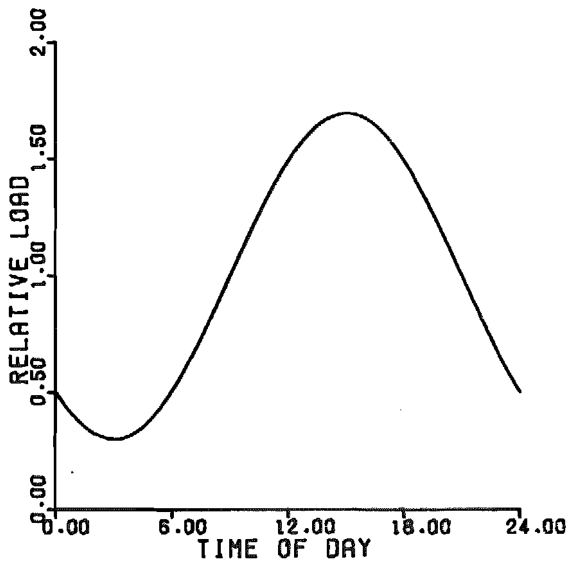

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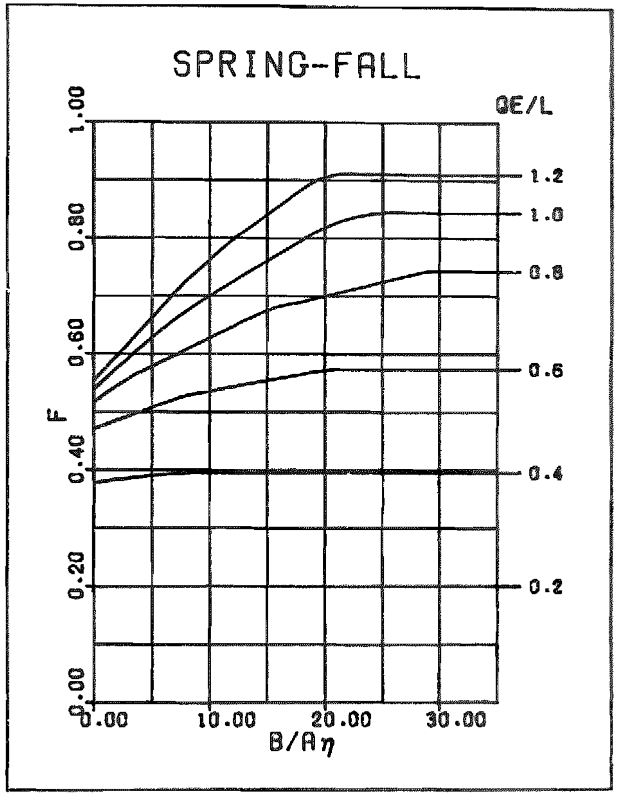
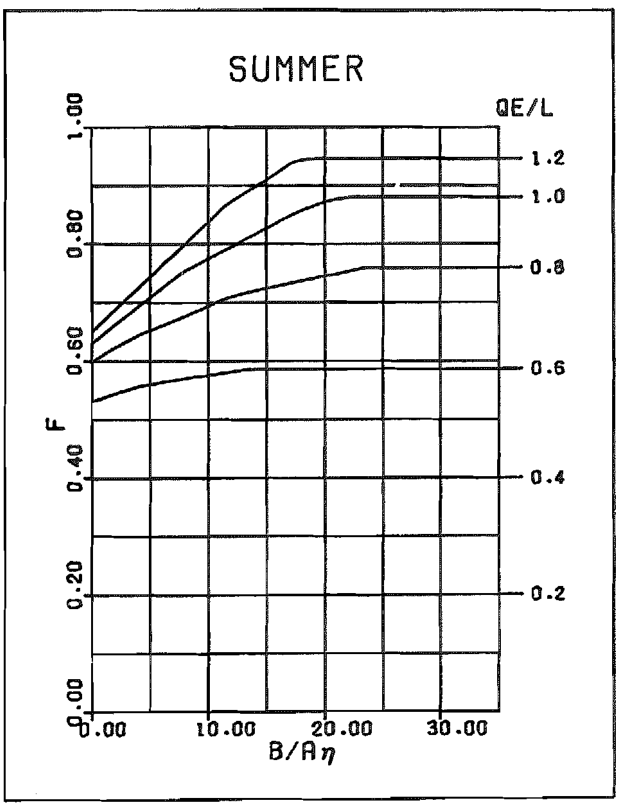
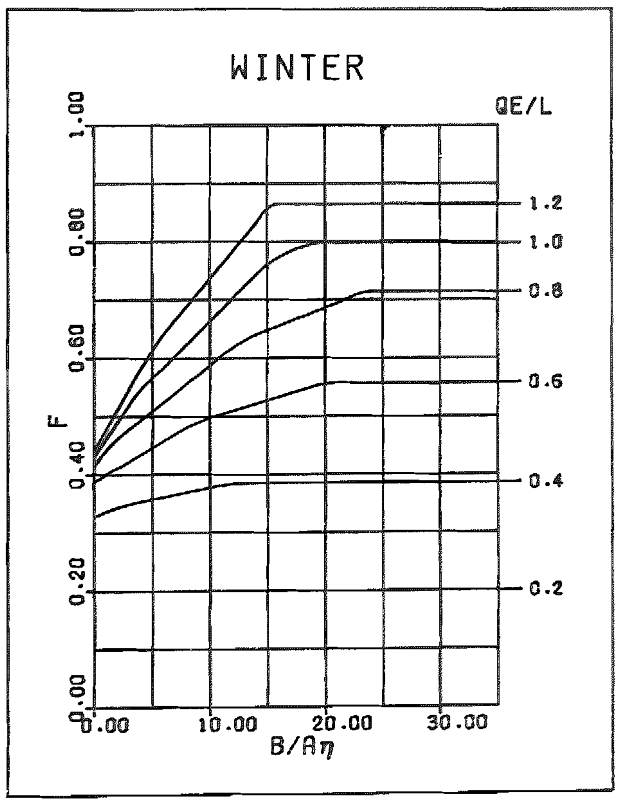
For Reading Key See Page A-63







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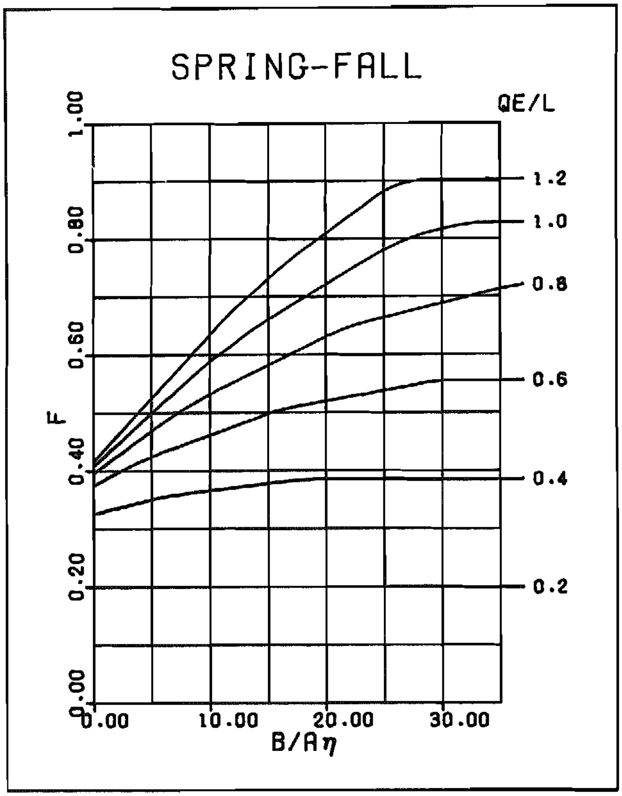

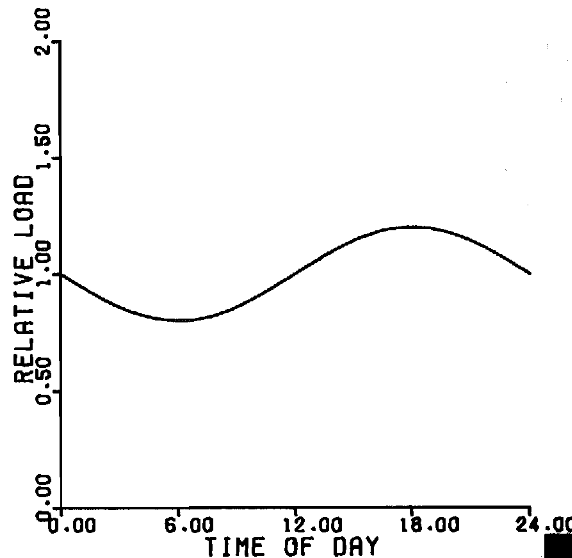

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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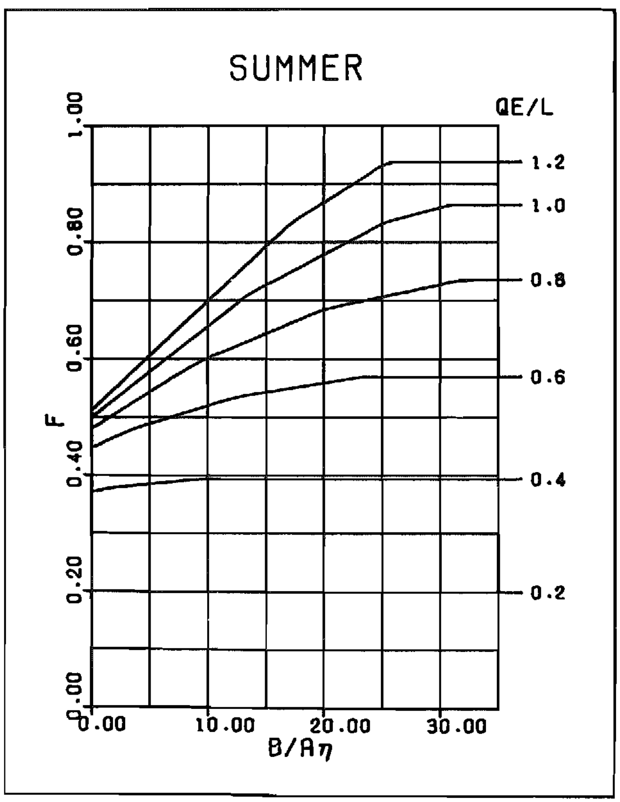

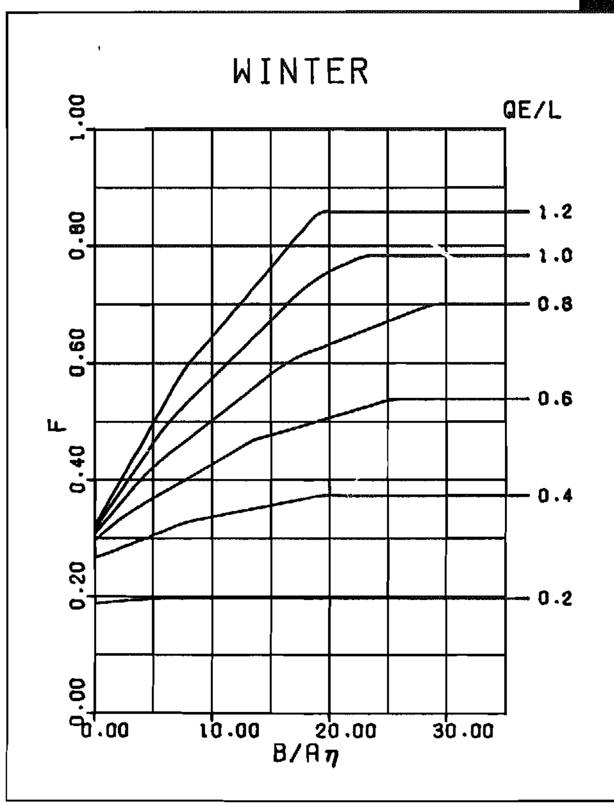

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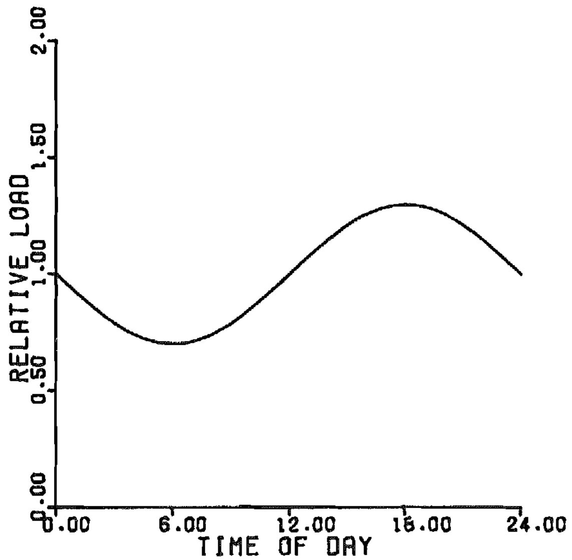
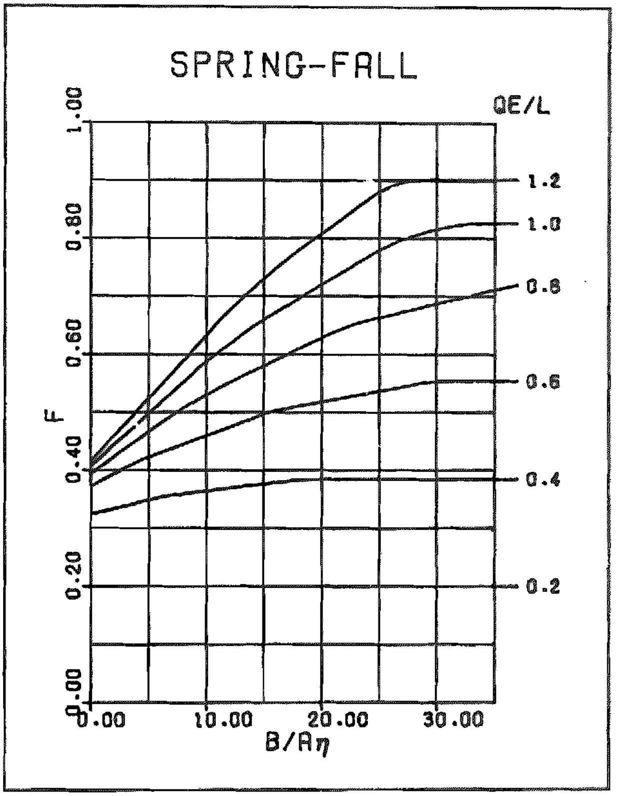
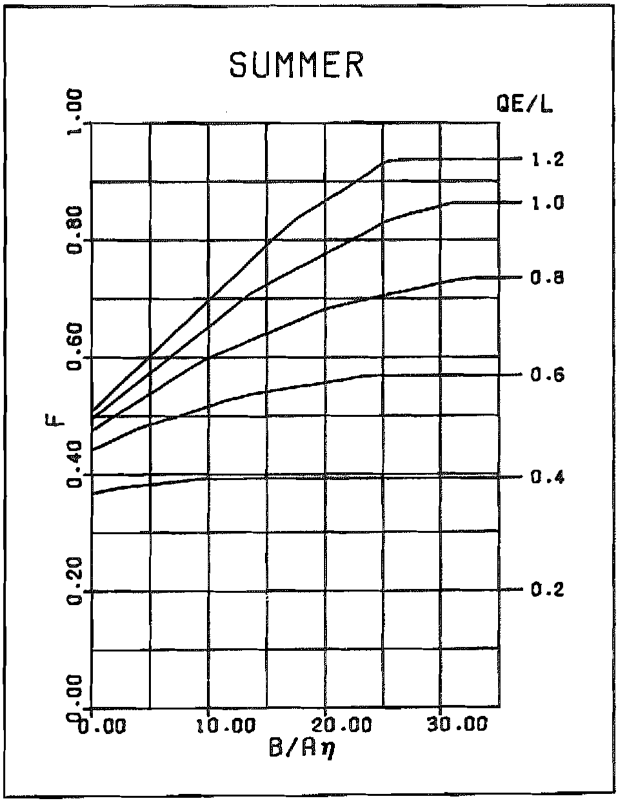
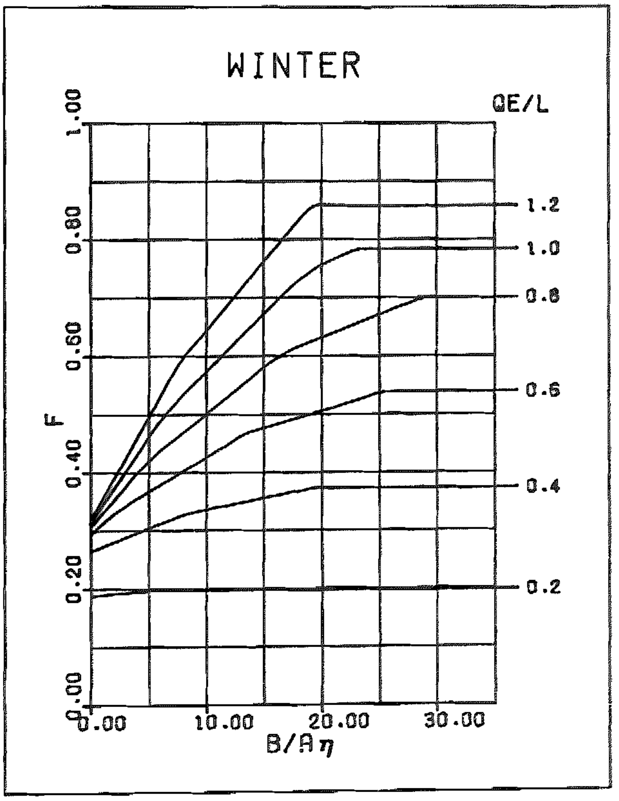


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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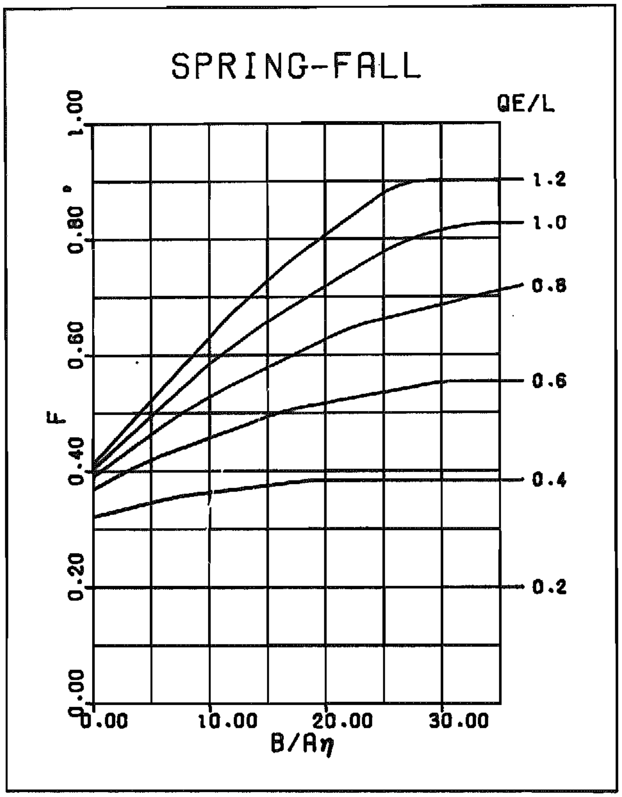

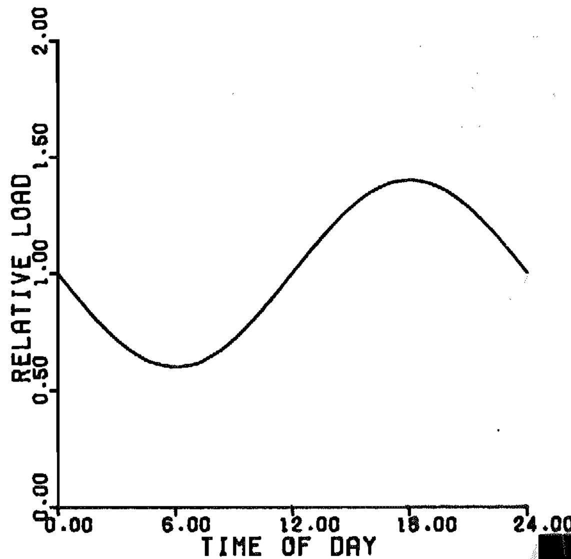

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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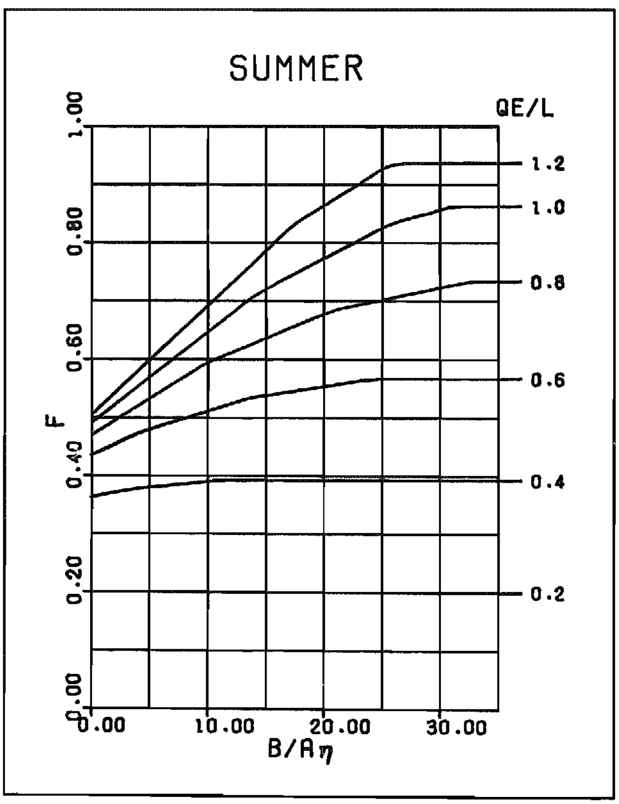

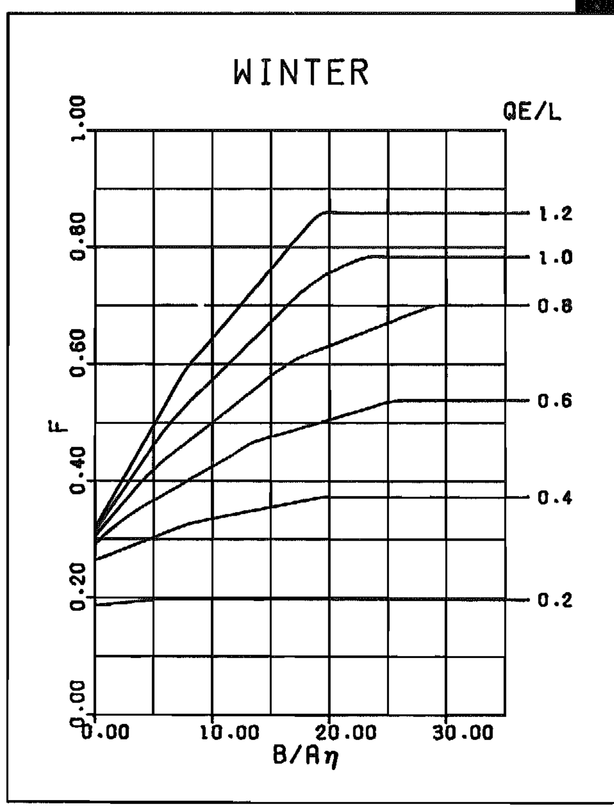

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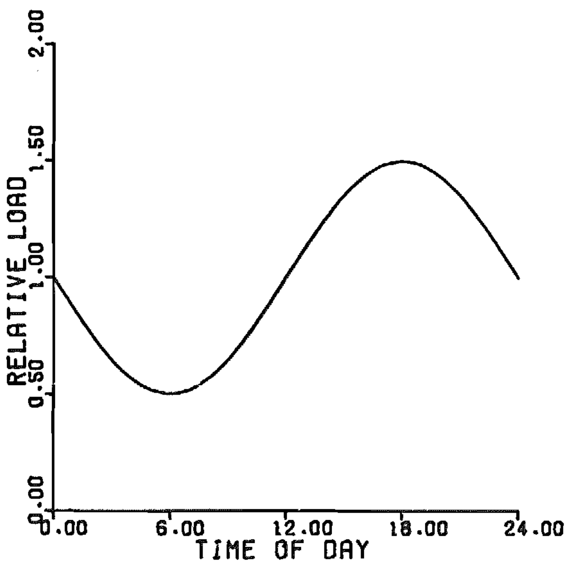


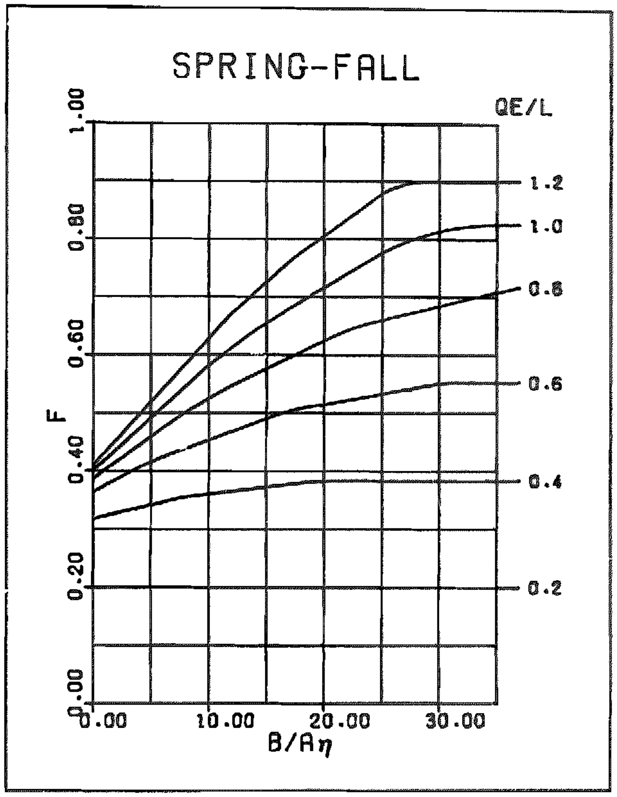
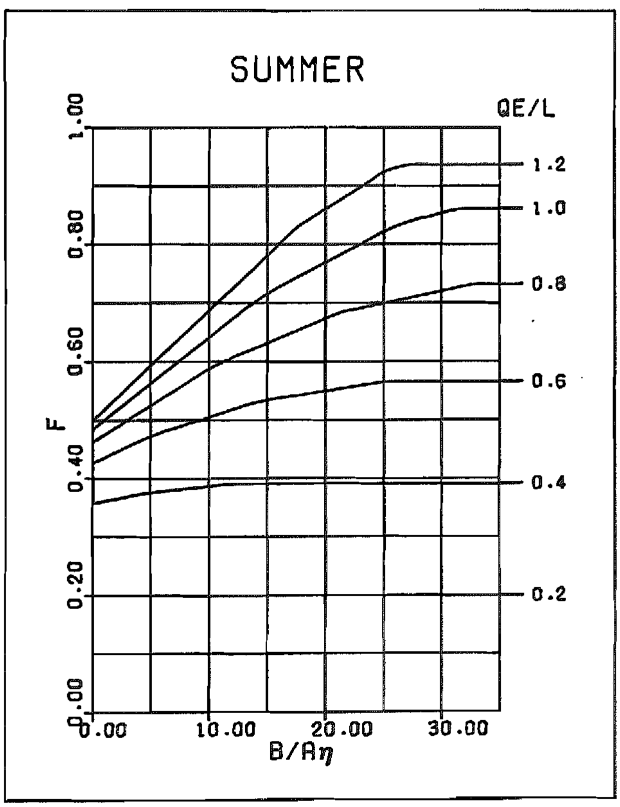
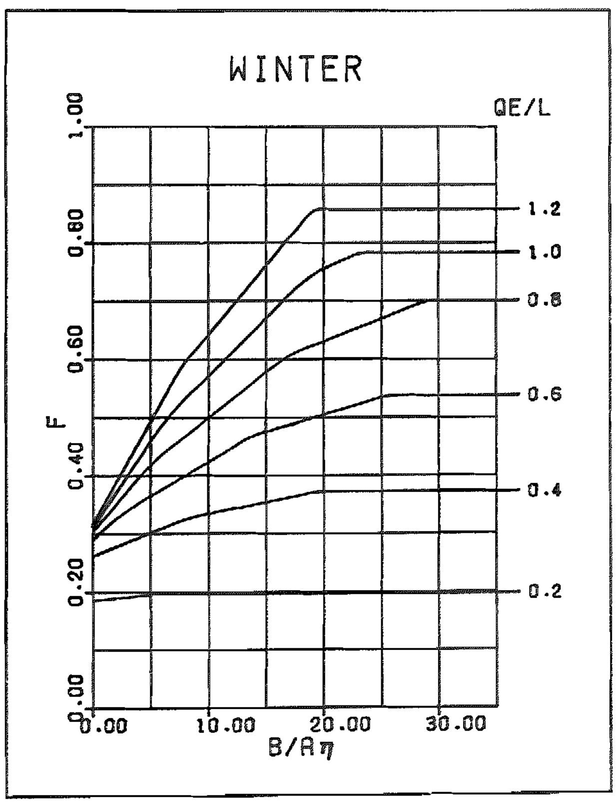
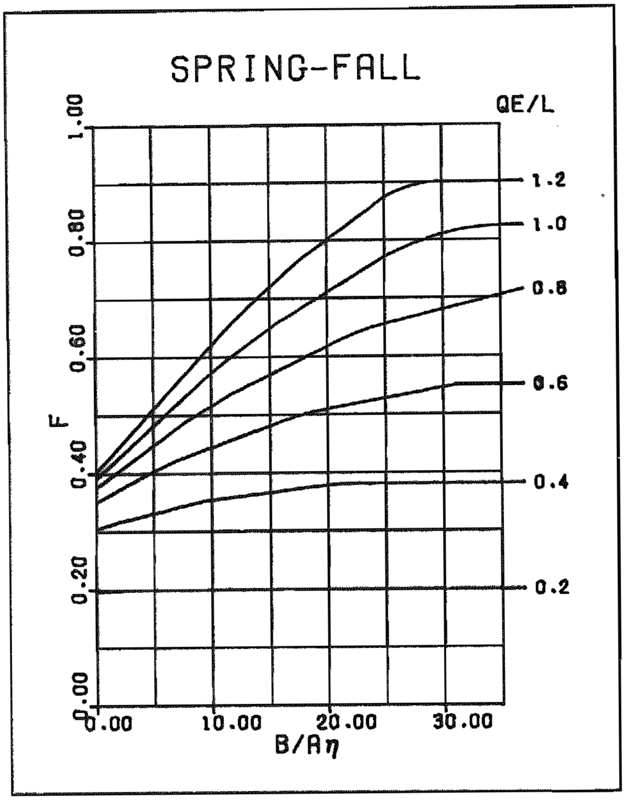


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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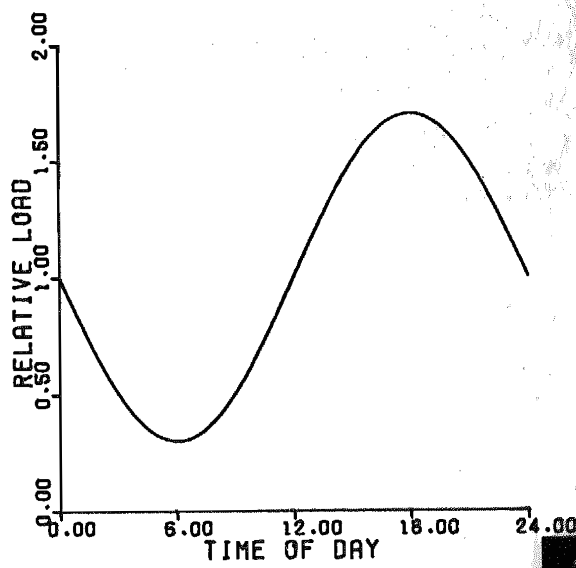
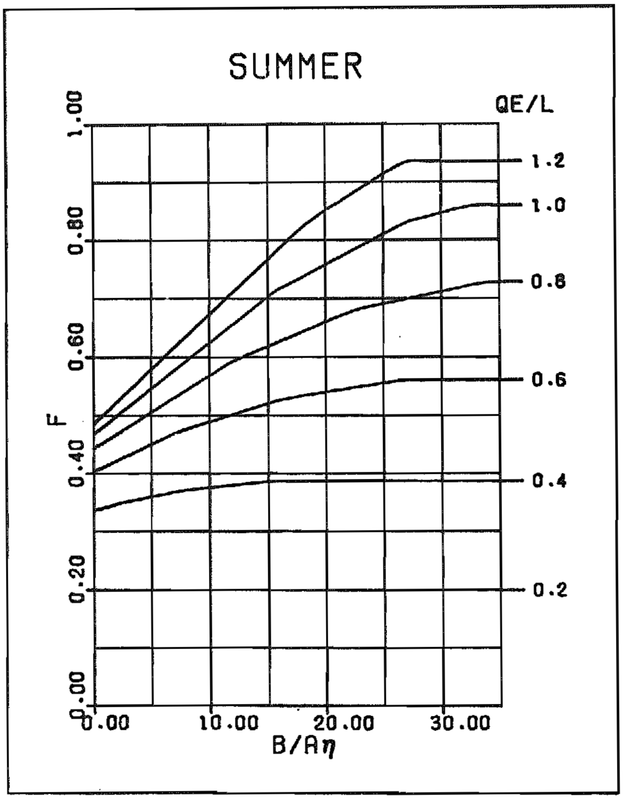
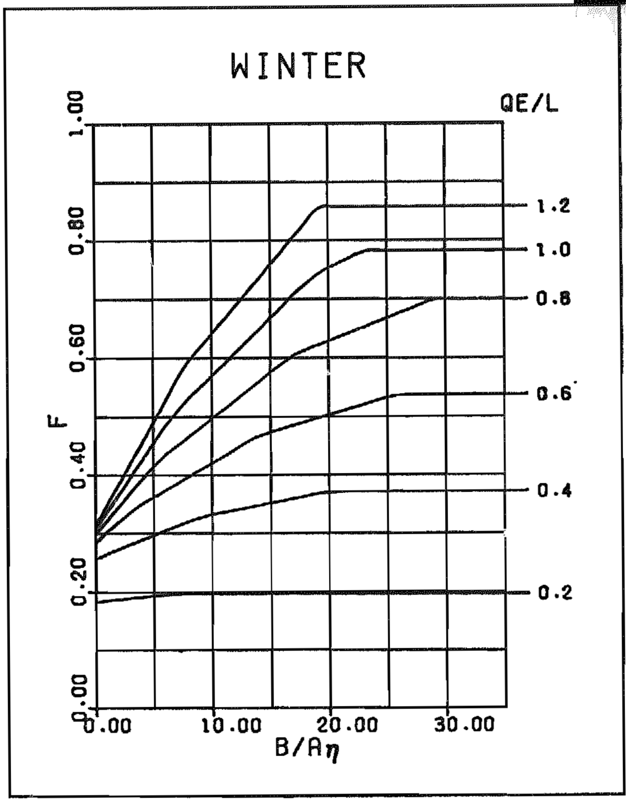


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





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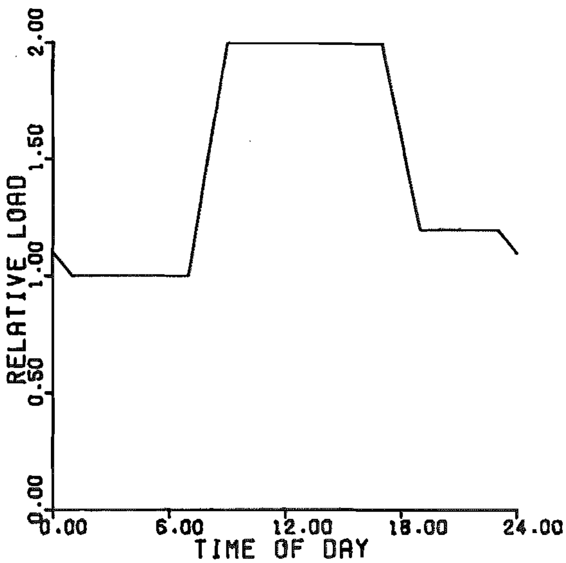
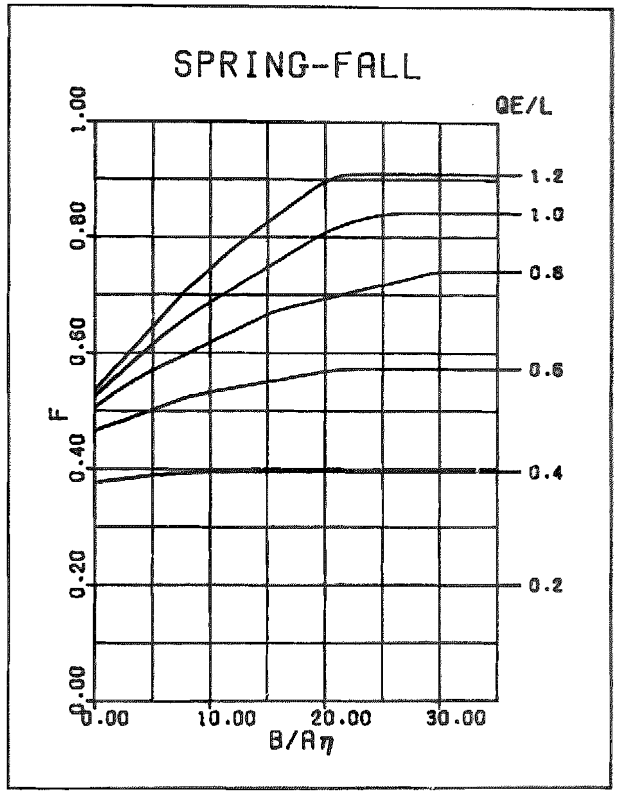
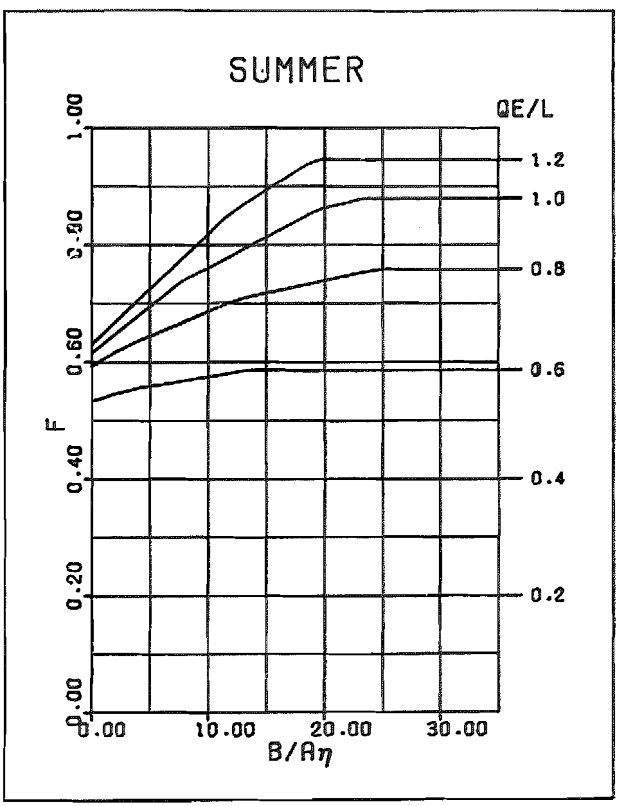
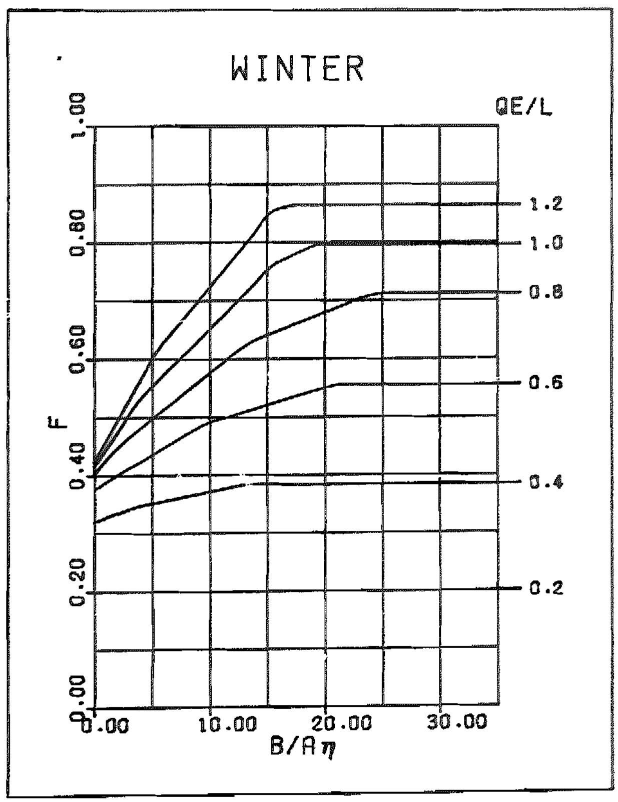


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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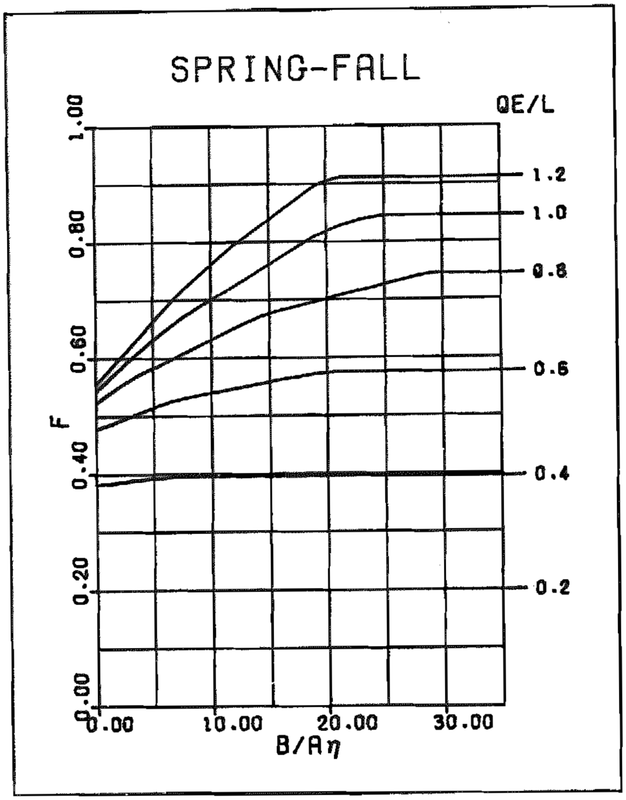


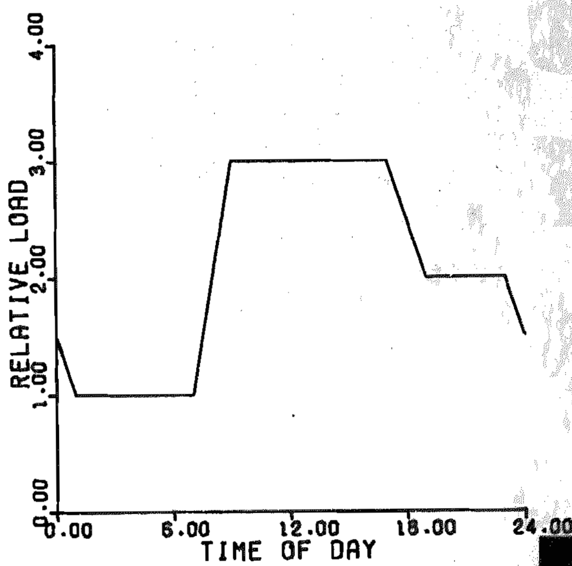
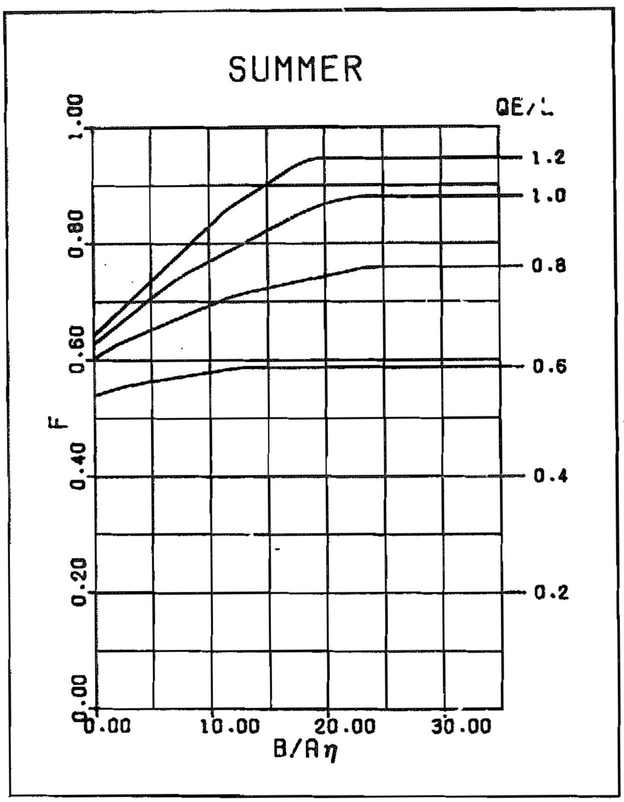
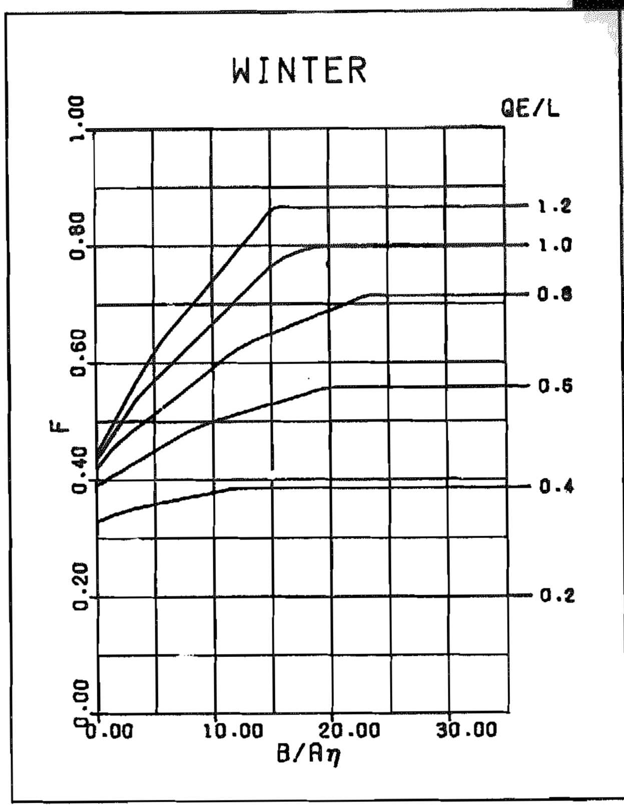


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





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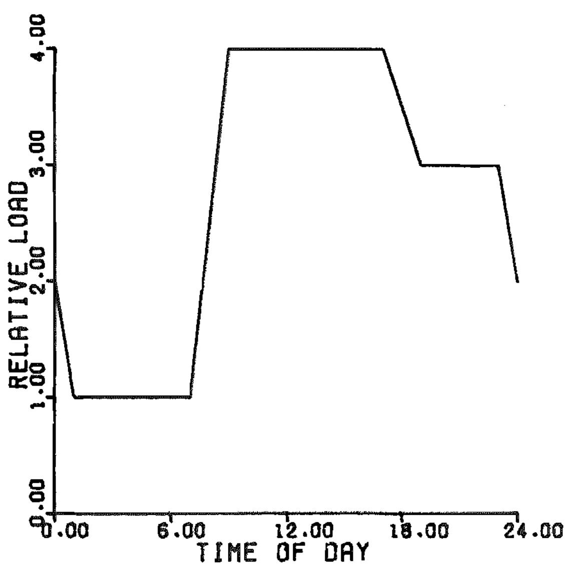
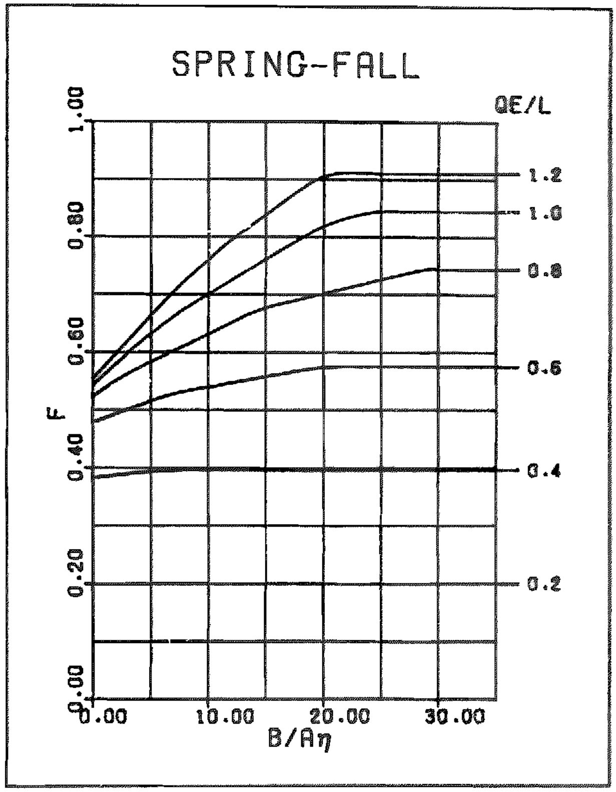
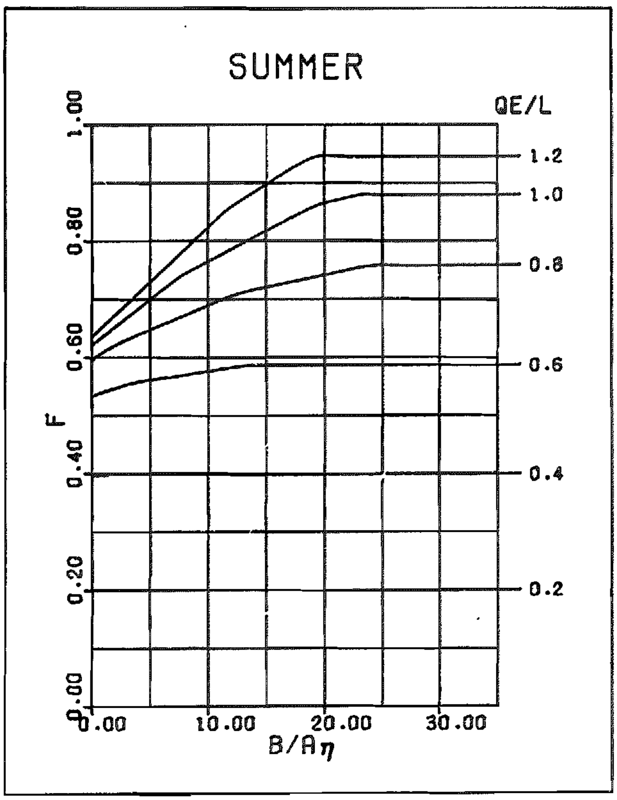
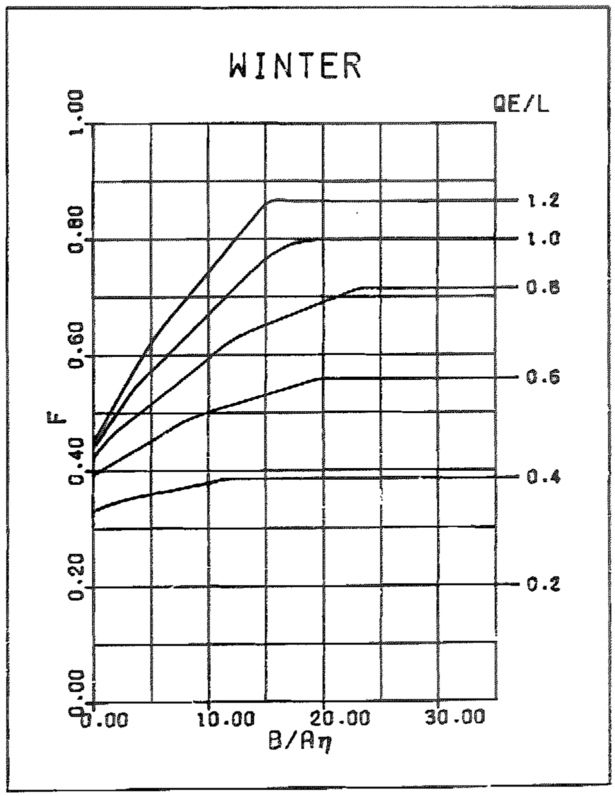


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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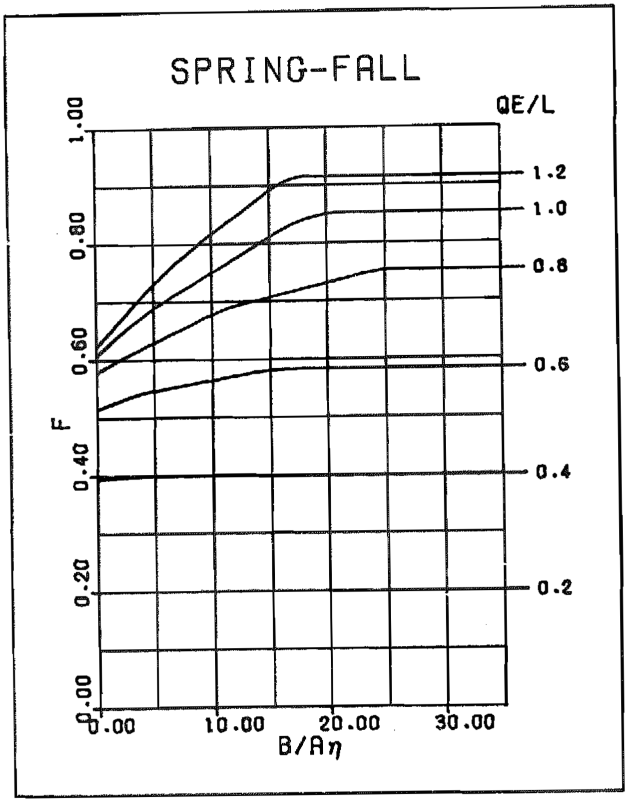

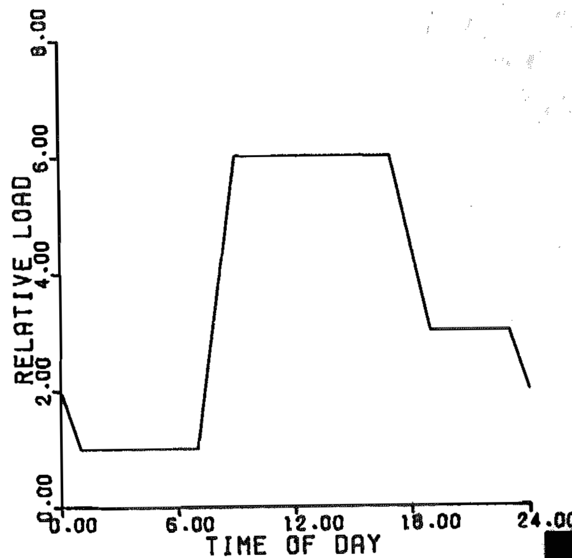

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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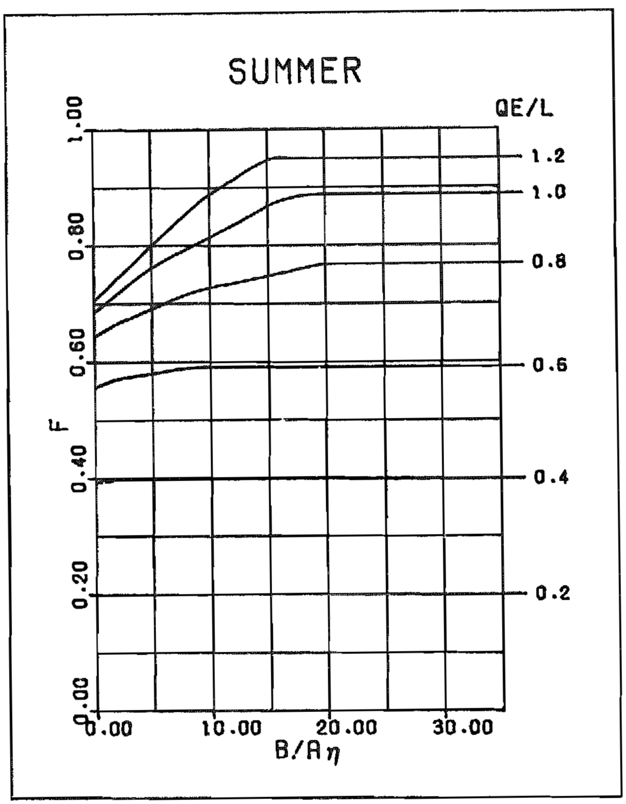

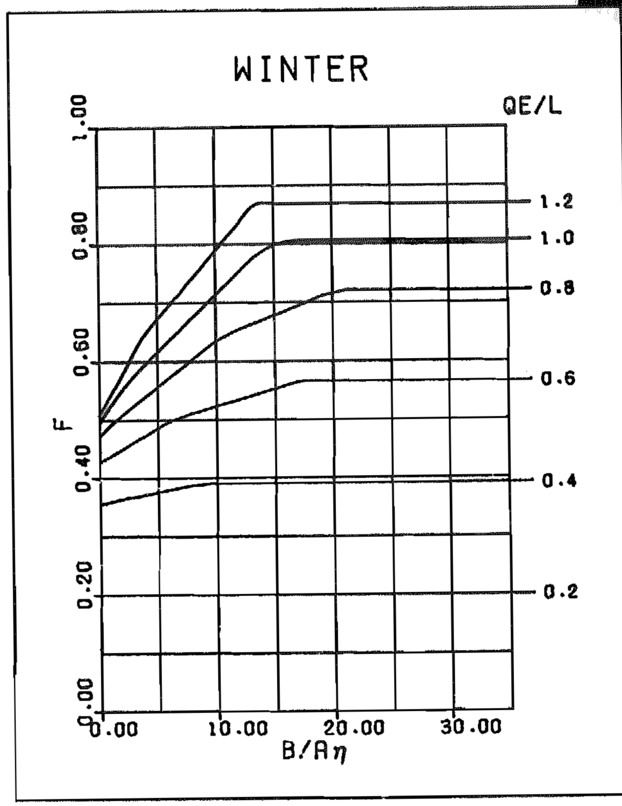

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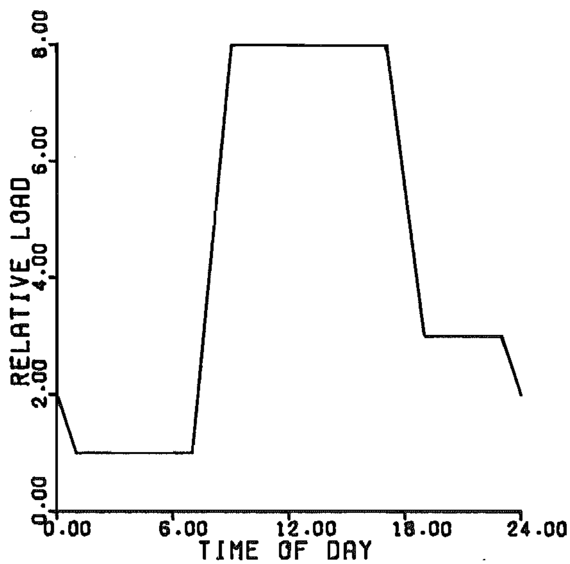
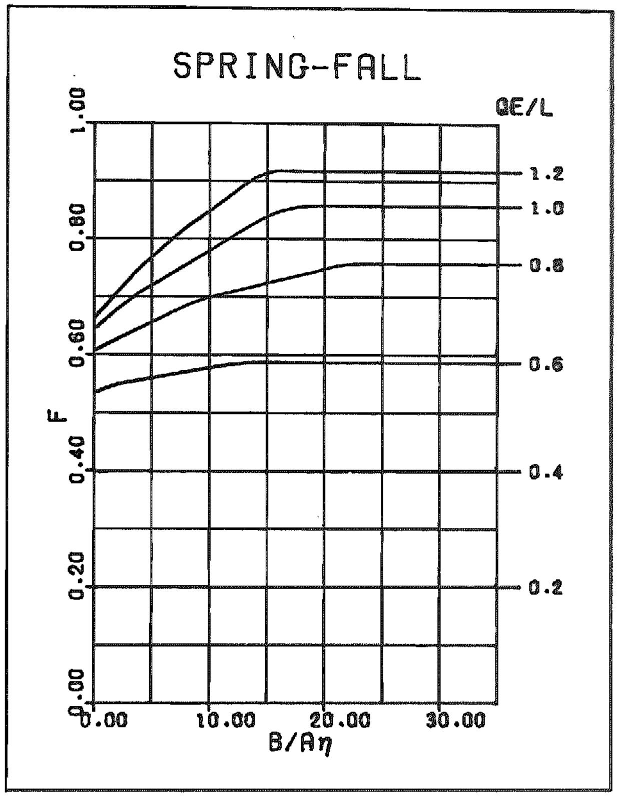
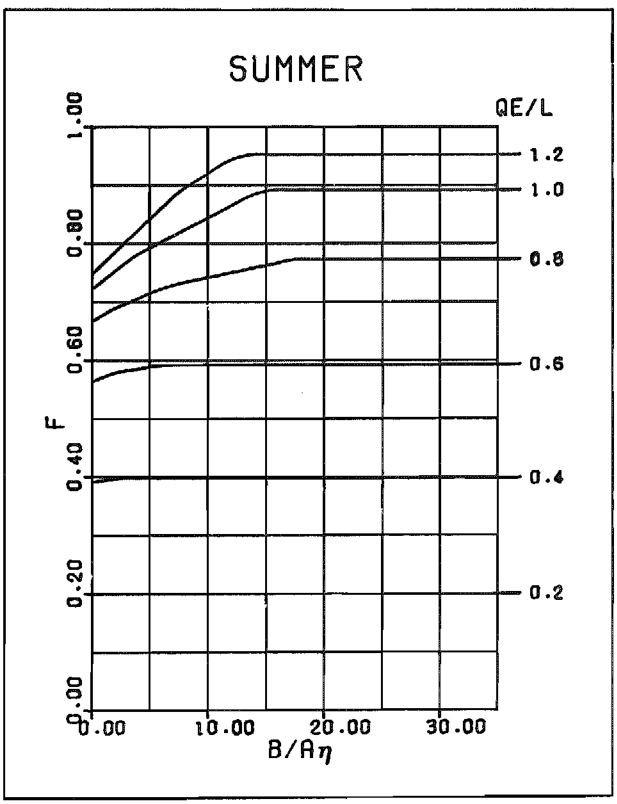
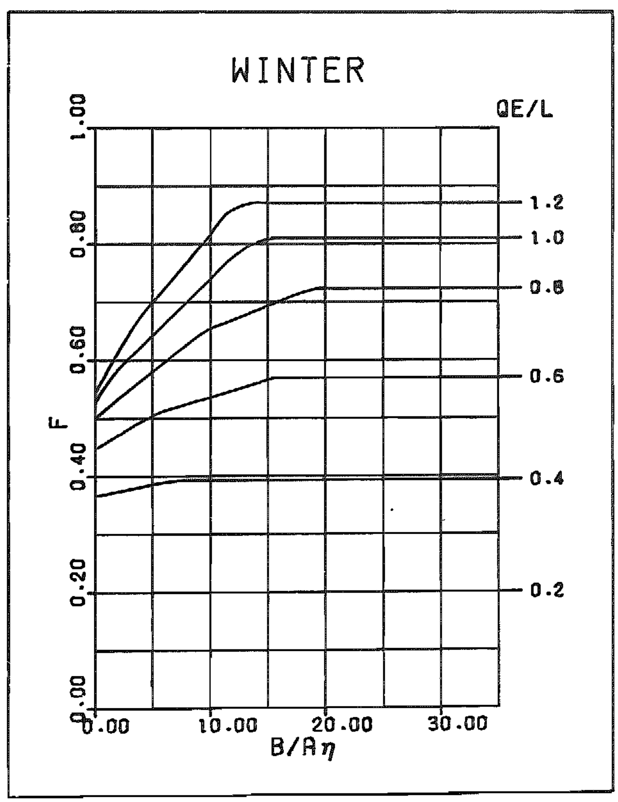
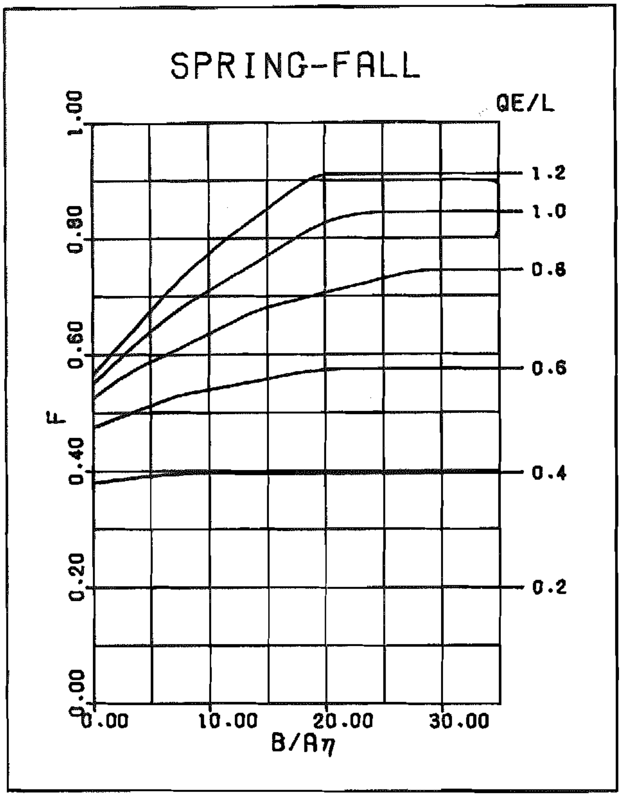


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63









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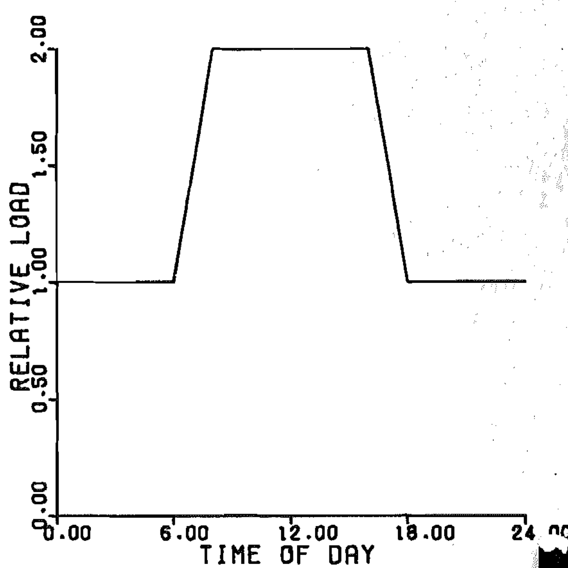

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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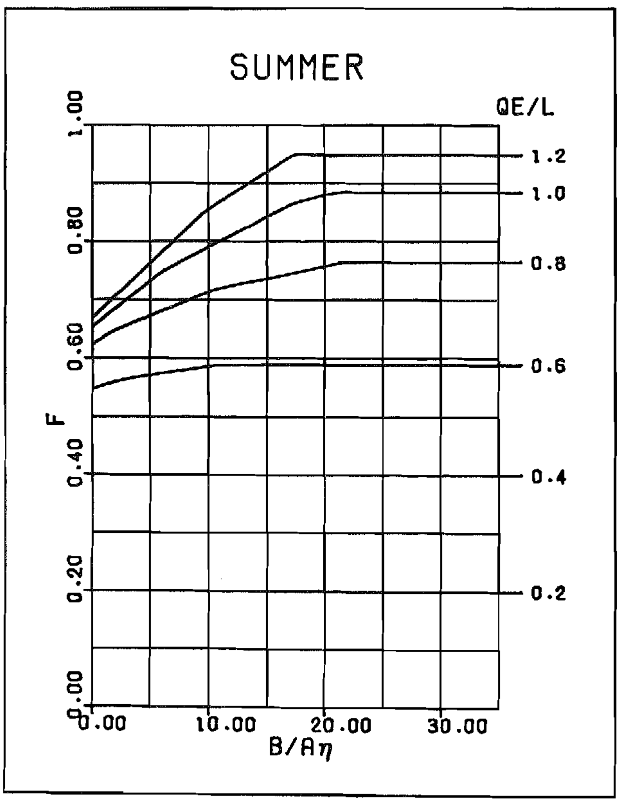
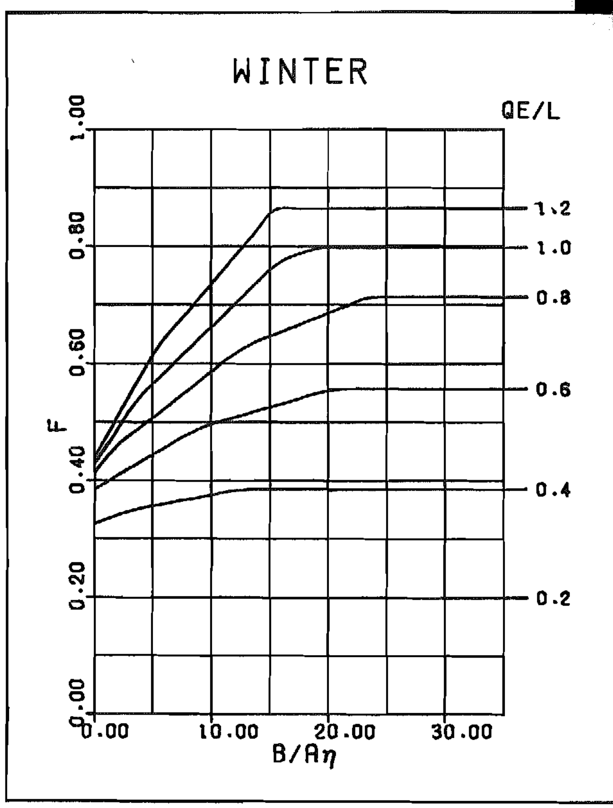




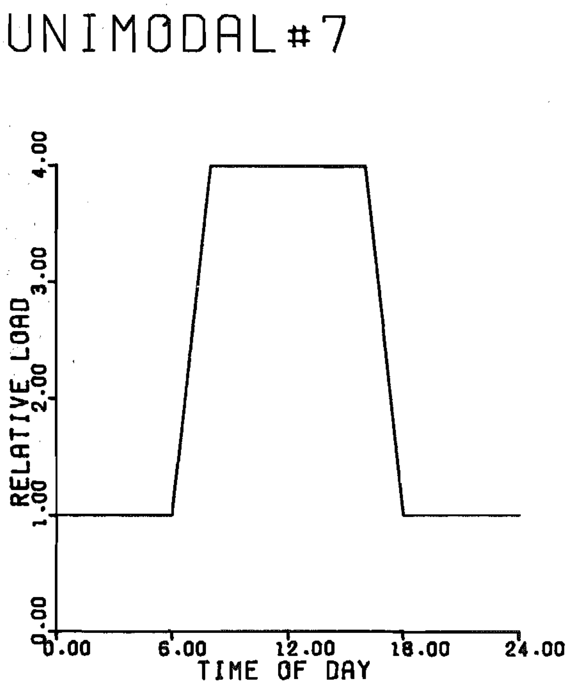
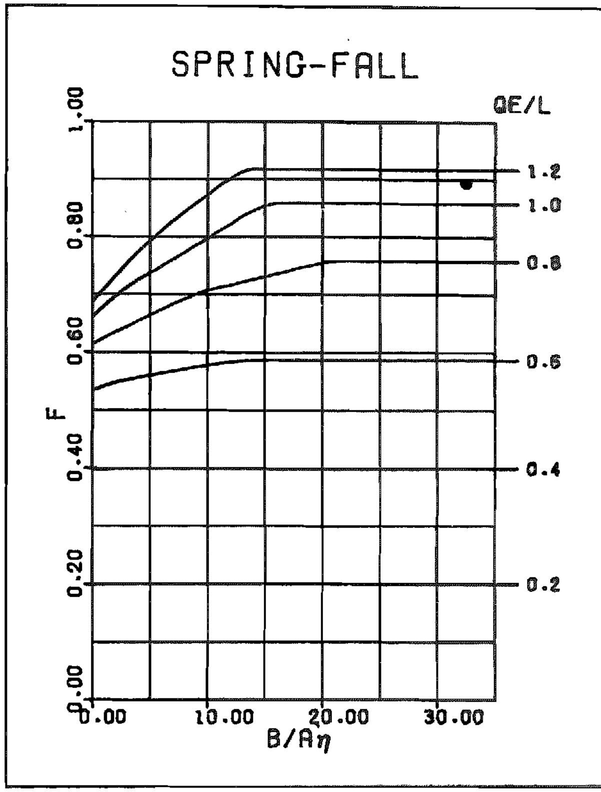
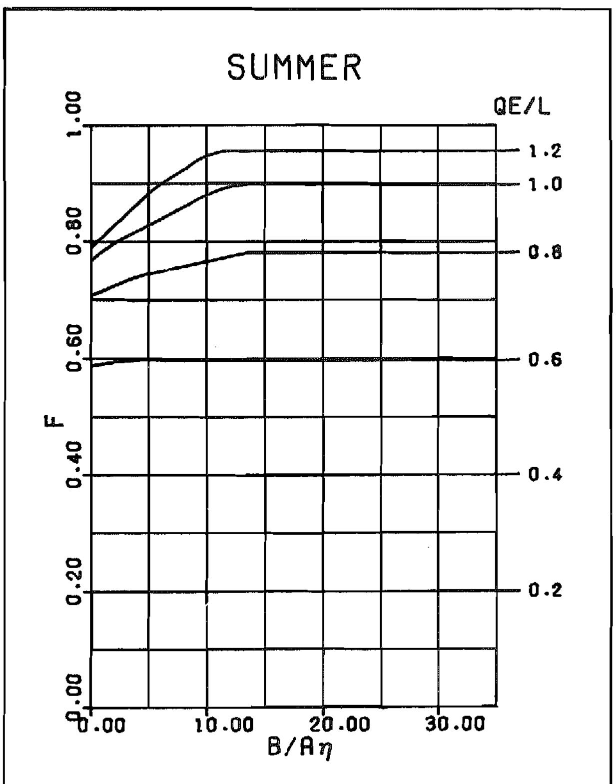
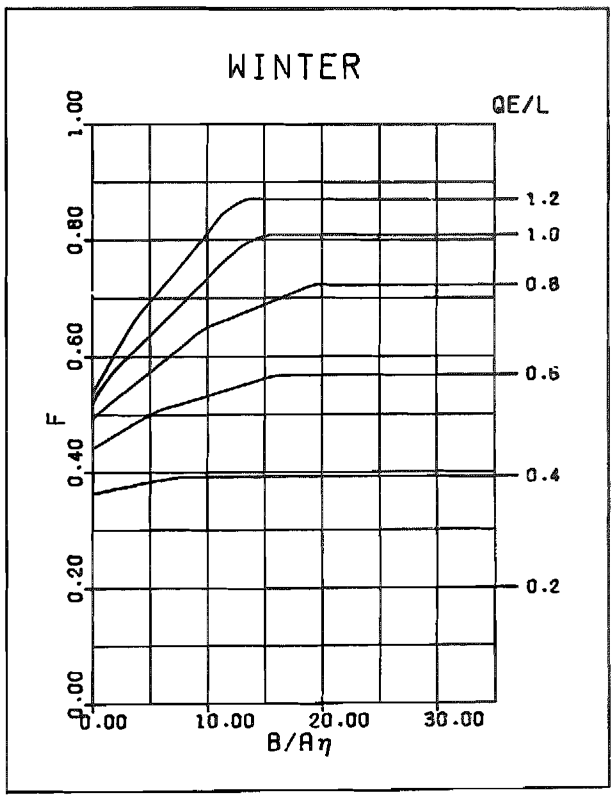


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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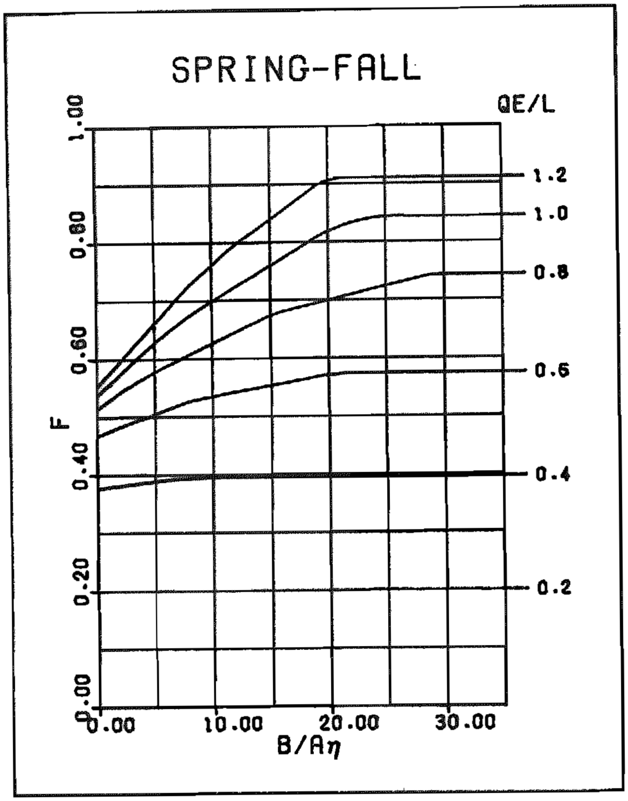

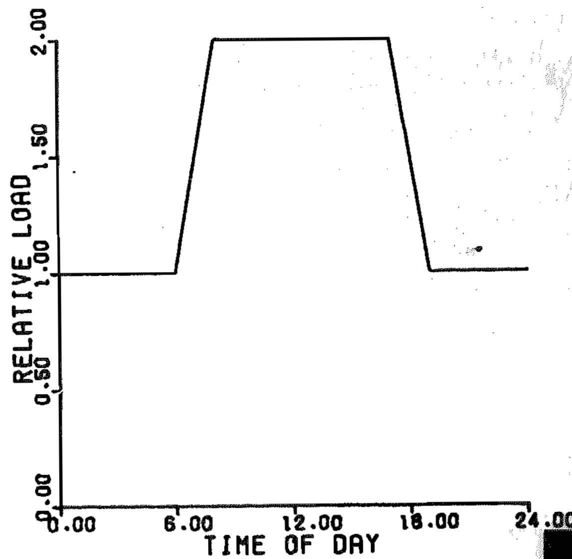

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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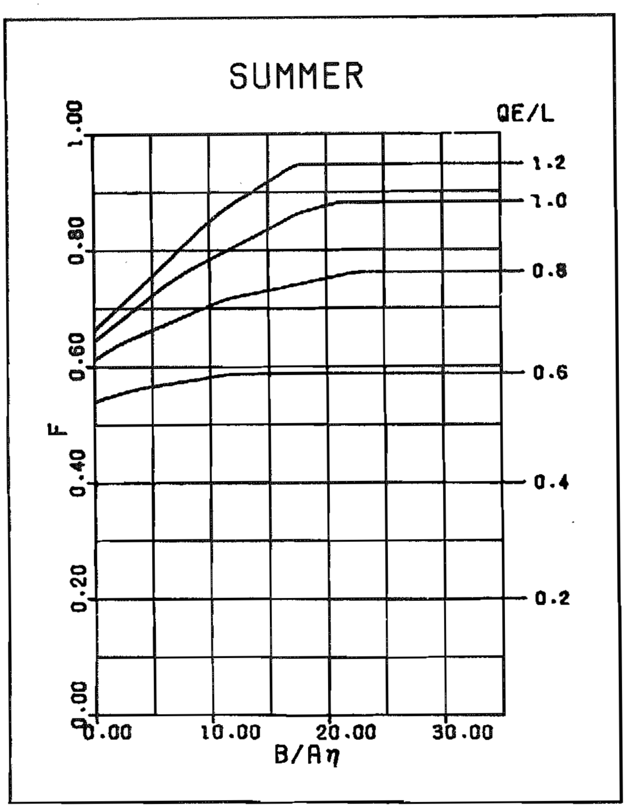

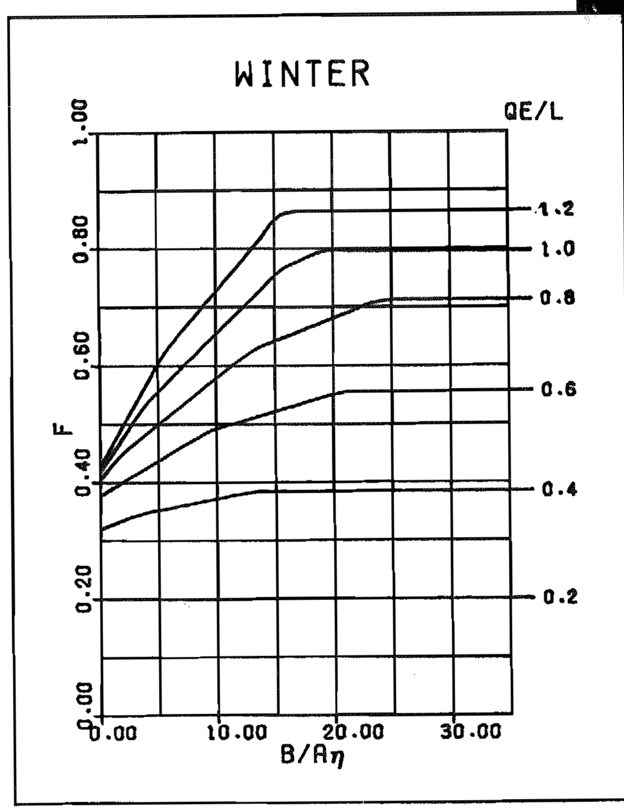

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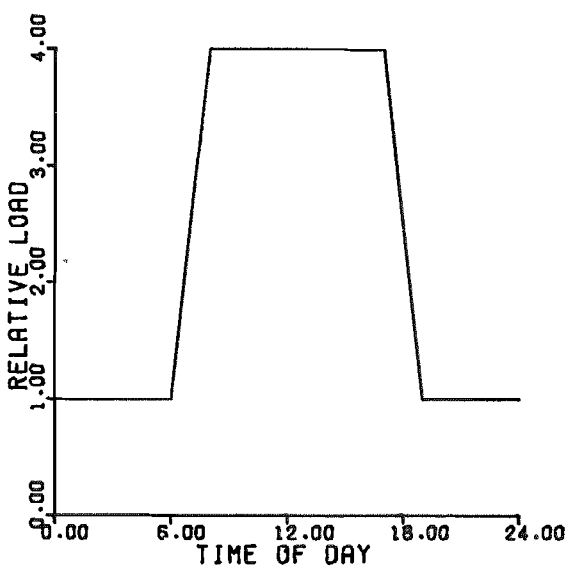
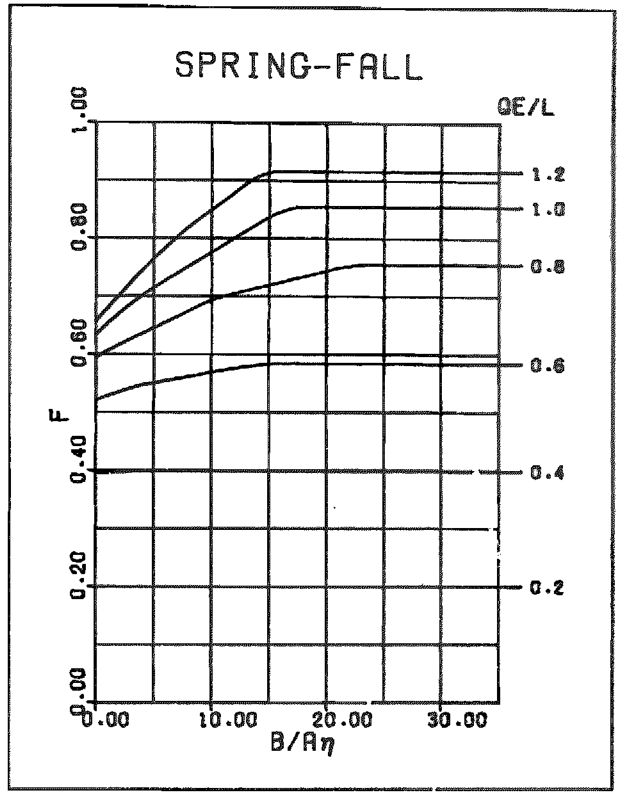
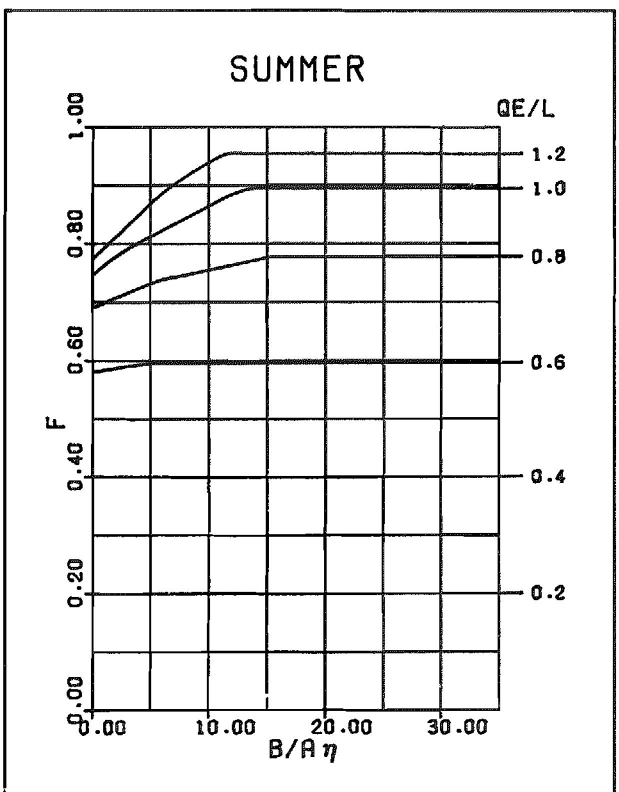
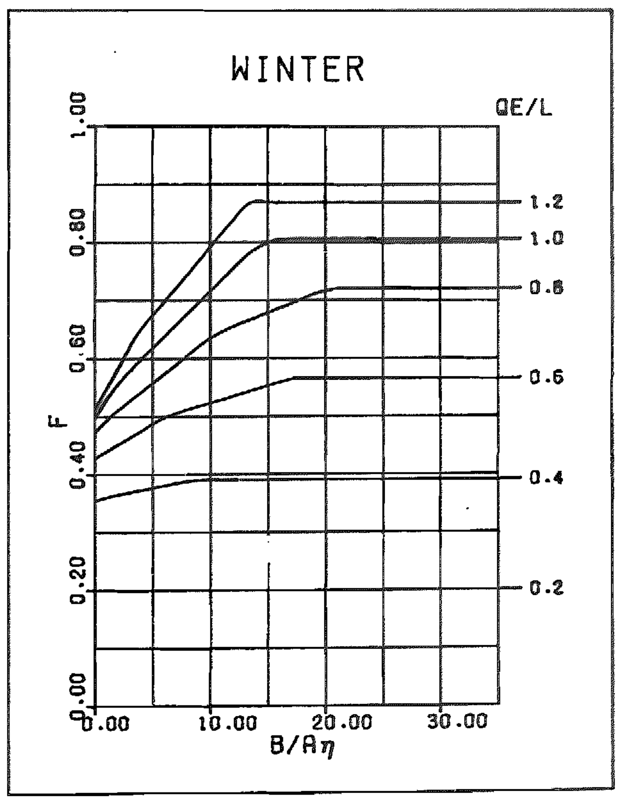


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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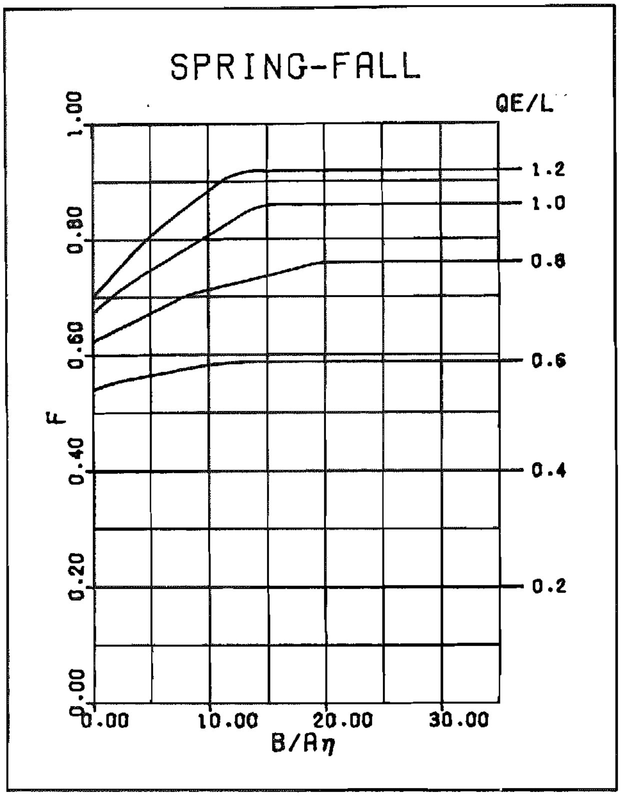

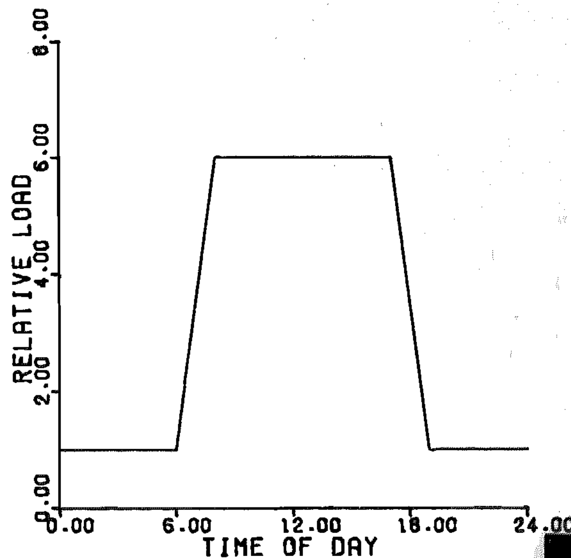

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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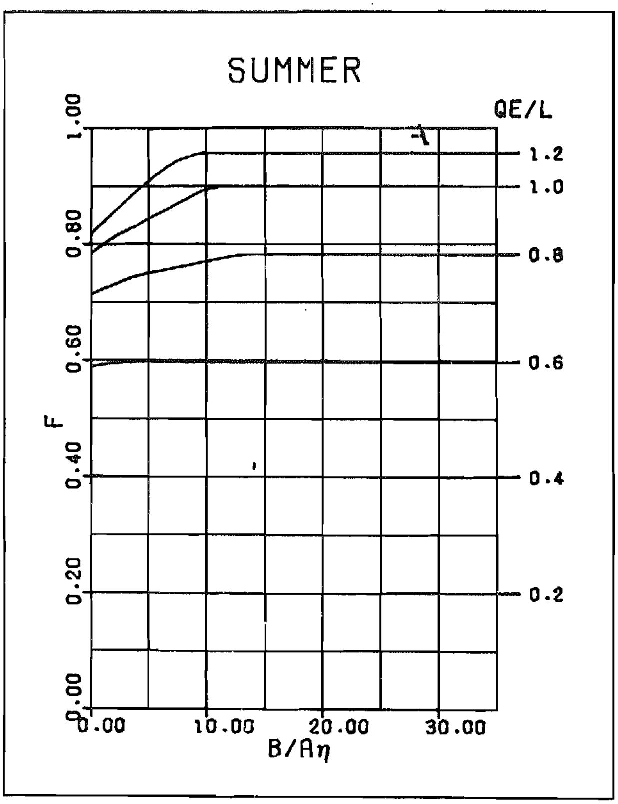

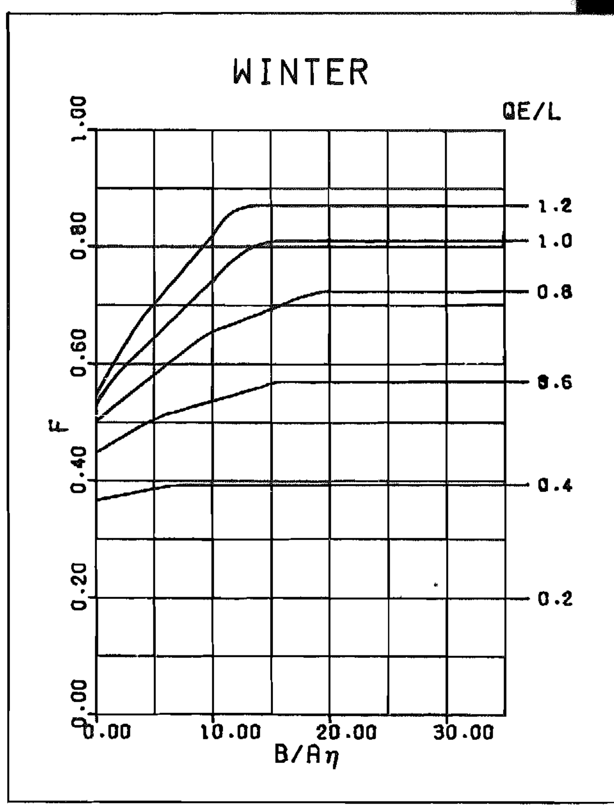

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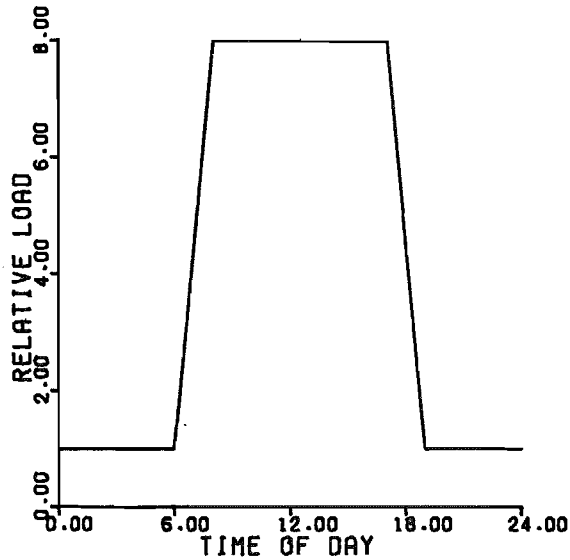
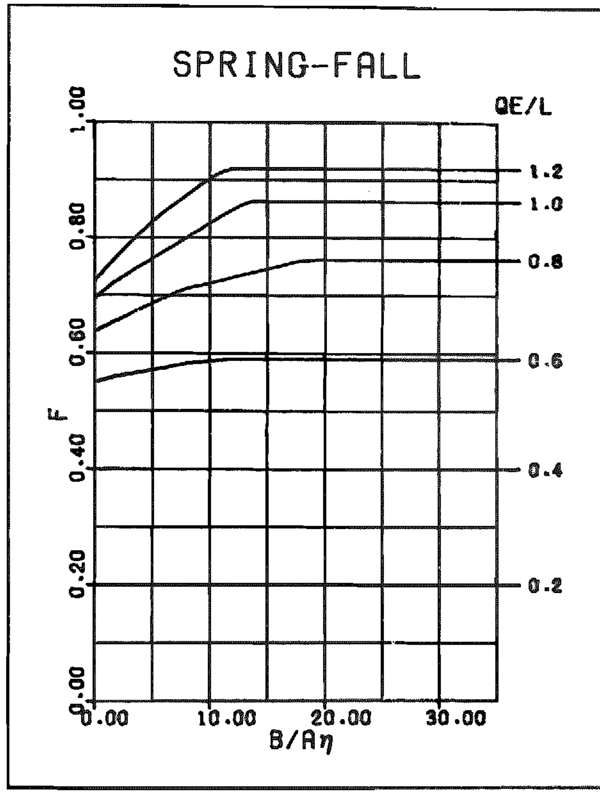
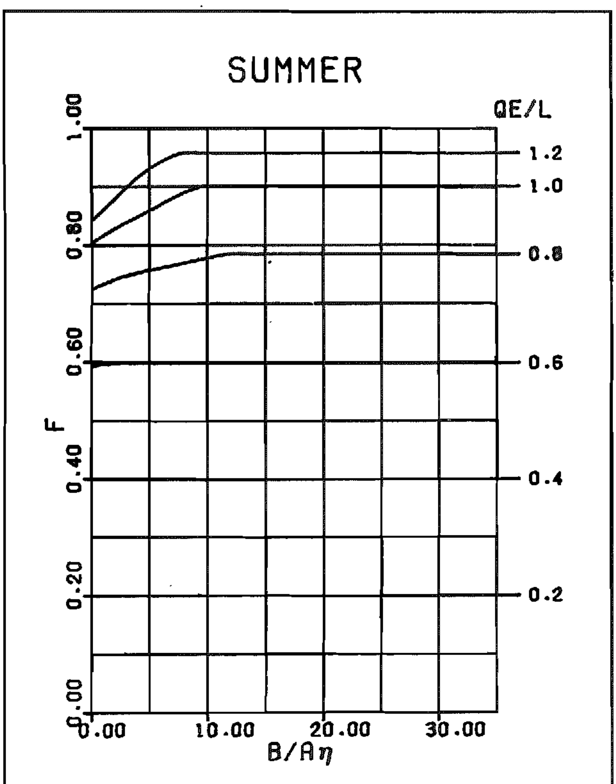
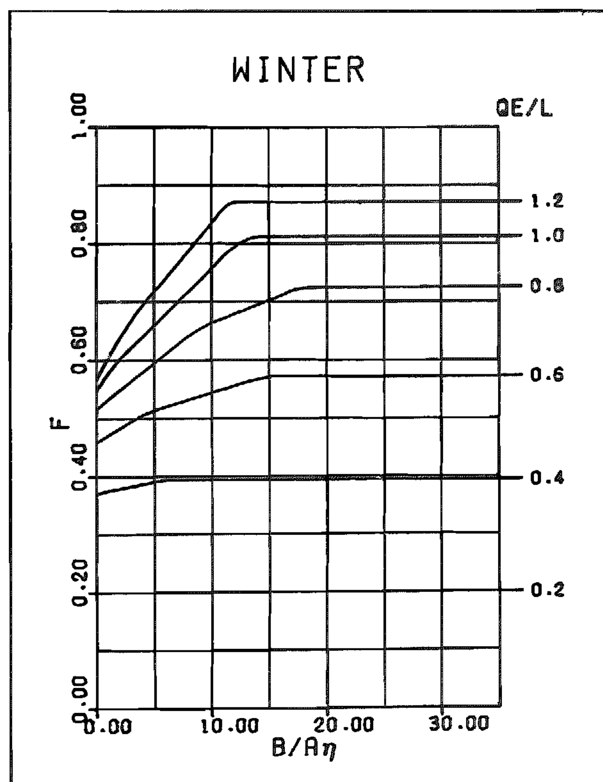


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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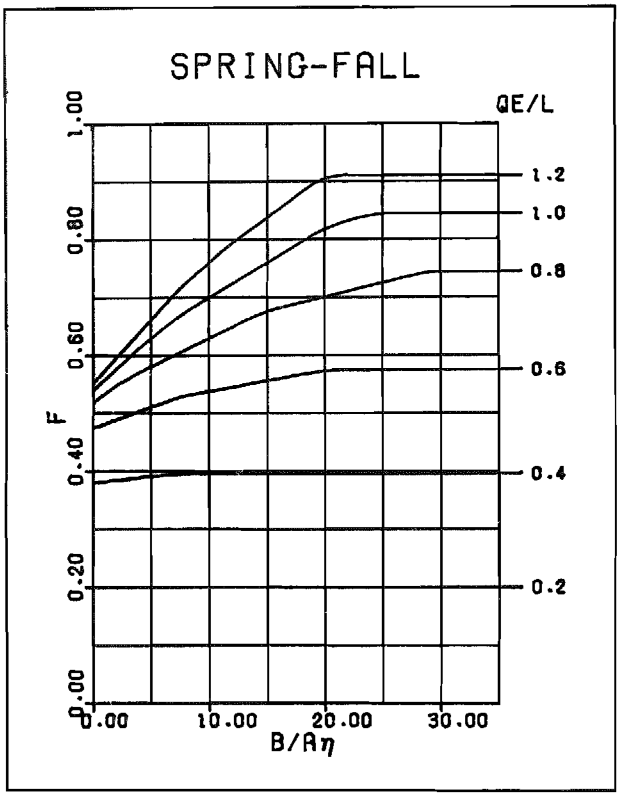

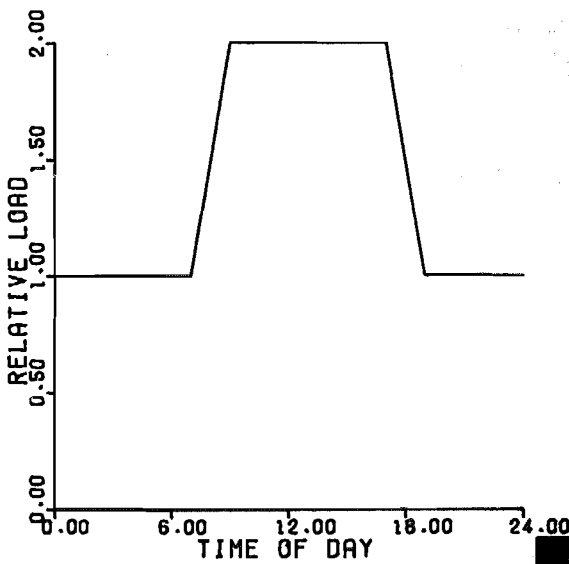

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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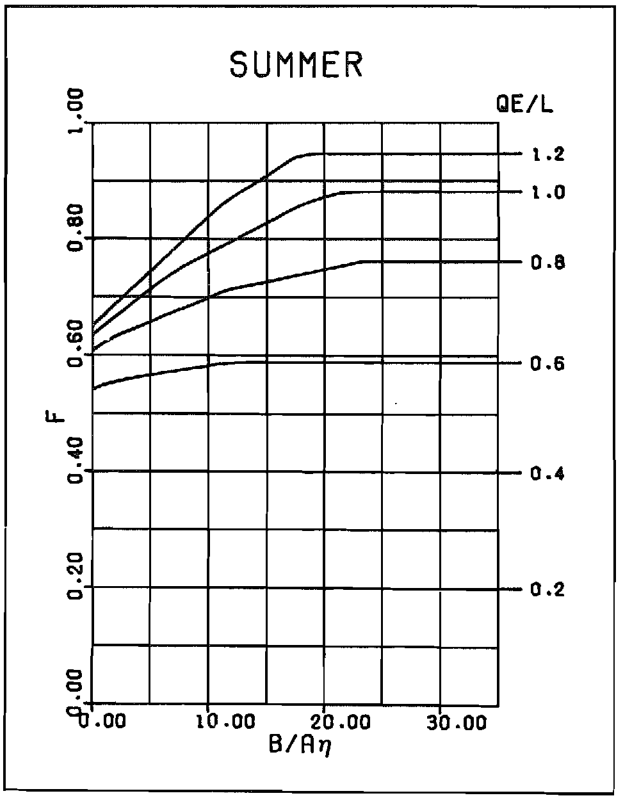

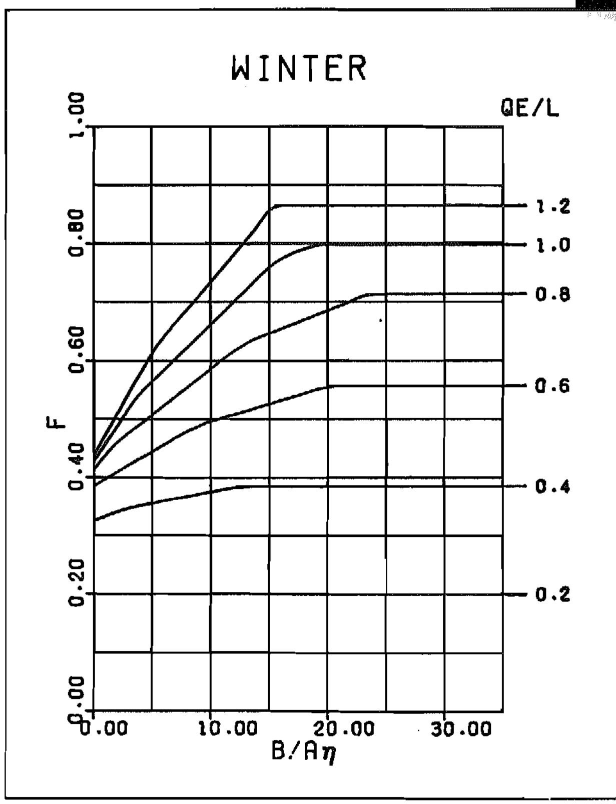

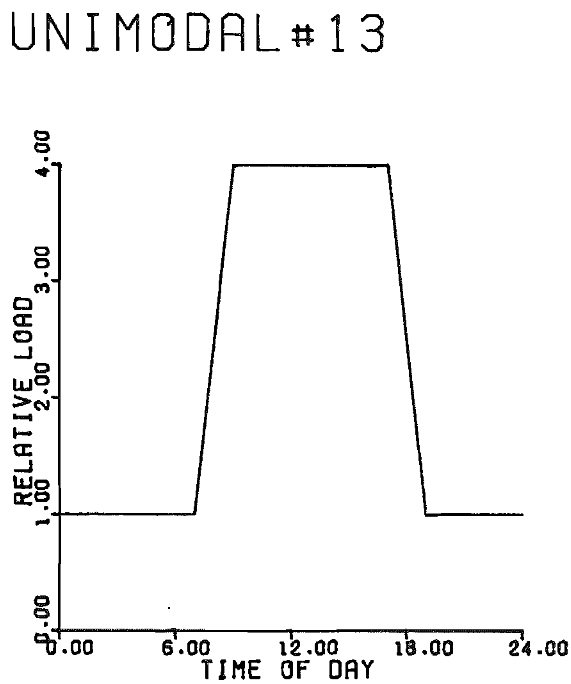

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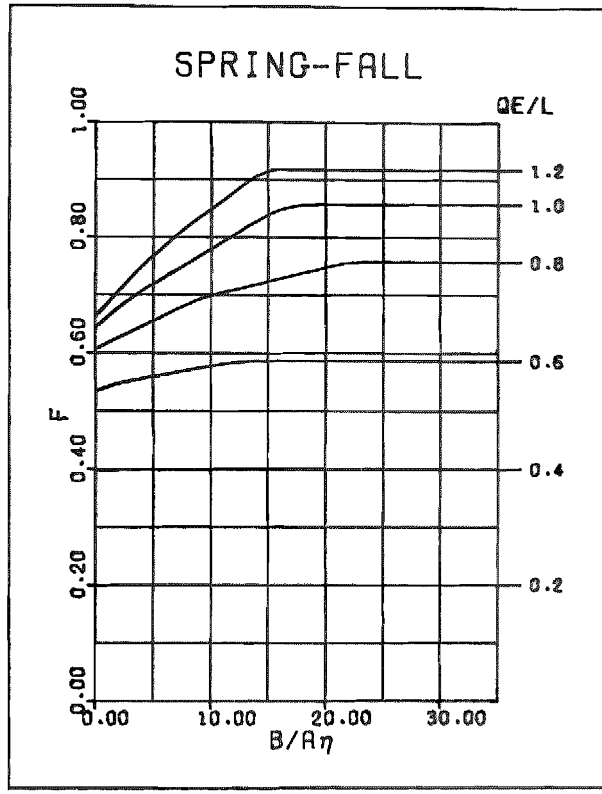

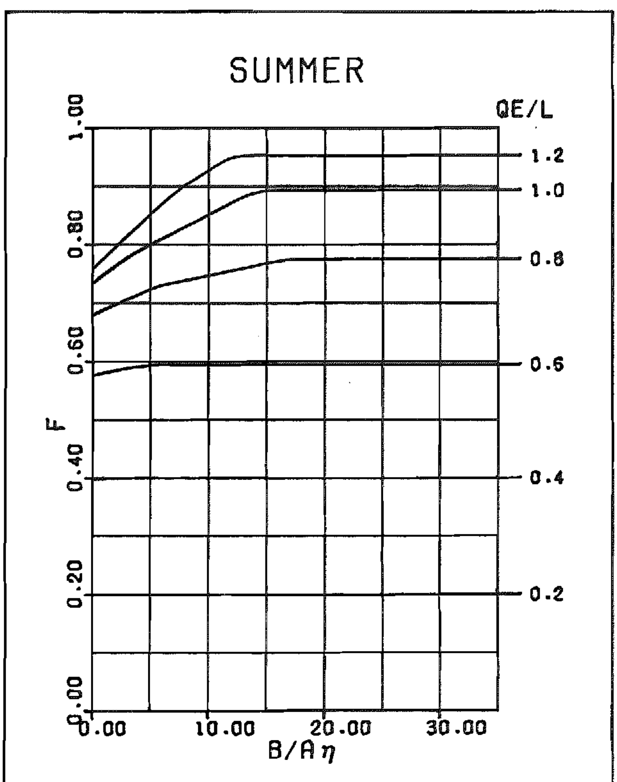

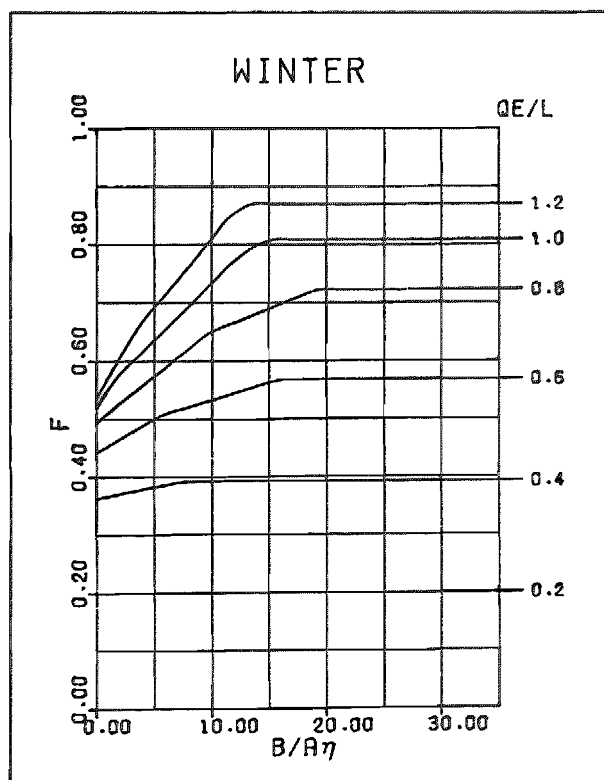

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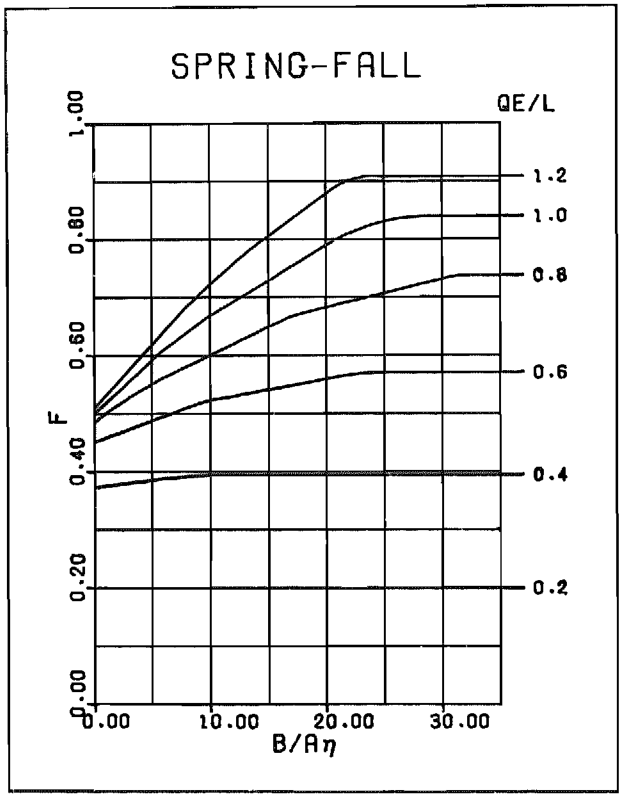

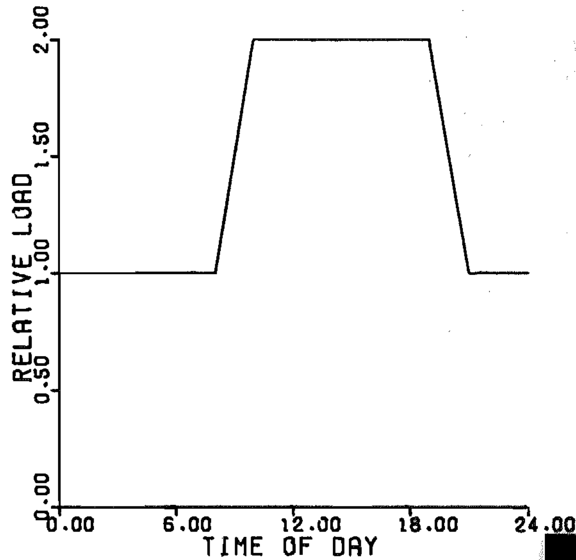

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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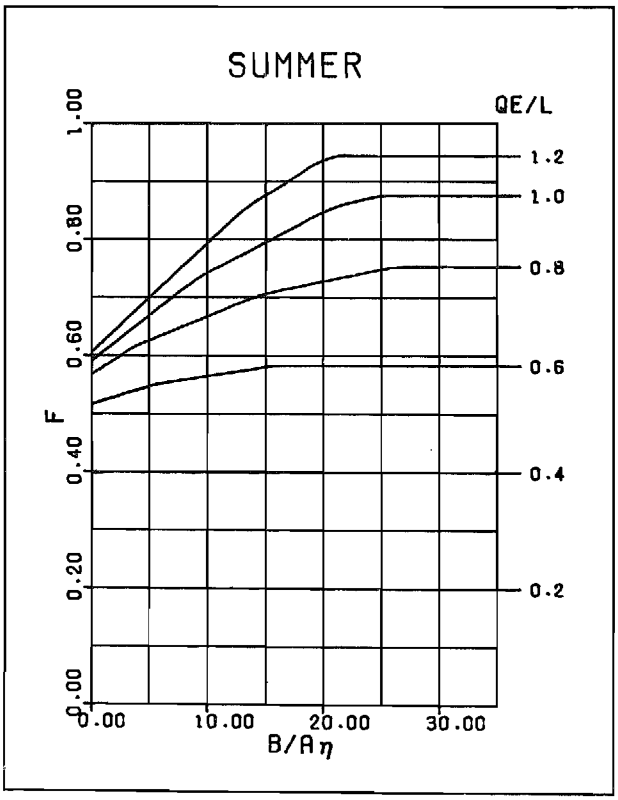

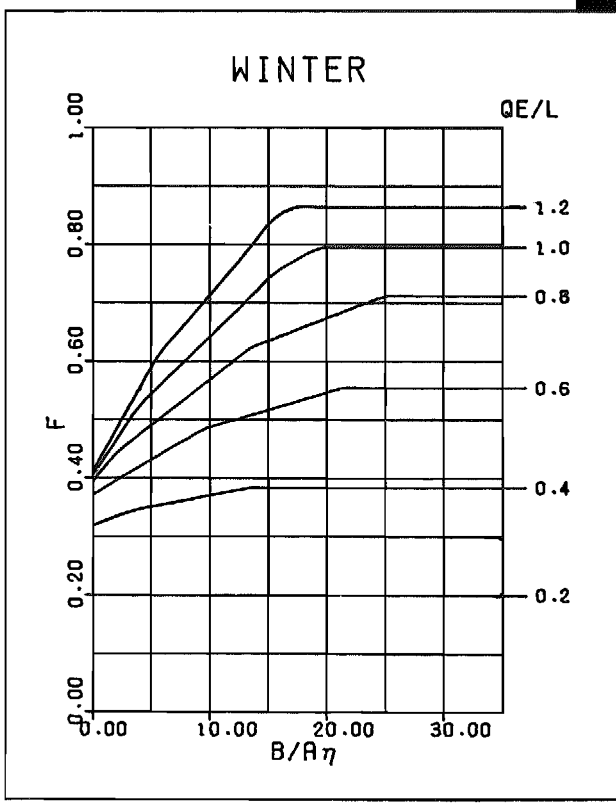

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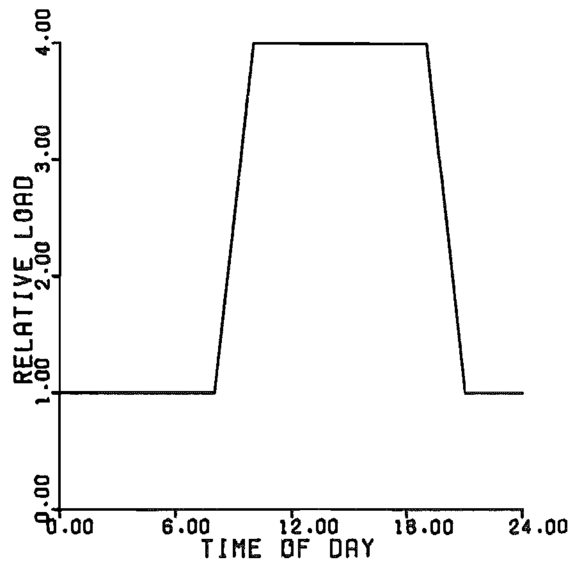


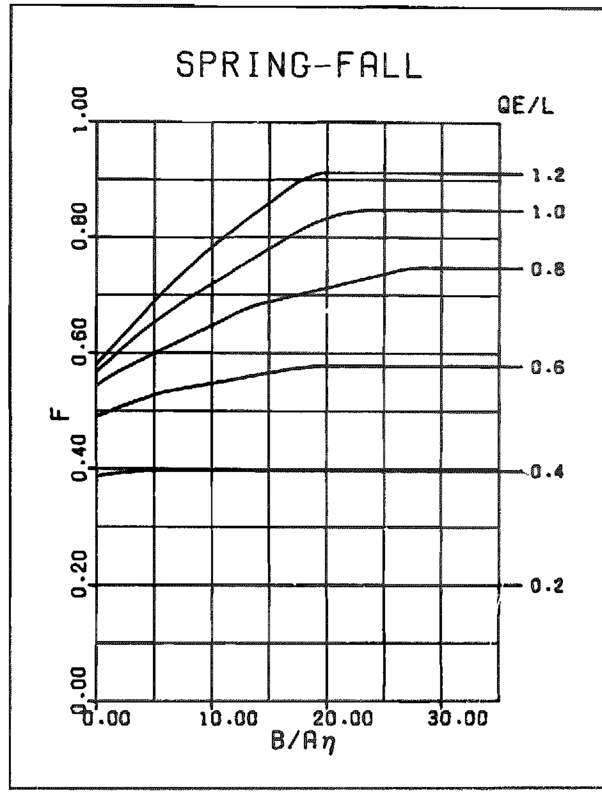
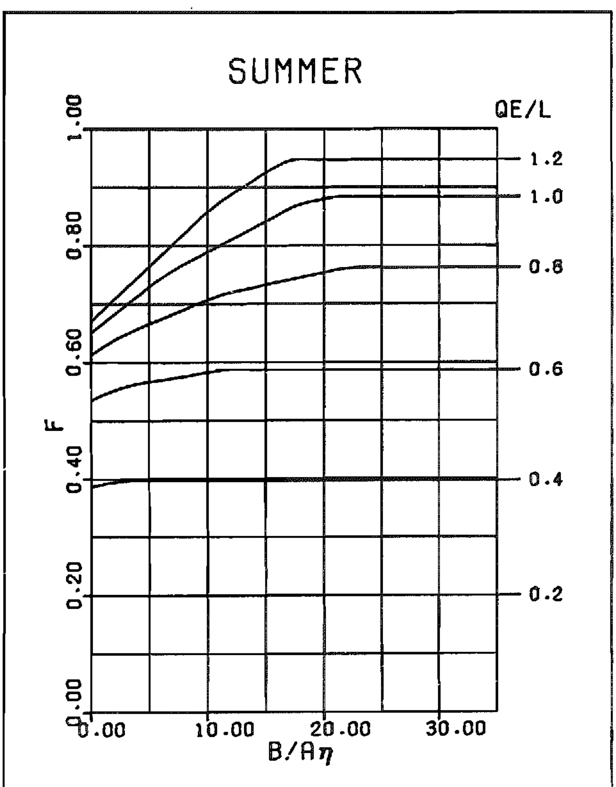
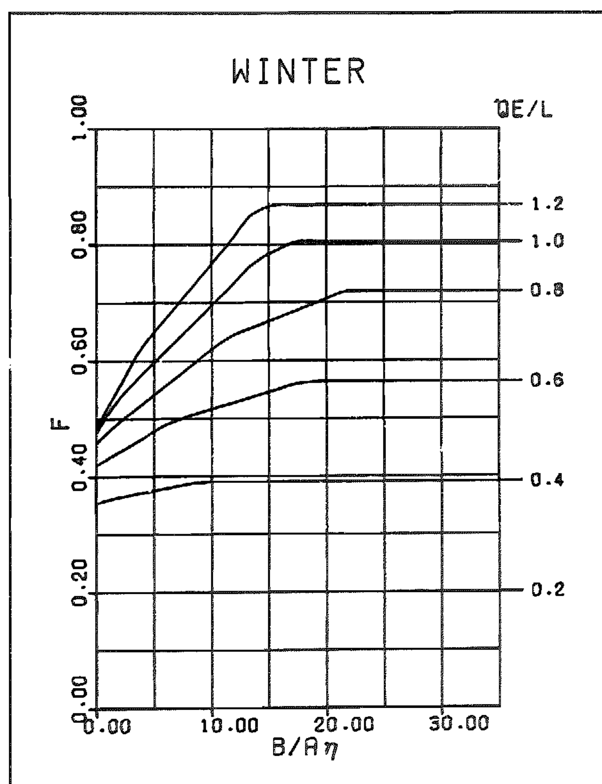


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





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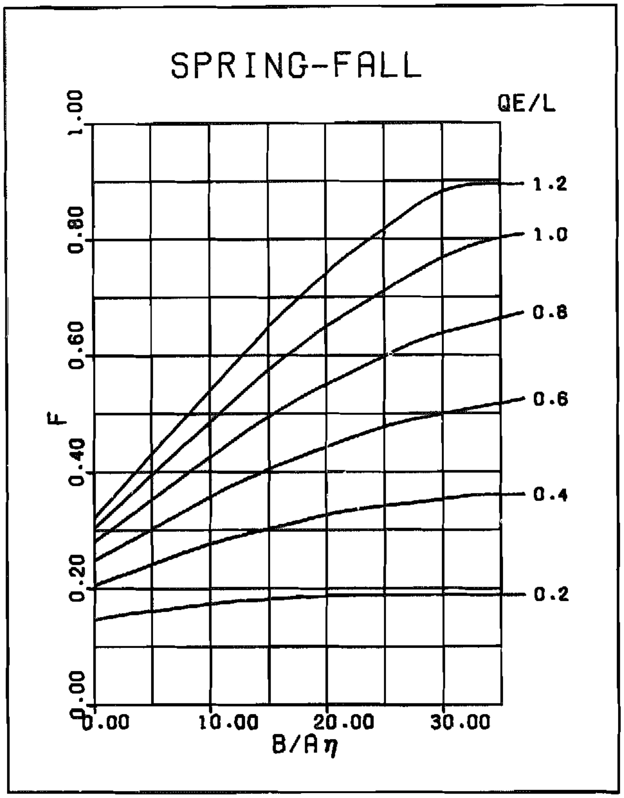

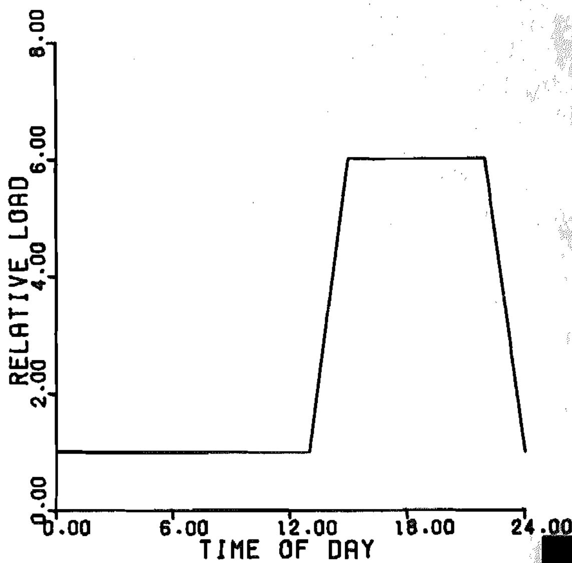

TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

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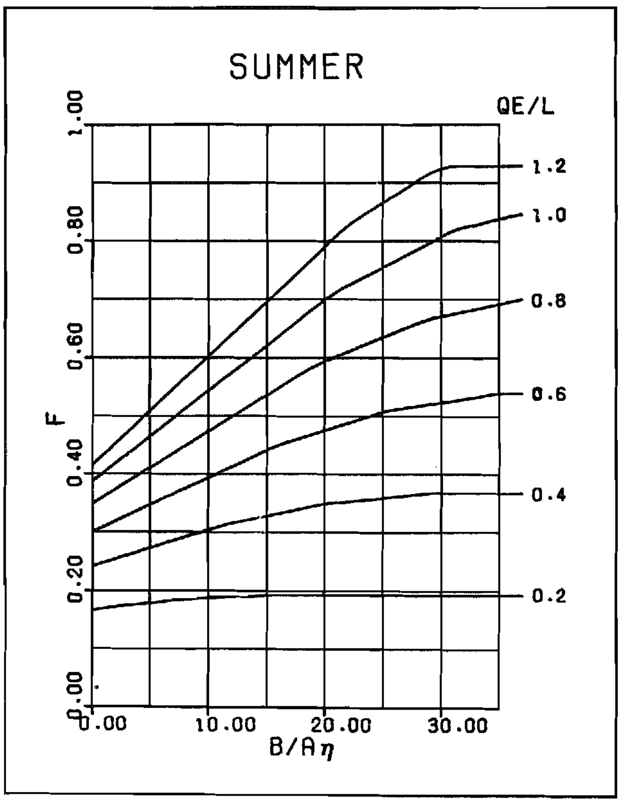

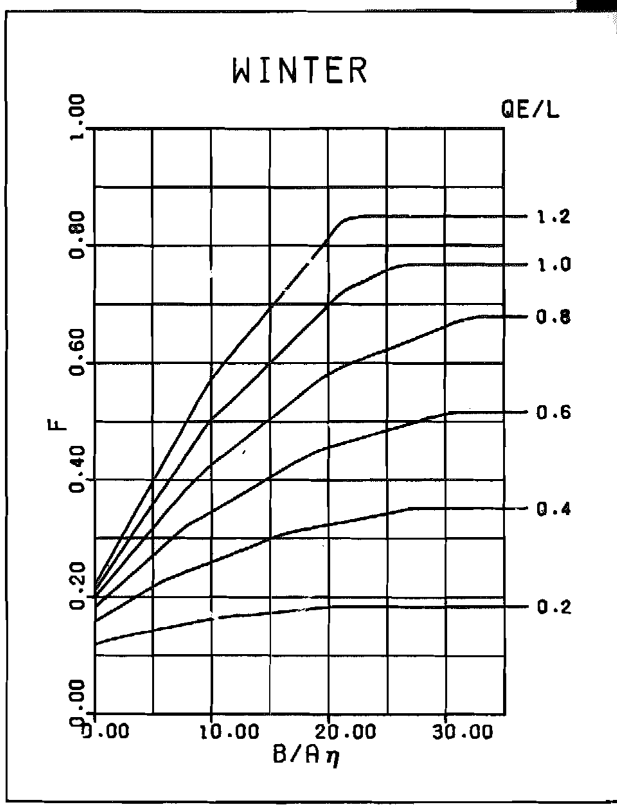

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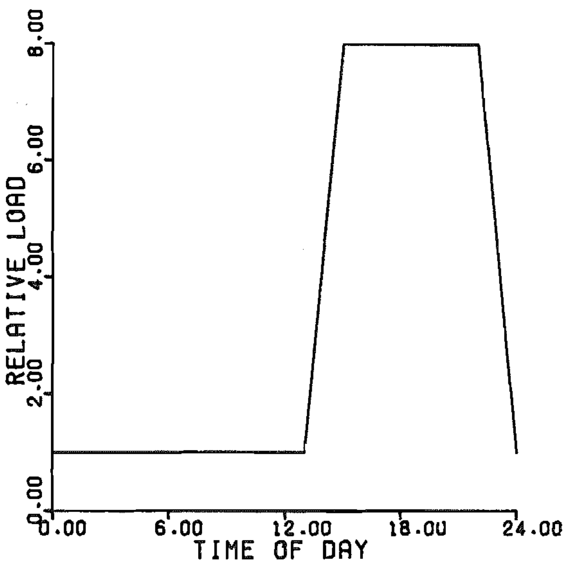
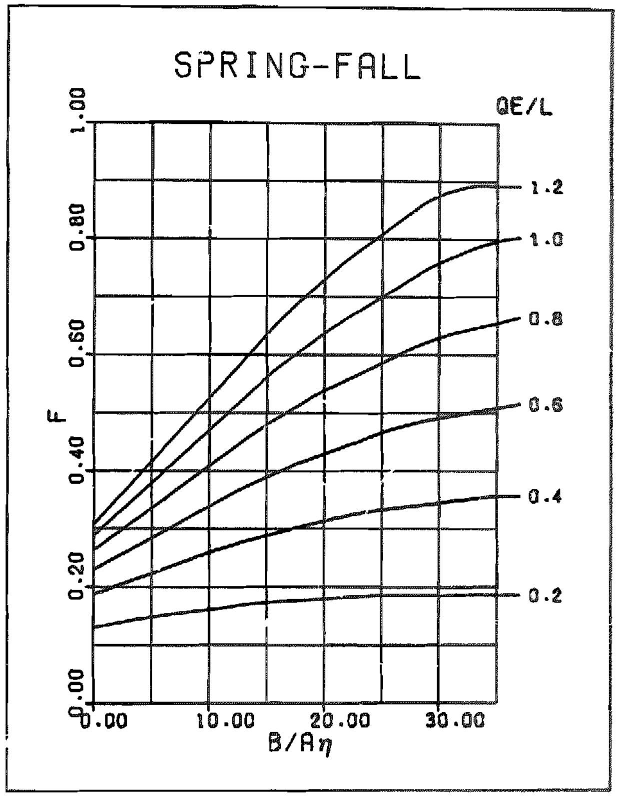
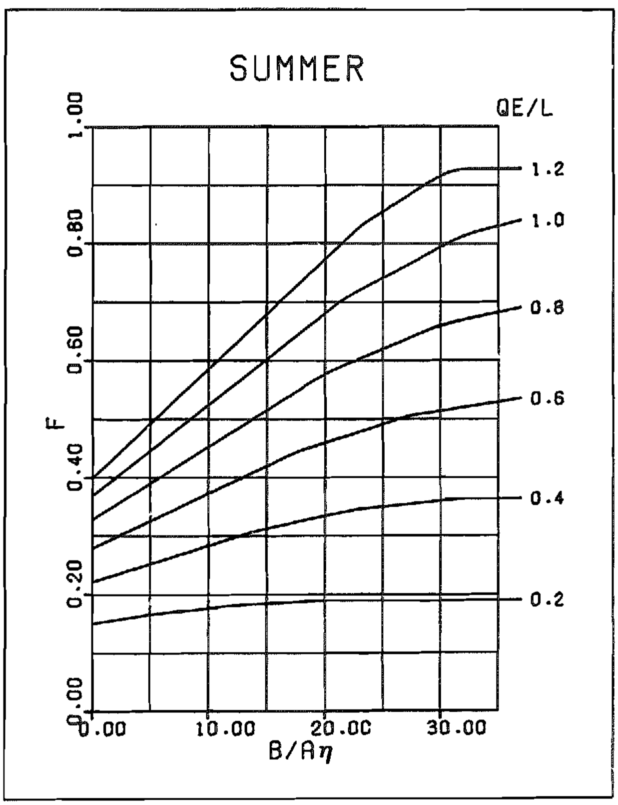
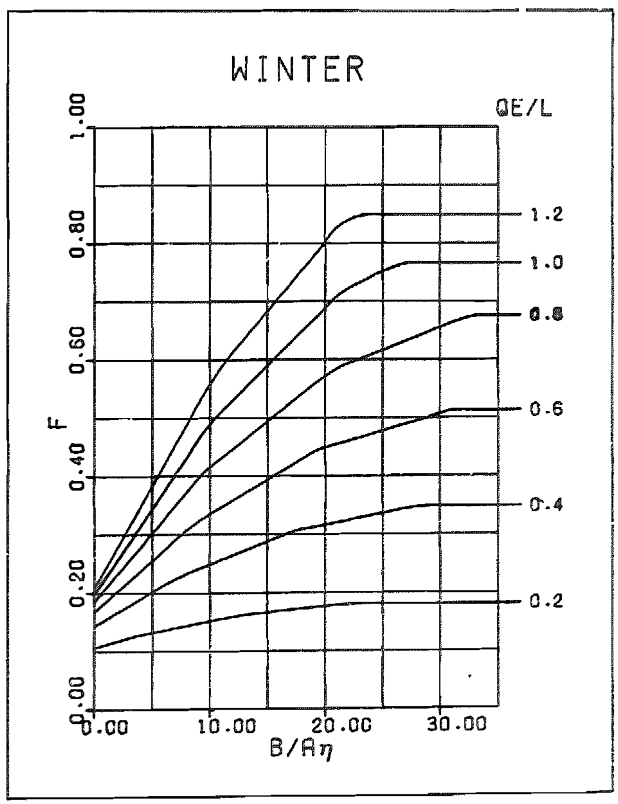


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63







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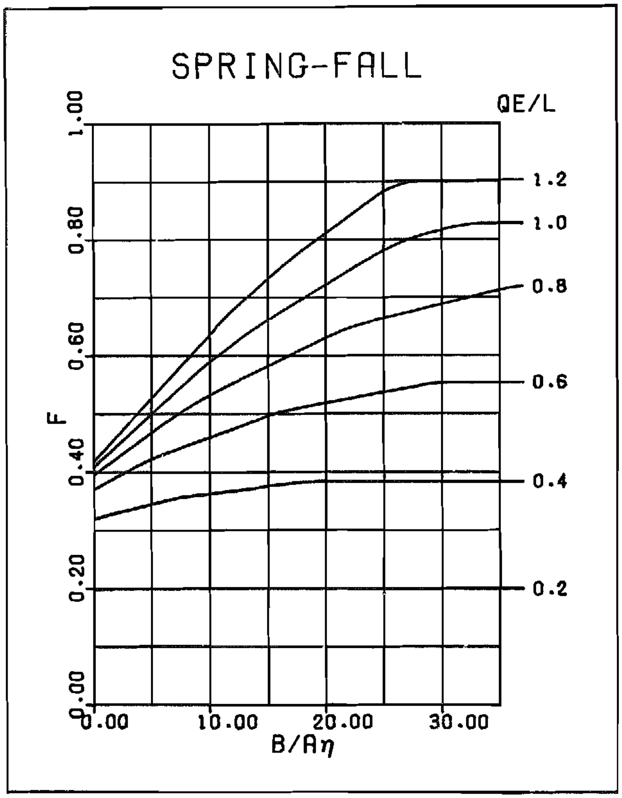


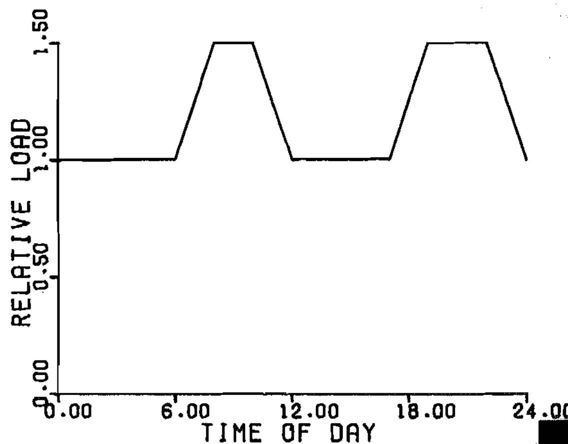
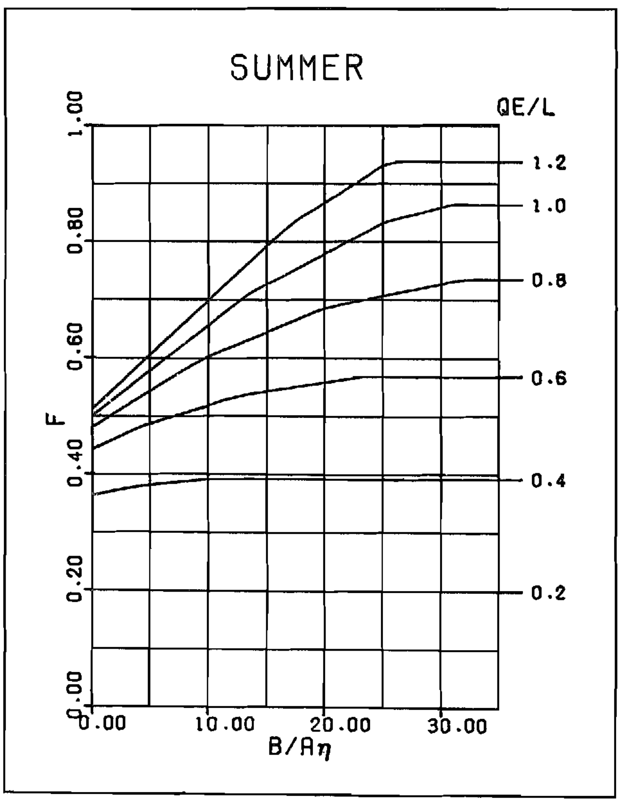
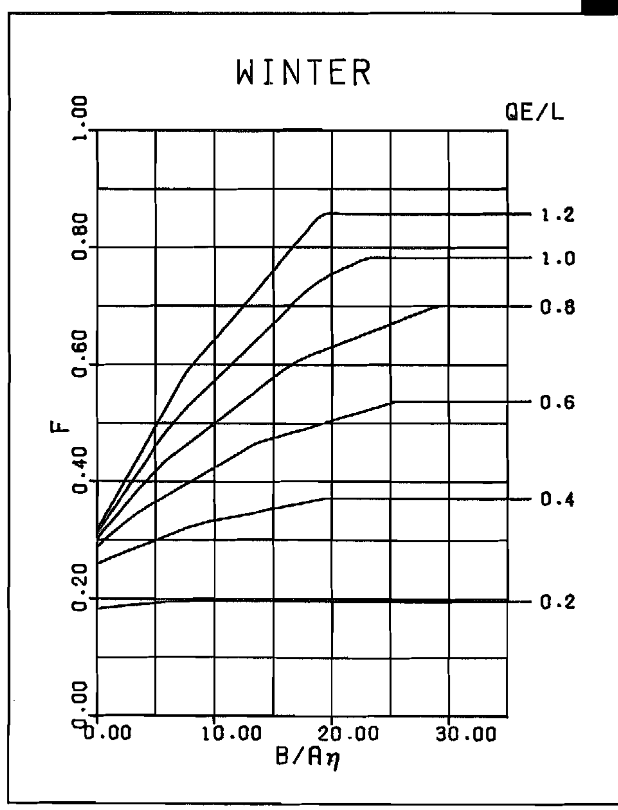


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63

Table III





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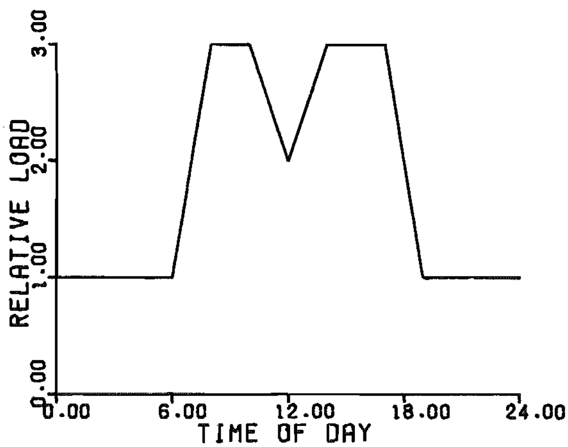


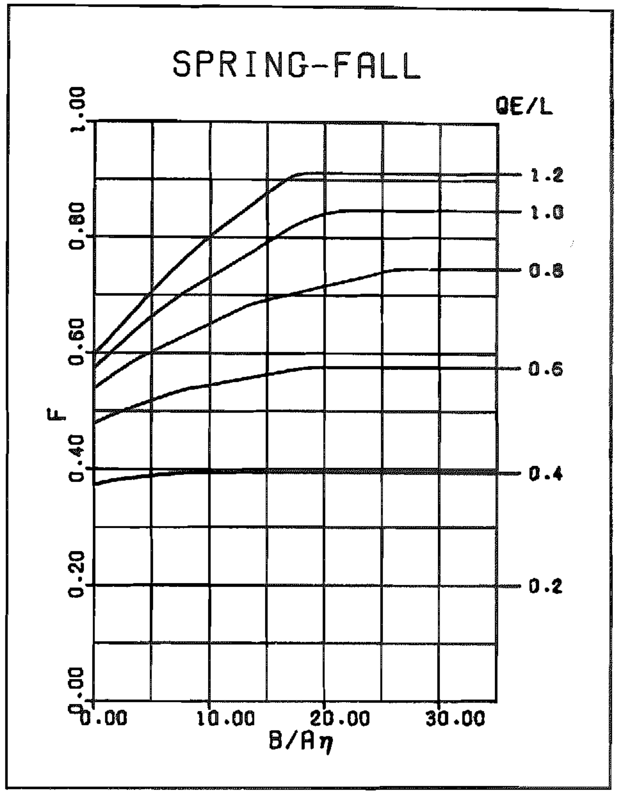
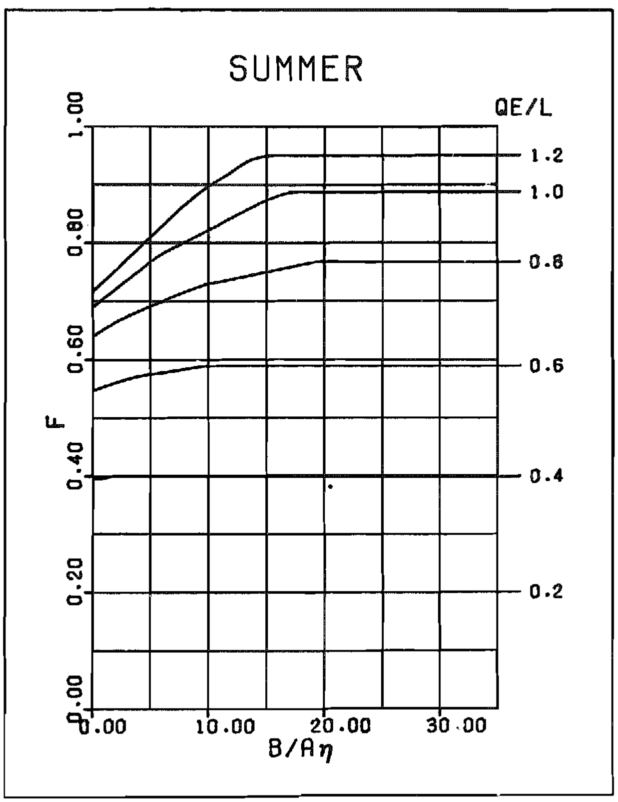
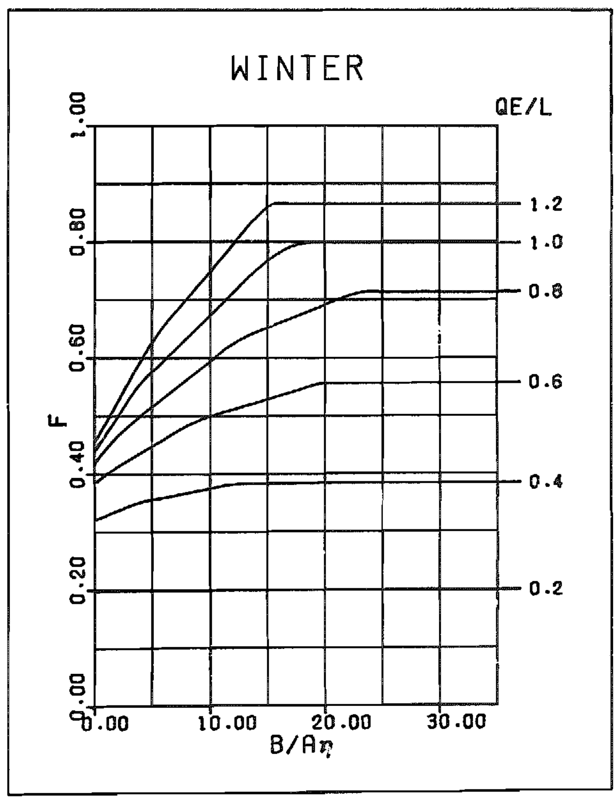


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





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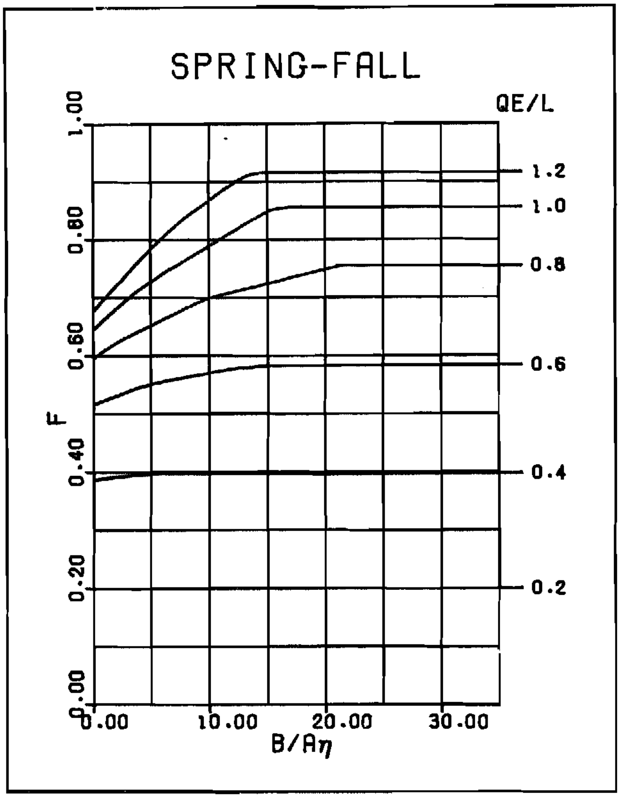


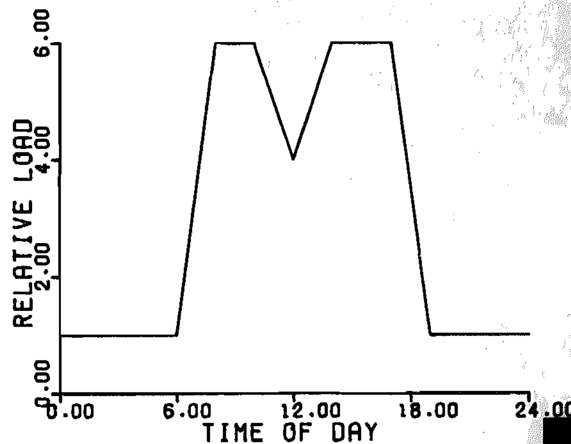
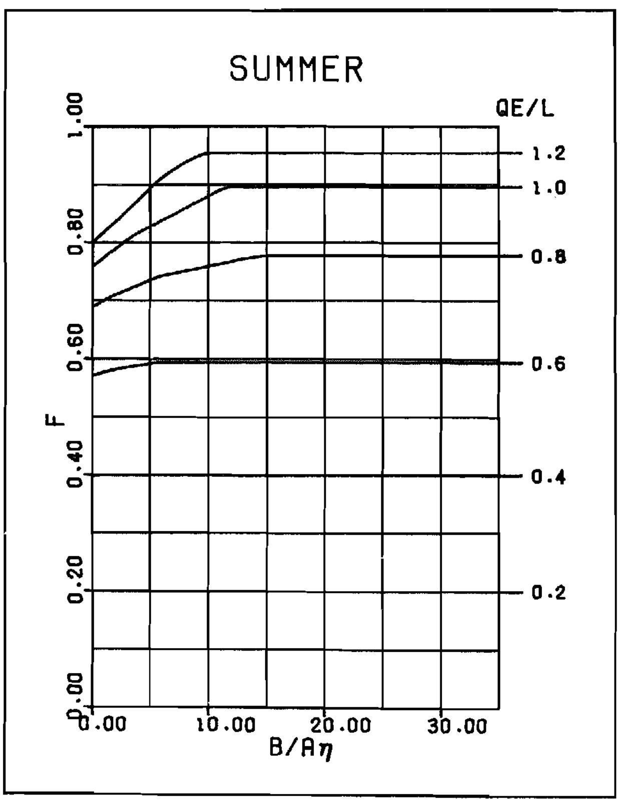
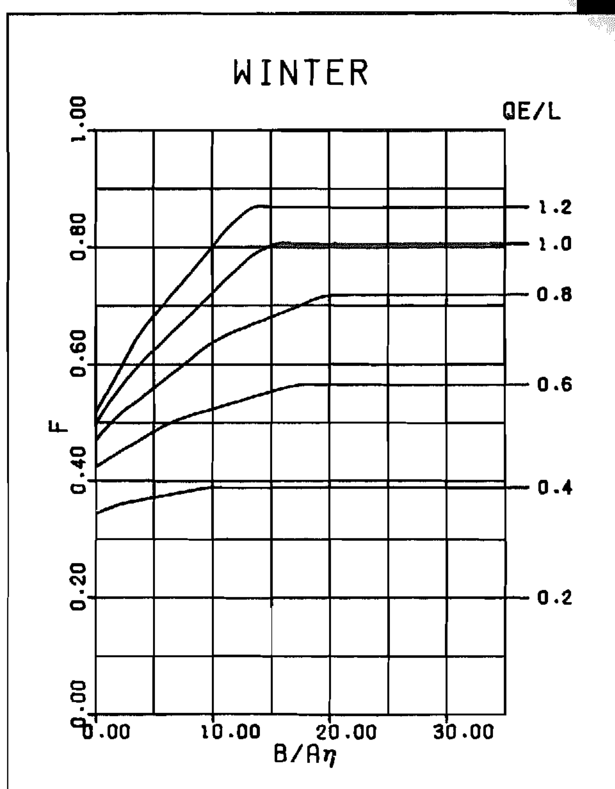


TABLE III SYSTEM PERFORMANCE GRAPHS
For Reading Key See Page A-63





WORKSHEET 1

Location ____________________ T_r = __________ [C] β = __________ [C^{-1}]

Latitude ____________________ η_r = __________ [%] η_{pc} = __________ [%]

NOCT = __________ [C] __________ kW/m^2, T_a = __________ [C] or U_L/α = __________ $kW/(m^2 \cdot C)$

Month	C1 WS [m/s] from Table I	C2 KT from Table I	C3 s_M from Table II (degrees)	C4 s designer's choice (degrees)	C5 $\lvert s-s_M \rvert$ = $\lvert$C4−C3$\rvert$ (degrees)	C6 TM [C] from Table I	C7 T_c from Fig. 2.1	C8 η[%] from Eq. 2.2 $\eta_r[1-\beta(C7-T_r)]$	C9 QS/A [kWh/m^2]	C10 QE/A [kWh/m^2] $= \frac{\eta_{pc}}{100} \cdot \frac{C8 \cdot C9}{100}$
JAN										
FEB										
MAR										
APR										
MAY										
JUN										
JUL										
AUG										
SEP										
OCT										
NOV										
DEC										

WORKSHEET 1

WORKSHEET 2

A = ______________ [m²] (designer's choice)

B = ______________ [Wh] (designer's choice)

Month	C11 d	C12 QE/A [kWh/m²] from WORKSHEET 1	C13 η[%] from WORKSHEET 1	C14 $(QS/A)_{lat}$ [kWh/m²] from Table I	C15 L [kWh]	C16 QE/L $= \frac{C12 \cdot A}{C15}$	C17 B/Aη [Wh/m²%] $= \frac{B}{A \cdot C13} \cdot \frac{C14}{C9} \cdot \frac{90}{\eta_{pc}}$	C18 F from C16, C17 in TABLE III	C19 L·d [kWh] = C11·C15
JAN	31								
FEB	28								
MAR	31								
APR	30								
MAY	31								
JUN	30								
JUL	31								
AUG	31								
SEP	30								
OCT	31								
NOV	30								
DEC	31								

$$\text{Annual F} = \frac{\sum (F \cdot L \cdot d)}{\sum (L \cdot d)} = \frac{\sum (C18 \cdot C19)}{\sum C19} = \_\_\_\_\_\_\_\_\_\_$$

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