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EVALUATION OF THE "TYPICAL METEOROLOGICAL YEARS" FOR SOLAR HEATING AND COOLING SYSTEM STUDIES

FINAL REPORT

DECEMBER 1979

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FOREWORD

This report is a summary of an evaluation of the weather data set, generated at Sandia Laboratories, known as the "Typical Meteorological Year " (TMY) Data. The purpose of the evaluation is to determine how well the TMY data represent actual long-term weather data in affecting the performance of solar heating and cooling systems. The two data sets are compared through detailed SHAC simulation.

This work was begun as a task under DOE contract EM-78-C-044261. This contract was transferred to SERI in 1979 as a Basic Ordering Agreement (Contract BP-9-8150-1) under the SERI prime contract with DOE (EG-77-C-01-4042). Thus this report is being issued as a SERI report.

Lyle Groome
Program Manager

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Acknowledgement

The author acknowledges the many suggestions of Peter Armstrong and Francis de Winter at Altas Corporation during the course of this study. The work of Peter Versteegan and Frank Varcolik of SAI in cleaning up the SOLMET and TMY data tapes was greatly appreciated. The cooperation of Herb Anderson and Dick Prairie at Sandia Labs in furnishing data generated during the development of the TMYs and in reviewing the draft of this report is gratefully acknowledged.

1.0 Introduction

1.1 Purpose

One of the obstacles in the solar heating and cooling systems studies area has been the lack of a commonly accepted year of hourly meteorological data for use in computer simulations. Consequently, it has been nearly impossible to compare the performance of different component and system designs as simulated by different investigators.

Several rather arbitrary and haphazard methods have been employed in the past to select a year of data for a simulation study in a particular location. To address this problem, the Department of Energy contracted Sandia Laboratories to generate a "Typical Meteorological Year" (TMY) for each of the twenty six U.S. cities having a long period of record of hourly meteorological data.

The purpose of the present study is to assess how well these TMY's represent the long term in-so-far as the performance of solar heating and cooling systems is concerned.

1.2 Contract and Scope

Under contract EM-78-C-04-4261 to the Department of Energy, Office of Conservation and Solar Applications, Science Application Inc. (SAI) and its subcontractors are funded to perform analysis of advanced solar heating and cooling systems for economical application throughout the U.S. Three primary task areas have been defined: 1) analyses of systems and subsystems, 2) component modeling, and 3) validation.

Meteorological data constitutes the forcing functions of solar systems and subsystems and hence is of great importance in Task 1. The analysis of the recently developed typical Meteorological Years has been identified as subtask 1.4 of Task 1 and has been performed by Altas Corporation of Santa Cruz, California under contract P.O.48125 to SAI. The stated objective of the subtask was to determine the adequacy of the TMYs for design and comparative analysis. This was to be done via comparison of simulations of various typical systems using the TMY and the SOLMET period of record for a limited number of sites representative of a range of climate types.

2.0 Background

2.1 Hourly Meteorological Data Base

The ultimate source of data available to a "Typical Year" selection method is the approximately twenty three years of records from the twenty six U.S. weather stations operated by the National Oceanographic and Atmospheric Administration (NOAA). NOAA undertook a major effort to reformat and rehabilitate this data when it became clear that it suffered from a number of deficiencies. The most serious of these were: "solar" and "surface" observations recorded in separate "card deck" formats, obsolete card formats incompatible with magnetic tapes and computer input, large numbers of gaps in the measurements, and inaccurate solar insolation measurements caused by degradation of the pyranometers. The reformatted and rehabilitated data is available from the National Climatic Center (NCC) and is known as the SOLMET (1) data. It has served as the immediate data base for the development of the TMYs and is the standard against which the TMYs must be assessed. As an interim solution to the problem of identifying a particular year for DOE funded simulation work, Hedstrom (2) proposed the use of a particular year for many sites from the SOLMET data base.

2.2 TMY Selection Methodology

The development of the TMYs, described in (3), used what the authors refer to as an "empirical approach". A typical month for each of the twelve calender months was selected from the approximately twenty three year SOLMET data base for each site. These typical months were then concatenated to form the TMYs and the discontinuities in the measurements at the month interfaces were smoothed.

The data which formed the basis for the selection of the typical months consisted of thirteen indices calculated from the hourly values of solar radiation, dry bulb temperature, dew point temperature, and wind speed. These indices were the total daily global horizontal radiation, and the average daily maximum, mean, minimum and range for each month for each of the other three meteorological variables. The cumulative distribution function (CDF) was generated for each of the indices for each month and for the long term of each month. A statistical means of measuring the "closeness" of the individual months' CDFs to the long term CDF was identified (the F-S statistic which will be defined later). Since it is generally impossible to find a month which is closest to the long term for all of the indices and since some indices are more important than others, it was necessary to "weight" certain statistics more heavily than others in the selection process. Hence, the sum of the products of the F-S statistics and corresponding weighting factors was used as the primary criterion for identifying the typical months. The TMY developers admit that the assignment of weighting factors is largely intuitive and depends on the intended application of the TMY. Because of the intended use in solar heating and cooling studies, solar radiation was assigned as much weight as the other statistics combined. The dry bulb, dew point, and wind speed statistics were each assigned approximately equal portions of the remaining weight. The weighting scheme actually used is shown in Table 1. Statistics not appearing in the table were assigned zero weight.

TABLE 1 WEIGHTING FACTORS USED IN TMY SELECTION PROCEDURE

Temperature						Wind		Solar
Dry Bulb			Dew Point			Speed		Radiation
MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MEAN	TOTAL
1/24	1/24	1/12	1/24	1/24	1/12	1/12	1/12	1/2

The weighted sum of the FS statistics was used to identify five candidates for each month of each TMY. The final selection of each month involved consideration of the "persistence" of the mean daily dry bulb temperature and daily total global solar radiation. Persistence was considered important because atypically long runs of cloudy or warm or cool days will clearly affect system performance. Persistence was characterized by the frequency and run length above and below fixed long term percentiles. For mean daily dry bulb temperature the frequency and run length of days above the sixty seventh long term percentile, and below the thirty third long term percentile, were computed. For solar radiation the frequency and run length below the thirty third long term pencentile were computed. The final selection of the months was "somewhat subjective" according to the TMY developers. They manually inspected the weighted sums of the FS statistics, the deviations of the means, and the frequency and run length structure to make the final selection from among the five candidate months.

Finally, discontinuities in the meteorological variables at the monthly interfaces were "smoothed" by spline interpolation a few hours on either side of the interface.

3.0 Method of Analysis

3.1 Weather Data Statistical Considerations

If it could be assumed that solar heating and cooling systems are sensitive only to global horizontal solar radiation, dry bulb and dew point temperature and wind speed (both singly and interdependently), theoretically it would have been possible to find or fabricate twelve months that drive a system in a manner identical to the long term. Each of these "perfect" months would have: totals and means of the meteorological variables, cumulative distribution functions, covariance of all combinations of two, three and four variables and individual and joint persistence characteristics the same as in the long term. A successful test for these conditions would ensure that the weather would be typical of the long term for any solar heating and cooling system or any other system whose performance is sensitive to the four meteorological parameters.

A spot-check of the means and cumulative distribution functions of the weather variables considered reveals significant differences between the TMYs and the long term however, especially for parameters lightly weighted in the selection process. This is not surprising given that there were only about twenty three months from which to chose a "typical" month. At any rate it is clear that a detailed statistical comparison of the TMY months to the long term will turn up many differences and many reasons to doubt the typicality of the TMY. Such a strict test, however, would prove inconclusive due to the highly random nature of the meteorological parameters and of the random deviations in weather structure between the TMY months and the long term. It is still possible to expect the TMYs to adequately represent the long term because of the multitude of compensating effects. For this reason computer simulations of the performance of typical solar heating and cooling systems were felt to be a better standard of comparison of the TMYs to the long term.

3.2 Solar System Simulation Methodology

Ideally, several different kinds of representative solar heating and cooling systems should be simulated for both the TMY and for the long term in each of the twenty six SOLMET sites. This is not feasable however, due to the enormous amount of simulation required. In addition, lack of generally accepted models for a number of generic system types, the particularly high expense of using many of them and the redundancy of much of the results make this approach impractical.

3.2.1 Base System Description

As a practical alternative, a single solar heating and cooling system was identified that is broadly representative of most solar systems in its sensitivity to meteorological data structure. This base system, shown in Fig.1, is an active residential space heating and cooling system. It consists of an array of two cover selective surface, flat plate collectors which heat a solution of anti-freeze and water, a fully mixed water filled storage tank, a liquid to liquid heat exchanger to isolate the collector and tank fluids, a water to air heat exchanger in the house air supply duct, a typical residential heating and cooling load, a hot water fired lithium-bromide absorption chiller with a cooling tower for space cooling, auxiliary heat supplies for both heating and cooling, and associated piping, pumps, and controls.

Appendix B contains a detailed listing of the parameters used to represent the base system in each of six test sites. The test sites were chosen to represent a broad range of climate types across the U.S. It is felt that these "random" samples from the twenty six SOLMET stations will adequately illustrate the range of differences in performance predictions between the TMY and the long term. The base system has been sized to meet between about 1/2 and 3/4 of the combined heating and cooling load in each of the test sites.

3.2.2 TRNSYS Modeling Considerations

The base system has been modeled with a modified version 10 of TRNSYS (4) which includes new and fairly sophisticated models of the absorption chiller and the cooling load. These models make it possible to realistically model the effects of chiller startup transients and the latent heat load and latent heat removal from room air during the cooling season. A detailed transfer function load model of the house allows consideration of the dynamic effects of heat gains (and losses) via conduction throught the walls and roof, solar heat gains through windows and heat gains from lights and occupants. Heat loss by infiltration is considered as is conduction through the slab floor.

The SOLMET data format does not explicity include wet bulb temperature or relative humidity, both of which are required for the TRNSYS simulation. Initially a set of algorithms recommended by ASHRAE (5) were used to convert the SOLMET dry bulb and dew point temperature and the station pressure into wet bulb and relative humidity. The iterative solution procedure proved to be unnecessarily exact and much too slow for our purpose, causing a several fold increase in the cost of a year's simulation. Therefore a fast empirical method of generating approximate values of wet bulb temperature and relative humidity was developed and added to TRNSYS.

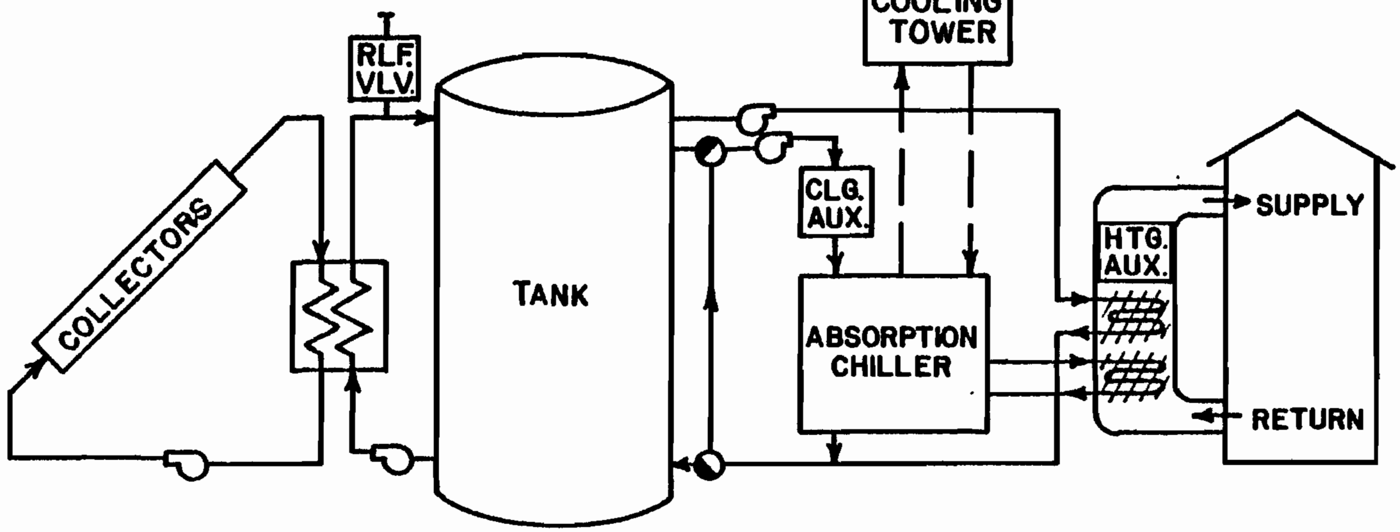

FIG 1. BASE SYSTEM SCHEMATIC

The base system's performance is responsive to the four meteorological variables used in the TMY selection process in a manner representative of many systems and in a manner roughly proportional to the selection process weighting factors. Solar radiation is of prime importance, largely determining the collected energy and secondarily affecting the heating and cooling loads via solar heat gains. The dry bulb temperature is of primary importance in the heating load calculation. It is important also in the sensible cooling load calculation and in the collector performance. The dew point temperature has no bearing on system performance in the heating season but is important to both the latent portion of the cooling load and the chiller output because of the cooling tower performance. The wind speed is of minor importance in the model, affecting only the collector heat loss coefficient.

Certain aspects of real installed systems of this type were neglected or altered in the model in order to reduce the complexity and expense of the simulations and because their inclusion would offer no additional information. A domestic hot water (DHW) preheating system was not included for this reason. Since the DHW load is insensitive to weather, it was felt that a DHW subsystem would only obscure differences seen in the space heating peformance between the TMY and the long term. Pipe and duct heat losses and heat capacitance effects and parasitic power requirements similarly were not modeled.

3.2.3 Data Reduction and Analysis

The TRNSYS output for all simulations consisted of monthly energy flows which were written to mass storage for subsequent processing. Later, the output from both the TMY and the long term simulation for each system-site combination served as input to a program which generated the yearly and monthly TMY vs long term comparison tables of Appendix C.

A series of runs was performed with the F-Chart method (6) using as input the gross monthly radiation, loads and average ambient temperatures generated by the TRNSYS simulations. The purpose of these runs was to determine the extent to which differences in the heating system performance could be ascribed simply to discrepancies between the TMY monthly totals and averages and the long term monthly totals and averages.

The simulation results of the base system in the test sites suggested a number of other simulation tests to investigate the effects of the system's time constant (ie storage size) and the "carry-over" effect of the weather in one month on the performance in the next.

4.0 Discussion of Results

4.1 TMY vs Long-Term Monthly Weather Statistics

A first step in comparing the TMYs to the long term is to compare the gross monthly meteorological statistics. An abundance of this type of data was generated and published on microfiche with (3) by the TMY authors but has not been presented in a manner convenient for comparisons. The statistics for a particular month of a TMY can be found only by first looking up the actual year from which that month came and then locating it in the lists of all the monthly statistics for every month on record for the site. This has been done for the six test sites considered in this report and the results are tabulated in Appendix A. The year of origin of each TMY month and other pertinent information are listed in Table 2 for each of the six test sites.

The "Long Term and TMY Meteorological Statistics" tables of Appendix A show the side by side comparison of the means of daily total horizontal radiation and daily average dry bulb temperature, dew point temperature and wind speed. Also shown are the averages of the standard deviations of the daily data for both the long term and the TMY. The F-S statistic, which is a measure of the closeness of the TMY and long term cumulative distribution functions (CDF), is also listed for each parameter.

Specifically,

$$F\text{-}S = (1/n) \sum_{i=1}^{n} \delta_i$$

Where:

δ_i = the absolute difference between the long term CDF and the TMY month CDF at X_i

X_i = the ith ordered observation of the meteorological variable X

n = the number of daily readings in the month.

The smaller the value of F-S, the closer the fit of the two CDFs and hence, the more the TMY resembles the long term. A zero value F-S statistic implies identical means, identical average standard deviations, and identical distributions.

Inspection of the tables of Appendix A, reveals that absolute differences between the long term and the TMY monthly radiation average about 3% with a 10% maximum difference. The differences in dry bulb average 0.4 ^{o}C with about a 1.0 ^{o}C maximum. The differencs in dew point average about 0.8 ^{o}C with about a 2.0 ^{o}C maximum. The differences in wind speed average about 10% with a 25% maximum. The F-S statistics average around 0.035 for solar radiation, 0.060 for dry bulb temperature, 0.075 for dew point temperature and about 0.100 for wind speed.

TABLE 2 TEST SITE DATA

Site	Weather Bureau Station No.	Latitude	Period of Record	Hedstrom Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					Origin of TMY Months											
ALBUQUERQUE	23050	35.05	52/7/1-75/12/31	62	58	53	65	66	64	69	57	54	67	65	59	54
FORT WORTH	03927	32.82	52/7/1-74/7/31	60	72	61	62	66	66	59	65	55	57	68	71	62
MADISON	14837	43.13	52/7/1-75/12/31	61	65	60	72	64	53	57	73	63	58	74	65	54
MIAMI	12839	25.80	52/7/1-75/12/31	59	62	74	67	59	64	53	57	63	57	65	61	68
NEW YORK	94728	40.78	52/7/1-75/12/31	58	58	59	59	74	74	61	60	72	58	56	71	67
WASHINGTON DC	93734	38.83	53/8/1-75/12/31	--	65	70	64	67	56	68	73	65	73	75	73	61

In short, the differences between the TMY and long term monthly statistics are generally moderate, occassionally significant, but apparently not systematic. The deviations from the long term in one TMY month are often compensated for in the next. Since representative years, or at least, representative heating and cooling seasons, will most generally be required by the TMY users, the month to month differences may not be very important. Furthermore, joint distributions and co-variances of the meteorological variables have not been addressed in the tables of Appendix A or any where in the TMY selection methodology, but might prove to be more significant than the differences in the monthly totals and averages. To address these concerns we turn to the results of the simulations of the base system in the six test sites.

4.2 Simulation Results Reporting Format

The base system of Figure 1, whose parameters are listed in Appendix B, was simulated with TRNSYS in each of the six test sites with both the Typical Meteorological Year and the entire long term SOMET data. The TRNSYS monthly summaries output was subsequently reduced by a program which generated the tables of Appendix C. For each site two summary tables are presented. The first (Table A) consists of yearly summaries of seventeen performance measures for each complete year of the long term SOLMET period of record, the long term mean and standard deviation of each of these performance measures, the values of these measures for the TMY year and the absolute value of the difference between the TMY and the long term mean. The second table for each site (Table B) consists of monthly summaries of the long term mean, standard deviation and TMY results for the same seventeen performance measures for each month of the year.

The performance measures include both "primary" results, which can be directly measured in an experiment or a simulation, and "derived" results which are computed from the primary results. The primary measures consist of the principal energy flows across "subsystem" boundaries. The derived measures consist of several figures of merit commonly used in rating solar system performance. Definitions of these performance measures are given in Table 3. It should be noted that the derived measures for both the annual long term means of Table A and the monthly long term means of Table B have been calculated from the long term means of the primary measures, not by averaging the twenty three or so derived measures. Hence, the derived measures accurately represent the performance for the long term period of record.

Table 3 PERFORMANCE MEASURES

Measure	Definition	Units
HDIF	Total diffuse radiation on a horizontal surface	GJ/m^2
HHOR	Total radiation on a horizontal surface	GJ/m^2
HTILT	Total radiation on the collector surface	GJ/m^2
QU	Total energy gained per unit collector area	GJ/m^2
QAUXH	Space heating auxiliary energy	GJ
QLH	Total space heating requirement	GJ
QAC	Total heat removed from room by chiller	GJ
QLAT	Latent heat removed from room by chiller	GJ
QLC	Total heat input to chiller's generator	GJ
QAUXC	Auxiliary heat input to chiller's generator	GJ
TBAR	Average tank temperature	^{o}C
FDIF	Fraction of horizontal radiation that is diffuse (HDIF/HHOR)	-
RBAR	Ratio of radiation on collector to horizontal (HTILT/HHOR)	-
FCOL	Long term collection efficiency (QU/HTILT)	-
F-HTG	Fraction of heating load met by solar [(QLH-QAUXH)/QLH]	-
F-CLG	Fraction of cooling load met by solar [(QLC-QAUXC)/QLC]	-
COP	Chiller Coefficient of Performance (QAC/QLC)	-

4.3 Simulation Results for the Base System

4.3.1 General Observations

The tables of Appendix C illustrate the year to year and month to month variability of the weather and solar system performance in different types of climate. A broad range of climates has been represented as evident from Table 4 where the long term average annual heating, cooling, and latent loads, and the global horizontal radiation and fraction diffuse for the base system in each of the test sites have been transcribed. Albuquerque has the most nearly balanced heating and cooling loads, a relatively small latent contribution, the greatest amount of total radiation and the lowest fraction of diffuse radiation. In Fort Worth the cooling load predominates but heating is still significant. In Madison the heating load is huge and the cooling load is small. In Miami the heating load is nearly non-existent, the cooling load is huge, and a substantial portion of the cooling requirement is for latent heat removal. New York is less severe than Madison in its heating season but has even less total radiation and a higher fraction of diffuse. Washington D.C. is much like New York except that the heating load is somewhat smaller and the latent and sensible cooling loads are somewhat larger.

TABLE 4 COMPARISON OF SELECTED ANNUAL PERFORMANCE MEASURES FOR THE LONG TERM, THE TMY, AND THE "HEDSTROM YEARS"

SITE		HHOR(GJ/m^2)	QLH(GJ)	QAC(GJ)	QLAT(GJ)	FDIF	F-HTG	F-CLG
ALBUQUERQUE	LONG TERM	7.56	56.1	22.3	8.0	0.253	0.624	0.624
	TMY	7.63	56.3	19.9	6.7	0.256	0.644	0.642
	HEDSTROM YR.	7.72	54.9	20.5	7.5	0.241	0.621	0.663
FORT WORTH	LONG TERM	6.10	32.2	54.5	21.4	0.365	0.724	0.470
	TMY	6.16	31.4	49.5	19.0	0.350	0.764	0.495
	HEDSTROM YR.	6.17	37.8	57.1	22.7	0.354	0.569	0.487
MADISON	LONG TERM	4.93	107.7	9.3	3.9	0.425	0.488	0.894
	TMY	4.93	107.9	8.0	3.3	0.435	0.486	0.958
	HEDSTROM YR.	5.03	108.1	9.6	4.4	0.410	0.476	0.918
MIAMI	LONG TERM	6.10	1.3	90.3	43.3	0.452	1.0	0.393
	TMY	6.14	1.4	90.1	43.0	0.449	1.0	0.409
	HEDSTROM YR.	5.97	1.3	90.9	44.9	0.462	1.0	0.395
NEW YORK	LONG TERM	4.55	72.9	13.9	6.0	0.469	0.590	0.775
	TMY	4.53	70.5	11.2	4.9	0.466	0.571	0.800
	HEDSTROM YR.	4.39	78.7	11.7	5.1	0.472	0.563	0.826
WASHINGTON DC	LONG TERM	4.99	68.2	20.4	8.9	0.444	0.646	0.782
	TMY	5.04	67.9	18.2	8.2	0.437	0.657	0.790

The TMY year is generally a better match to the long term performance than any single year of data. The best TMY-long term matches are in Albuquerque and Miami. Albuquerque's clear skies and its evenly distributed, substantial heating and cooling loads are probably responsible. Miami's consistantly large cooling load and its miniscule heating requirements account for its TMY-long term agreement.

Some of the performance measures of Appendix C, like the cooling loads QAC, QLAT, and QLC, are highly variable from one year to the next since they are functions of several meteorological variables which, themselves, are highly variable. Other indices are very nearly the same every year, like the ratio of tilted to horizontal radiation, RBAR. When the yearly standard deviations are presented as percents of the long term means, as they are in Table 5, some patterns emerge very clearly. The variability of the heating performance measures is generally greater in a "warm climate". Even more pronounced, the variability of the cooling performance measures is greater in a "cold climate". For example, the heating load (QLH) and the heating auxiliary (QAUXH) have the least variability in Madison and the most in Miami and Fort Worth. The cooling load (QCL), latent cooling load (QLAT), air conditioner output (QAC), and auxiliary cooling (QAUXC) all have the least variability in Miami and Fort Worth and the most in Madison.

It follows from these observations that a TMY composed from real data may have trouble accurately predicting the long term cooling indices in a climate or season that has a small, dispersed cooling load. The same seems to be true, to a lesser degree, of the heating indices in periods of low heating loads. A closer look at the fractions of the heating and cooling loads met by solar energy (solar fractions) predicted by the TMY and the long term is required to substantiate these concerns.

TABLE 5 STANDARD DEVIATION OF YEARLY PERFORMANCE MEASURES AS PERCENT OF LONG TERM MEANS

	ALBUQUERQUE	FORT WORTH	MADISON	MIAMI	NEW YORK	WASHINGTON
HDIF	2.5	2.3	2.3	2.7	2.7	1.3
HHOR	2.4	4.5	4.0	2.8	4.2	3.7
HTILT	2.6	4.8	4.4	3.0	4.4	4.1
QU	6.0	7.3	5.2	7.1	5.4	5.4
QAUXH	18.5	35.8	9.1	-	15.2	17.3
QLH	8.3	10.5	5.1	60.5	7.2	9.3
QAC	25.1	11.3	33.9	8.2	26.3	30.6
QLAT	36.3	8.2	32.4	7.8	27.3	29.4
QLC	22.5	10.2	32.9	7.9	24.9	29.8
QAUXC	35.4	10.1	84.9	9.7	56.3	63.7
FDIF	4.0	6.0	4.2	5.1	4.1	3.8
RBAR	0.7	0.9	0.8	0.6	1.0	1.0
FCOL	5.1	4.6	4.4	5.7	5.0	4.9
F-HTG	6.9	10.2	6.6	-	6.9	6.0
F-CLG	8.5	7.0	5.8	6.6	10.2	9.6
COP	3.1	1.5	1.3	0.6	2.0	1.1

4.3.2 Comparison of the "Solar Fractions"

Large percentage errors in small loads and small auxiliary requirements translate into larger errors in the solar heating or cooling fractions. This situation is mitigated somewhat by the fact that both the solar heating and cooling fractions "saturate" at 1.00. Hence, errors in the annual and monthly solar fractions between the long term and the TMY tend towards 0 as 100% solar is approached.

4.3.2.1 Solar Heating Fraction

Figure 2 is a "scatter plot" showing the monthly and annual deviation of the TMY solar heating fraction from the long term average solar heating fractions for all test sites (except Miami which always has 100% solar heating). In this plot of the long term solar fraction versus the TMY solar fraction, the deviation is the vertical distance to the 45° line. The maximum monthly deviations occur between the long term solar fractions of 0.7 and 0.9. The deviations generally diminish for months having large loads and hence, small solar fractions. The yearly solar fractions, denoted by the encircled symbols have small deviations between the long term and the TMY, partly because the high load months heavily weight the yearly result, and partly because many of the month to month deviations tend to cancel. The deviations increase for lighter loads, until the effects of saturation begin to dominate, because lighter loads are more dispersed and the distribution and co-variance of meterological parameters become more critical.

A tendency towards TMY over-prediction of the solar heating fraction for large values of F-HTG can be observed in Figure 2. The TMY F-HTG prediction frequently saturates when the long term prediction does not. Never does the reverse of this occur. Figures 3 and 4 were plotted in search of an explanation. Figure 3 shows the monthly and yearly scatter of the horizontal radiation totals for the long term and the TMY. Figure 4 shows the scatter of the heating loads. There does not seem to be a bias in either of these graphs that would account for the bias in the F-HTG plot. All differences seem acceptably small and random. The problem must therefore lie in the structure of the data.

Long term monthly solar fractions in the 0.8 to 0.9 range are frequently the result of the influence of one or more unusual months. These are the very months the TMY selection method has been designed to reject as atypical. For example, for 22 Aprils a city may have little or no heating load and hence F-HTG equal to 1.0. In the 23rd April an unusual weather pattern may create a significant load at a time when little energy is stored in the tank. The result might be that only 80% of that load is met by solar, causing the average F-HTG for all Aprils to be 0.85. In the search for a typical real month to represent all Aprils, the TMY methodology would reject the unusual month in favor of one which yields 100% solar heating.

It has been maintained that a month yielding 100% solar heating in the situation described above is more representative than one yeilding 85% since all months but one yeilded 100%. In this highly skewed situation a month yeilding the median result (F-HTG=1.0) is arguably a better measure of the long term than one yeilding the mean result (F-HTG=0.85). The fact remains, however, that the median month in such situations tends to over-predict solar system performance for that month in the long term.

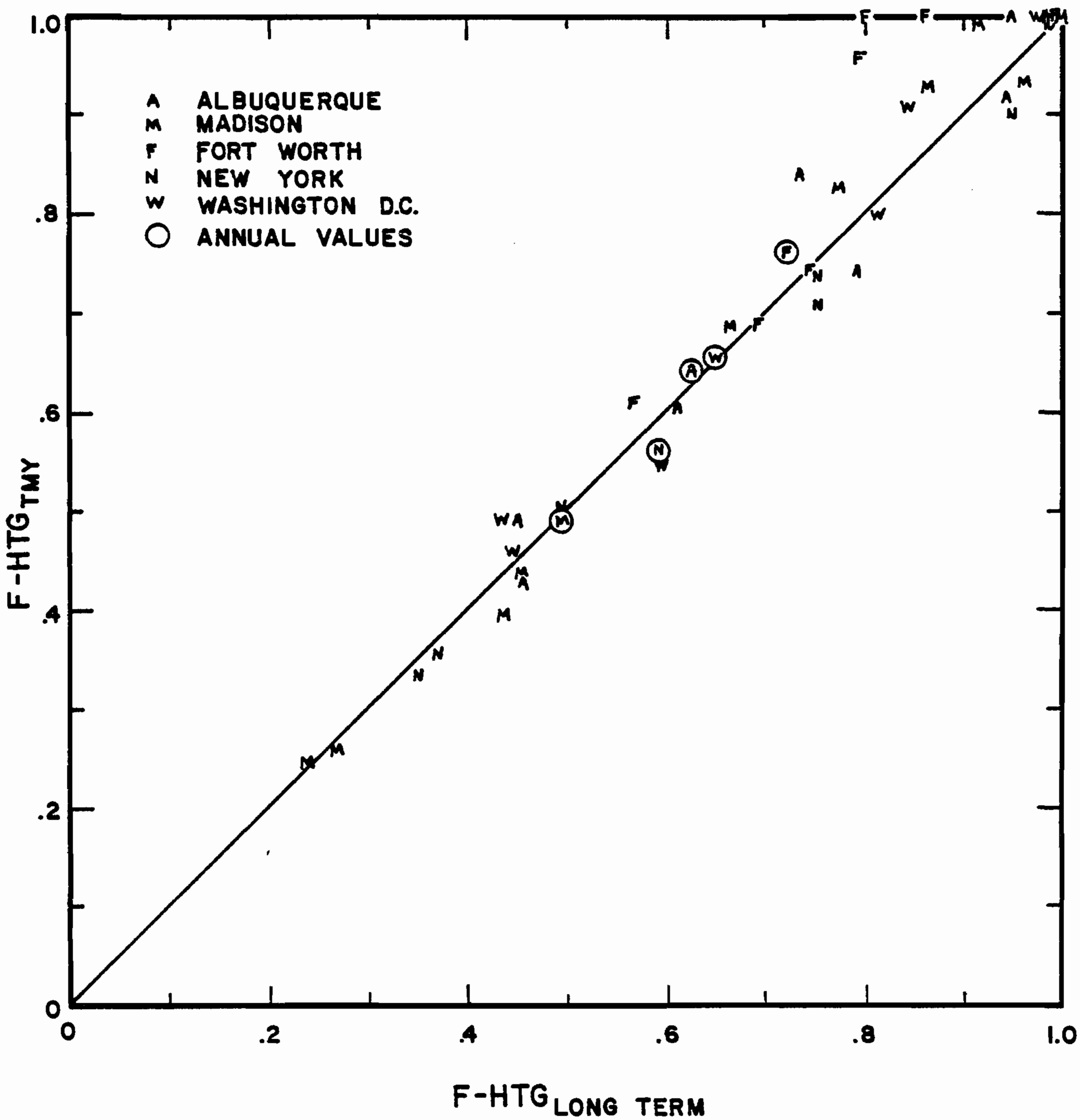

FIG. 2 SOLAR HEATING FRACTION SCATTER

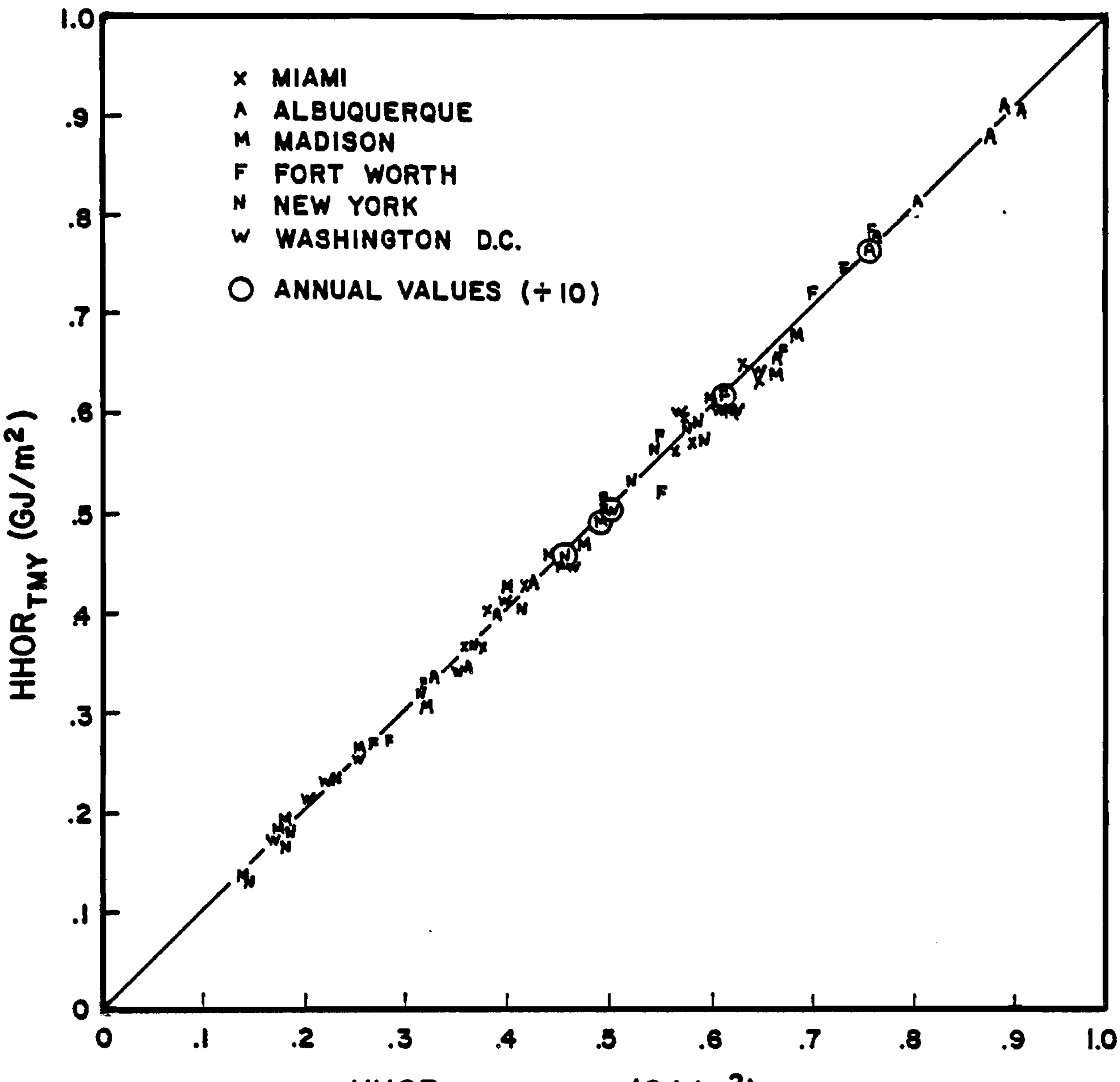

FIG. 3 TOTAL HORIZONTAL RADIATION SCATTER

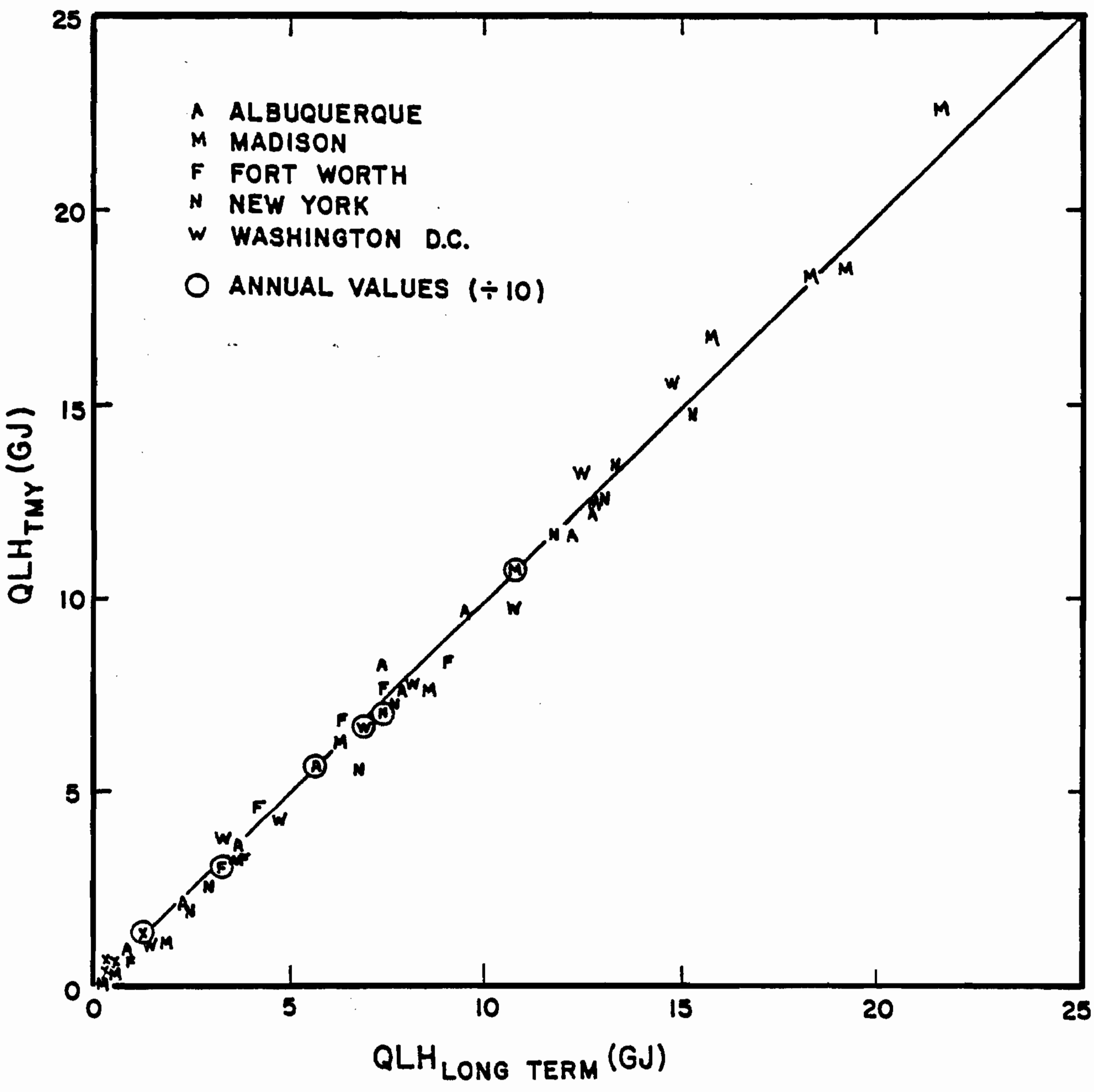

FIG. 4 HEATING LOAD SCATTER

The tendency of the TMY months to over-predict performance is most significant in the climate-month-system combinations where light and dispersed loads occur. In Northern climates the excellent agreement in heating performance prediction for the winter months heavily weights the yearly results, causing good, unbiased long term-TMY yearly agreement. Note in Figure 2 that the yearly results for Madison and New York are the only ones on or below the 45° line, while Albuquerque, Washington, and Fort Worth all lie above it. Fort Worth has the lightest and most dispersed monthly loads and they significantly bias the yearly TMY results towards overprediction of solar system performance.

4.3.2.2 Solar Cooling Fraction

The effect discussed above has more serious consequences in the cooling season performance because of some important differences between cooling and heating loads. First of all the cooling loads are generally smaller and more dispersed than heating loads. Secondly, since a much higher temperature is required from the solar system to drive the chiller (about 77°C verses about 30°C for heating) the cooling system performance is much more sensitive to weather structure, that is, the variance and co-variance of insolation and temperature.

A scatter plot of monthly and annual solar cooling fraction for the long term verses the TMY for all test sites is shown in Figure 5. As expected the errors are generally larger and spread out over a wider range of solar fractions than in the heating season. Differences of 0.1 and larger occur for solar cooling fractions from 0.5 to 0.9. More disturbing, however, is the strong tendency for TMY over-prediction of cooling system performance. Even in large cooling load climates like Miami and Fort Worth monthly cooling performance is frequently over-predicted resulting in slightly over-predicted yearly results. In small cooling load climates like Madison's over-prediction of cooling performance by the TMY causes much larger deviations in the yearly solar fraction (0.064 for Madison).

Figure 6 shows the monthly and yearly scatter of the air conditioning load for the long term verses the TMY. In contrast to the heating load plot of Figure 4, there is a noticable bias in the cooling load. The TMY months and years tend to under-predict the long term average load when the load is small. The reason for this is similar to that given for the bias in the solar heating fraction. The months which contribute the most to the long term average cooling load for a given calendar month are most often atypical in one respect or another and therefore are never selected for use in the TMY. When the effect of the atypically low cooling loads predicted by the TMY are coupled to the atypically "optimistic" data structure of the TMYs, the TMY over-prediction of performance of Figure 5 results.

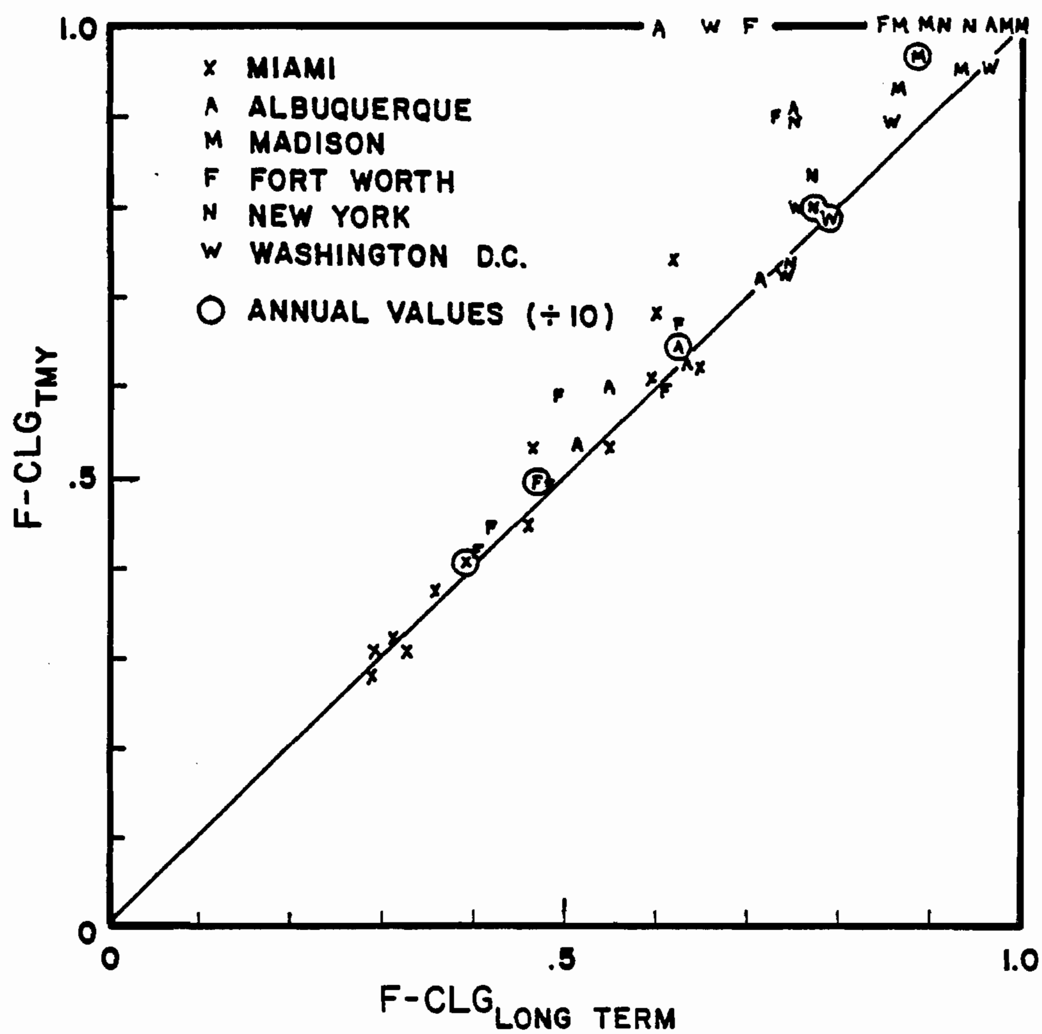

FIG. 5 SOLAR COOLING FRACTION SCATTER

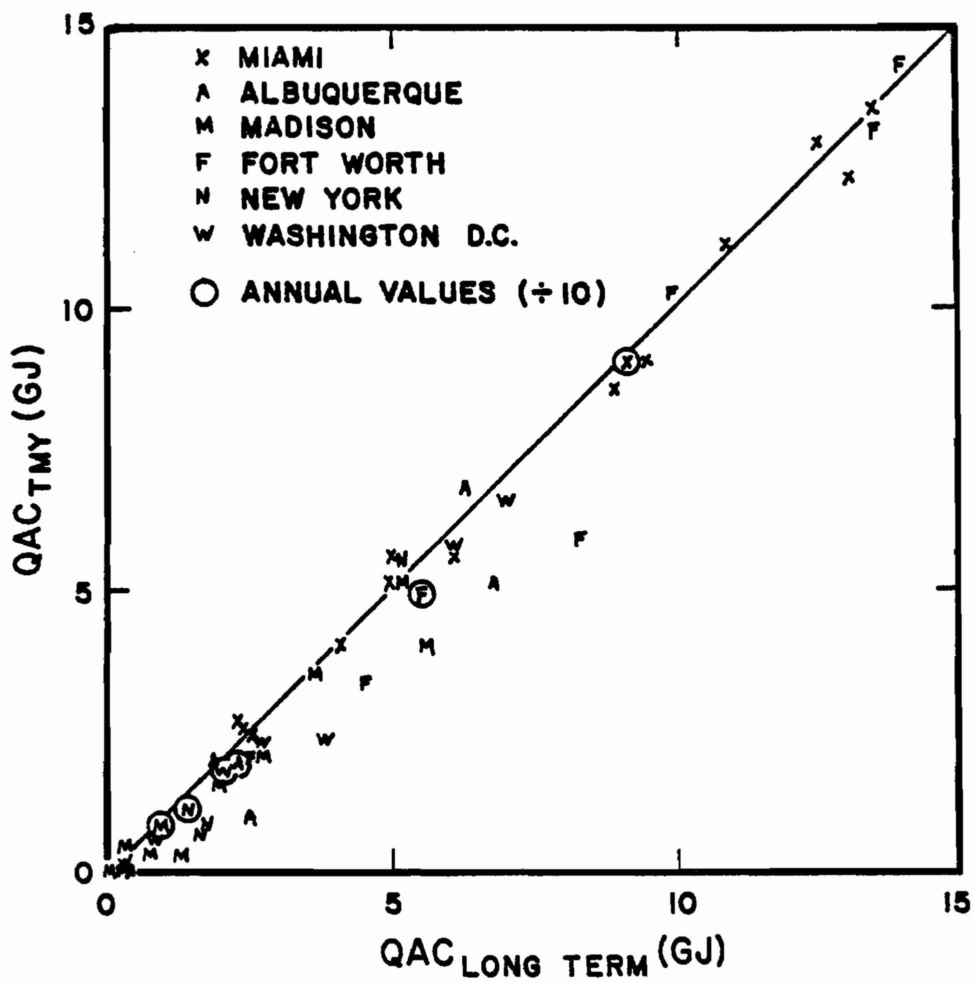

FIG. 6 AIR CONDITIONING LOAD SCATTER

4.3.3 Comparison of the Diffuse Radiation

Returning to the annual performance tables of Appendix C, it can be seen that the TMY yearly performance measures are generally well within one standard deviation of the long term results except as noted above. One other noteable exception is the diffuse radiation, and, by virtue of its complementary relationship, the direct radiation. The diffuse radiation is a significant meteorological variable not considered in the TMY selection method, hence any typicality of the TMY diffuse radiation may be almost coincidental. In the Madison and Fort Worth TMYs the annual total diffuse radiation differs from the long term mean by more than one standard deviation while the New York and Miami TMYs show good agreement with the long term. However, when the monthly tables of Appendix C are examined it is apparent that the longterm and TMY diffuse radiation totals are significantly different month to month in every city. Differences in excess of one standard deviation are seen in every city and differences in excess of two standard deviations occur in Madison and New York.

The TRNSYS algorithm which converts the global horizontal and direct normal radiation into beam and diffuse on the horizontal was checked for errors. In addition, the monthly diffuse radiation comparison plots of Figure 7 were made to see if there were any systematic seasonal differences. The differences were found to be both genuine and randomly distributed from month to month.

Differences in diffuse radiation did not significantly affect the performance of the base system considered here because both beam and diffuse radiation could be utilized by the collector. The same would not be true for a system employing concentrating collectors, however.

4.3.4 Comparison of Monthly Performance

In general, the month to month differences between the long term and TMY indices are greater than they are on an annual basis. However, the standard deviation of each monthly index is also a much larger fraction of the long term mean. As a result nearly all TMY indices are well within one standard deviation of the long term as seen in Appendix C. The exceptions, again, are in the cooling performance measures for climate-month combinations where a moderate and dispersed cooling load exists, (e.g. August and September in Madison, March and April in Fort Worth and September in Albuquerque) and in the diffuse radiation as noted above.

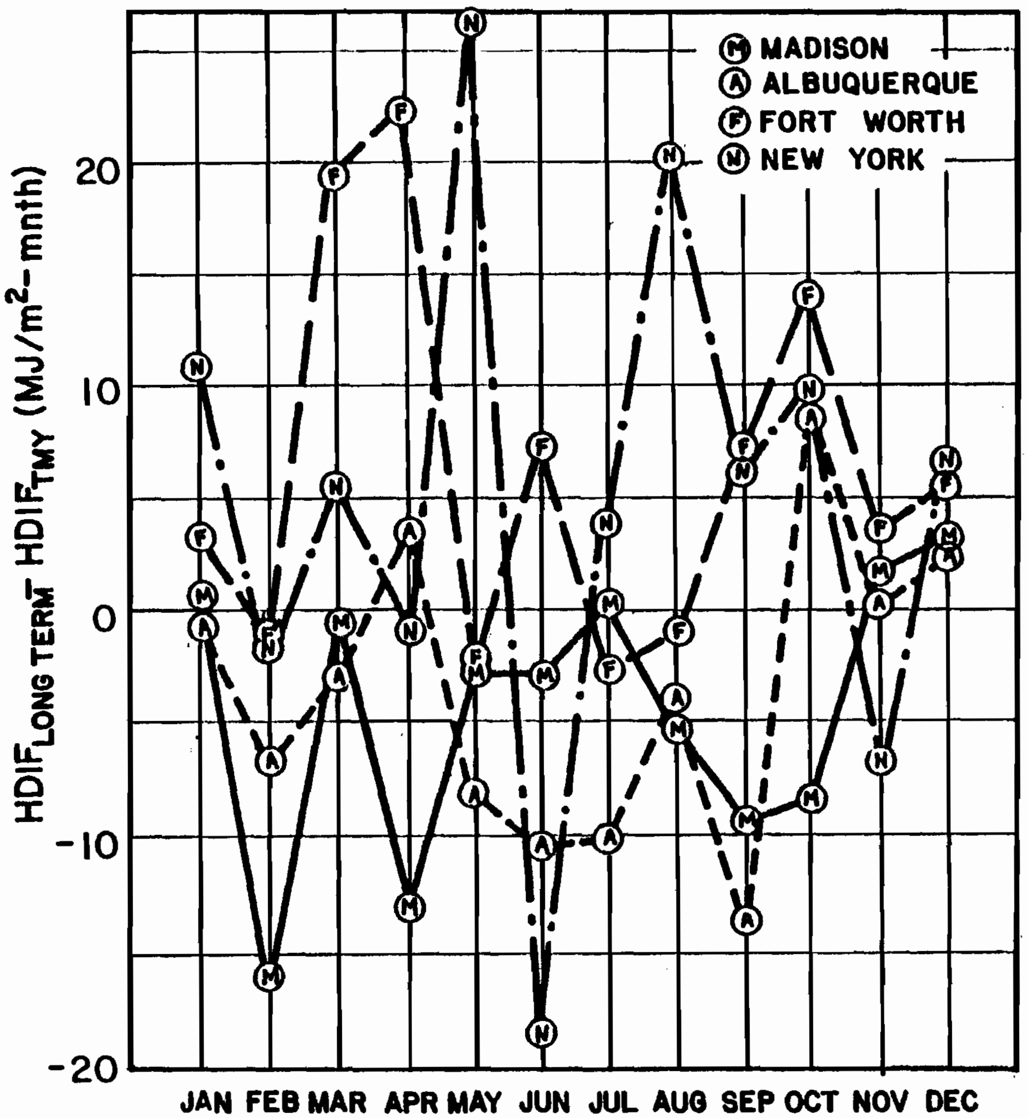

FIG. 7 DIFFUSE RADIATION DEVIATION

Complete monthly results for every year of record for each test site would be too voluminous to present here. Instead, in Appendix D selected performance measures have been tabulated by months for the base system in Madison for every month in the period of record, the TMY, and the long term. The months marked with "H" and "T" are the Hedstrom and TMY source months, respectively.

Wide ranges of the monthly values of radiation and heating and cooling loads are obtained for every calendar month. When a month having particularly low radiation also has a high heating load, the solar heating fraction can be very low; when the reverse occurs, the solar heating fraction can be quite high. The range of solar cooling fractions is even wider due to the sporadic nature of the load and the sensitivity to meteorological sequences.

When the long term solar fractions for each month are compared to those for each individual month, it is seen that the TMY month is usually among the closest. Madison's TMY January (January 1965) has the closest solar fraction match to the long term of all 23 Januaries. The TMY month is the seventh and eighth closest in February and March respectively. However, many of those month's with closer solar fraction matches have atypical loads and radiation. For example, Madison's 1967 February has 10.5% more radiation and 13.9% more heating load than the long term average and yet its solar heating fraction exactly matches the long term for February. Thus the solar fraction is a necessary but not sufficient index of typicality.

4.3.5 Performance of the "Hedstrom Years"

It is interesting to compare the "Hedstrom year" performance measures to the long term and the TMY because the Hedstrom Years were identified with the very criteria just found unreliable. These years were selected using matches of only the yearly solar heating fraction. No attempt was made to identify representative months or to determine if the weather was representative for another kind of system.

Referring to Table 4 again it can be seen that the long term insolation and heating loads are more closely matched by the TMY than by the Hedstrom year as expected. Not surprisingly the solar heating fraction is consistantly better matched by the TMY. Only in Albuquerque is the Hedstrom year solar fraction closer than the TMY to the long term. However, the air conditioning loads and the fraction of diffuse radiation are as likely to favor the Hedstrom years as the TMYs. As a result the yearly solar cooling fraction is often predicted better by the Hedstrom year than the TMY.

Since no single real year of data will be close to the long term in every month, more significant deviations are seen in the Hedstrom years on a month to month basis. This can be seen clearly from the monthly summary tables for Madison in Appendix D discussed previously. The performance of any single month of the Hedstrom year (1961 for Madison) is likely to be quite different than the long term for that month. For some months, the Hedstrom year month is among the least representative of all months on record (April in Madison, for example).

The Hedstrom year selection process was at least able to select years that had very representative annual heating performance in every test site except Fort Worth. By coincidence mostly, the cooling season performance measures for the test sites investigated here are also fairly representative.

4.4 Comparisons to F-Chart Results

Differences between TMY and long term monthly performance are due to "non-typicality" of the individual months. "Typicality" may be ascribed to climate statistics of at least two different classes or levels of detail: 1.) the gross monthly totals and averages, represented in Appendix A, and 2.) the structure of the hour by hour data, including the distributions of each individual meteorological variable and the co-variance of all variables. It is possible to identify at least the first order performance effects of non-typicality of the TMY gross monthly meteorological statistics, and to separate them from the effects of non-typicality of data structure. The F-Chart method can be used to do this since it is sensitive only to monthly statistics which are fairly straightforward transformations of the monthly data in Appendix A. (The radiation on the collector surface is a transformation of the daily average horizontal radiation and the heating load is a transformation of the average dry bulb temperature).

Using the TRNSYS computed monthly tilted radiation and heating loads, and the system description of Appendix B, the heating system performance was estimated with F-Chart for both the long term and the TMY for all test sites. Shown in Table 6 are the solar heating fractions estimated by both TRNSYS and F-Chart for both the TMY and the long term for all test sites except Miami which always has 100% solar heating. There are frequent month to month differences but the yearly solar fractions predicted by TRNSYS and F-Chart agree very well. It is, however, the differences between the long term and the TMY predictions that are of particular interest.

TABLE 6 SOLAR HEATING FRACTION PREDICTIONS FOR THE LONG TERM AND THE TMY BY TRNSYS AND F-CHART

	ALBUQUERQUE				MADISON				FORT WORTH				NEW YORK				WASHINGTON			
	TMY		LONG TERM		TMY		LONG TERM		TMY		LONG TERM		TMY		LONG TERM		TMY		LONG TERM	
	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH	TRN	F-CH
JAN	.442	.465	.450	.471	.259	.310	.266	.318	.608	.626	.559	.608	.364	.383	.366	.388	.461	.483	.440	.457
FEB	.607	.618	.610	.625	.391	.454	.432	.484	.738	.880	.736	.853	.504	.520	.497	.519	.553	.578	.592	.607
MAR	.741	.812	.789	.885	.688	.706	.659	.695	-	-	.862	-	.742	.758	.748	.760	.908	.924	.839	.884
APR	-	-	.947	-	.932	-	.868	-	-	-	.991	-	.895	-	.952	-	-	-	.975	-
MAY	-	-	.987	-	.929	-	.960	-	-	-	-	-	-	-	.991	-	-	-	.996	-
JUN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JUL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SEP	-	-	.971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCT	.924	-	.935	-	.994	-	.907	-	-	-	-	-	-	-	.990	-	-	-	.995	-
NOV	.844	.766	.731	.727	.438	.472	.447	.456	.950	-	.885	-	.708	.655	.748	.670	.801	.807	.808	.778
DEC	.496	.510	.450	.465	.234	.251	.226	.261	.691	.688	.690	.704	.338	.338	.346	.354	.487	.464	.427	.429
YEAR	.644	.654	.624	.651	.486	.525	.488	.538	.764	.800	.724	.791	.571	.583	.590	.599	.657	.666	.646	.656

In Figure 8 are plotted the monthly (and annual) "differences" between the long term and the TMY solar heating fractions as predicted by both TRNSYS and F-Chart. First note that the errors predicted by both methods are largest in the spring and fall when the loads are moderate and most dispersed. The errors are zero during the summer, because the function saturates at 1.00. The errors are small in the peak heating months of December, January and February where loads are heavy and evenly distributed.

The main point of Figure 8, however, is that the TMY - long term F-Chart difference coincides significantly with the TMY - long term TRNSYS difference. These results confirm the significance of the differences in the TMY - long term gross monthly, statistics. In other words, the non-typicality of the TMY months is largely due to differences between the TMY and long term monthly statistics listed in Appendix A.

4.5 Investigation of the "Carry-Over Effect"

The weather in any month has some influence on the system's performance in subsequent months because of energy storage in the tank, and to a lesser degree, in the building's structure. In the process of concatenating typical months to form the TMYs, typical weather patterns have been interrupted. The "history" of the weather and of the stored energy are thus different for every month in the TMY from what it was in the real years from which the months came.

The magnitude of this carry-over effect clearly depends a great deal on the storage size, although the nature of the relationship is not simple. For very small storage sizes the effect of the previous month's weather is quickly erased. For very large storage sizes the sensitivity to weather patterns and monthly discontinuities is small. The maximum carry-over effect can probably be seen for storage sizes of the order of one to several days of storage, which is about the size of the tanks in the base systems.

Shown in Table 7 and 8 are selected performance measures for the TMY months when located in the TMY year <u>and</u> when located in the context of the original year from which they came, for Albuquerque (a clear, dry climate) and for Washington, (a cloudy, humid climate). The horizontal radiation differs very slightly because of round off errors (the SOLMET and TMY tapes were supplied in a different format. The SOLMET radiation data was in W/m^2 where as the TMY data was in $KJ/hr\text{-}m^2$). The heating and cooling loads differ mainly because of stored energy in the structure month to month. The solar fractions differ mainly because of the stored energy in the tanks.

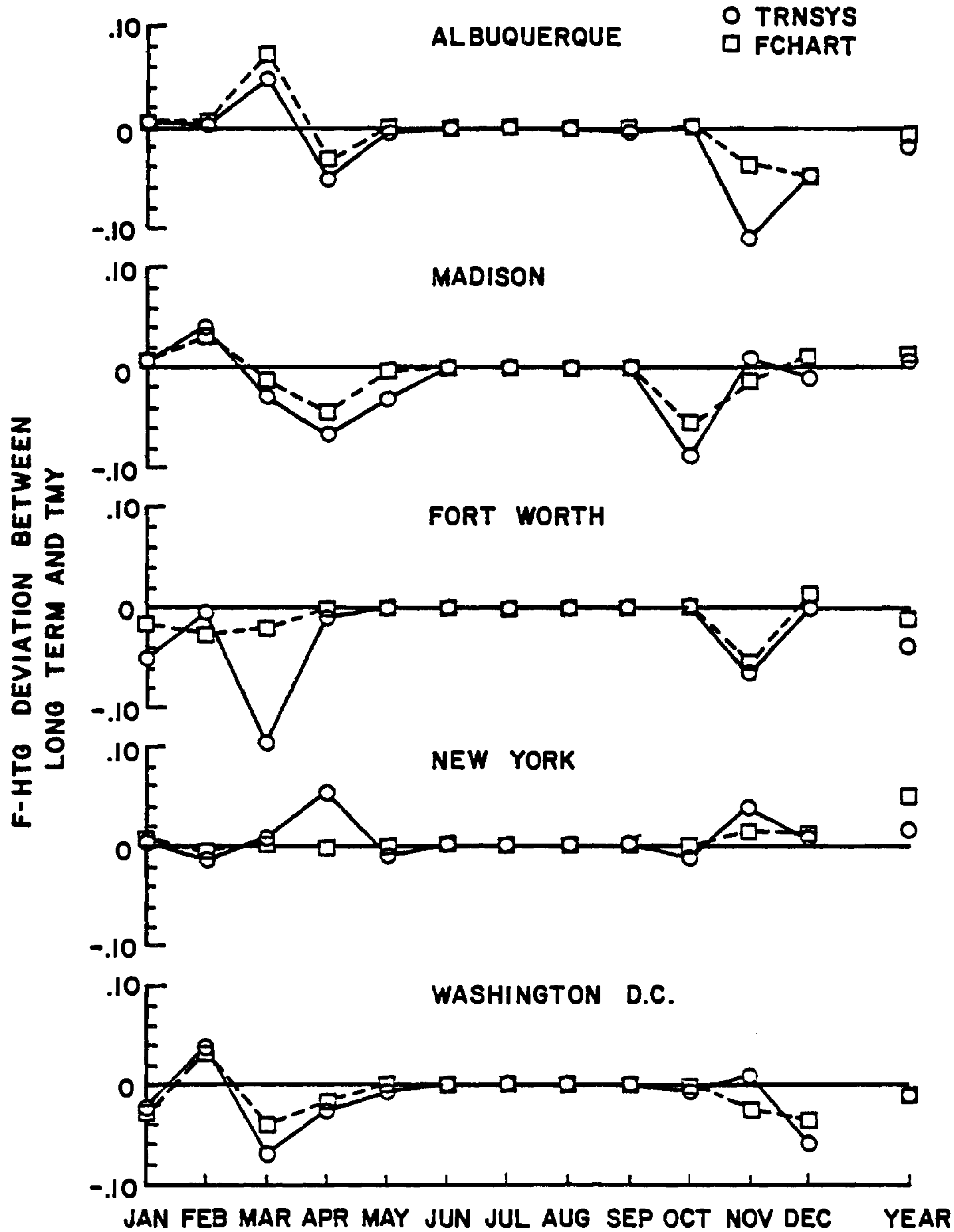

FIG. 8 SOLAR FRACTION DEVIATIONS PREDICTED BY TRNSYS AND FCHART

TABLE 7 PERFORMANCE OF TMY MONTHS IN CONTEXT OF TMY AND IN CONTEXT OF ORIGINAL DATA FOR ALBUQUERQUE

	TMY CONTEXT					ORIGINAL CONTEXT				
	HHOR	QLH	QAC	F-HTG	F-CLG	HHOR	QLH	QAC	F-HTG	F-CLG
JAN	0.3446	12.310	0	0.442	1.0	0.3441	12.400	0	0.439	1.0
FEB	0.4275	9.760	0	0.607	1.0	0.4270	9.723	0	0.610	1.0
MAR	0.6135	8.351	0	0.741	1.0	0.6129	8.303	0	0.757	1.0
APR	0.7797	3.562	0	1.0	1.0	0.7790	3.528	0	1.0	1.0
MAY	0.9089	0.988	1.95	1.0	0.597	0.9081	0.982	2.08	1.0	0.577
JUN	0.9035	0	5.15	1.0	0.532	0.9028	0	5.54	1.0	0.525
JUL	0.8747	0	6.85	1.0	0.628	0.8739	0	6.85	1.0	0.626
AUG	0.8120	0	5.05	1.0	0.717	0.8113	0	5.17	1.0	0.708
SEP	0.6660	0.034	0.93	1.0	0.909	0.6653	0.034	0.88	1.0	0.922
OCT	0.5617	2.065	0	0.924	1.0	0.5611	2.219	0	0.929	1.0
NOV	0.3987	7.669	0	0.844	1.0	0.3982	7.692	0	0.815	1.0
DEC	0.3343	11.550	0	0.496	1.0	0.3338	11.580	0	0.507	1.0
YR	7.625	56.29	19.92	0.644	0.642	7.618	56.46	20.52	0.644	0.636

TABLE 8 PERFORMANCE OF TMY MONTHS IN CONTEXT OF TMY AND IN CONTEXT OF ORIGINAL DATA FOR WASHINGTON

	TMY CONTEXT					ORIGINAL CONTEXT				
	HHOR	QLH	QAC	F-HTG	F-CLG	HHOR	QLH	QAC	F-HTG	F-CLG
JAN	0.2141	15.530	0	0.461	1.0	0.2136	15.620	0	0.475	1.0
FEB	0.2585	13.340	0	0.553	1.0	0.2579	13.280	0	0.564	1.0
MAR	0.4154	9.921	0	0.908	1.0	0.4147	9.967	0	0.877	1.0
APR	0.5048	4.395	0.10	1.0	1.0	0.5042	4.321	0.11	1.0	1.0
MAY	0.6021	1.163	0.68	1.0	0.954	0.6014	1.058	0.71	1.0	0.942
JUN	0.6442	0	2.42	1.0	0.889	0.6434	0.029	2.40	1.0	0.885
JUL	0.6041	0	6.73	1.0	0.729	0.6033	0	6.73	1.0	0.737
AUG	0.5984	0	5.83	1.0	0.801	0.5977	0	5.80	1.0	0.796
SEP	0.4470	0.113	2.41	1.0	0.778	0.4464	0.114	2.50	1.0	0.755
OCT	0.3458	2.967	0	1.0	1.0	0.3452	2.939	0	1.0	1.0
NOV	0.2303	7.850	0	0.801	1.0	0.2298	7.794	0	0.798	1.0
DEC	0.1722	12.620	0	0.487	1.0	0.1717	12.640	0	0.481	1.0
YEAR	5.037	67.90	18.18	0.657	0.790	5.029	67.76	18.25	0.655	0.787

In no month does the difference in either the solar heating fraction or the solar cooling fraction exceed 0.03. It is considerably less than that in every month with a significant load. The yearly solar fractions computed from the results of the TMY months in context of the original years are almost identical to those predicted by the TMY. It is concluded that the carry-over effect of one month's weather on the performance in the next is not great enough to invalidate the method of concatenation of months taken from different years.

4.6 Effects of the System Time Constant

To address the concern that the TMY-long term agreement might be dependent on the time constant of the system, a series of simulations was performed with smaller storage tanks. The storage tanks of the base system in Albuquerque, Madison, and Washington were reduced by factors of two and four. The systems were resimulated with both the TMY and the entire SOLMET period of record, and the results are tabulated in Appendix E.

In general, neither the variability of the monthly or yearly performance measures, nor the differences between the long term and TMY results, increased appreciably as the storage size decreased. An informative way of seeing the over-all effects of storage size on the long term-TMY agreement is shown in Figures 9-12. These figures are scatter plots of long term versus TMY monthly and yearly solar fractions for three different storage sizes in Madison and two storage sizes in Washington. The shifts in both solar heating and cooling fractions progress uniformly toward lower solar fractions for both the TMY and the long term with each reduction in storage size. There is no tendency for the results to diverge from the 45° line as storage decreases except for the special cases when the solar fraction is saturated at 1.00, as seen in Figure 10 and 12. In such cases, differences between the TMY and the long term discussed in 4.3.2 can be accentuated as storage size is decreased. The decrease in the solar system's time constant makes the system more sensitive to weather persistence and thereby magnifies the inherent differences between the TMY and the long term. This effect is apparent only for months at or near solar fraction saturation and does not significantly affect the yearly performance of the systems investigated here. However, greatly "over-sized" solar heating and cooling systems could be expected to show less sensitivity to storage size in the TMY than in the long term.

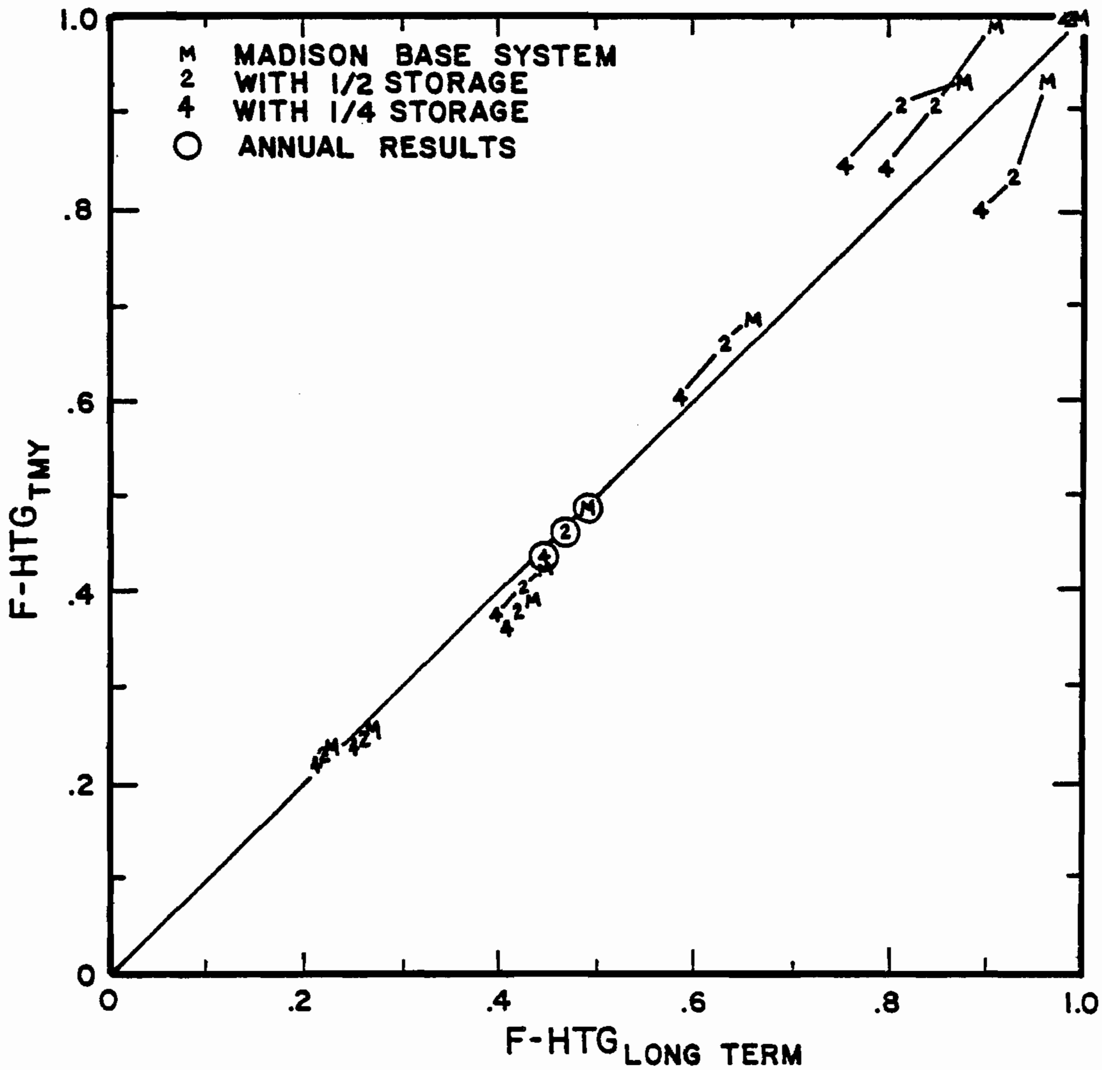

FIG. 9 SOLAR HEATING FRACTION DEVIATION FOR THREE STORAGE SIZES IN MADISON

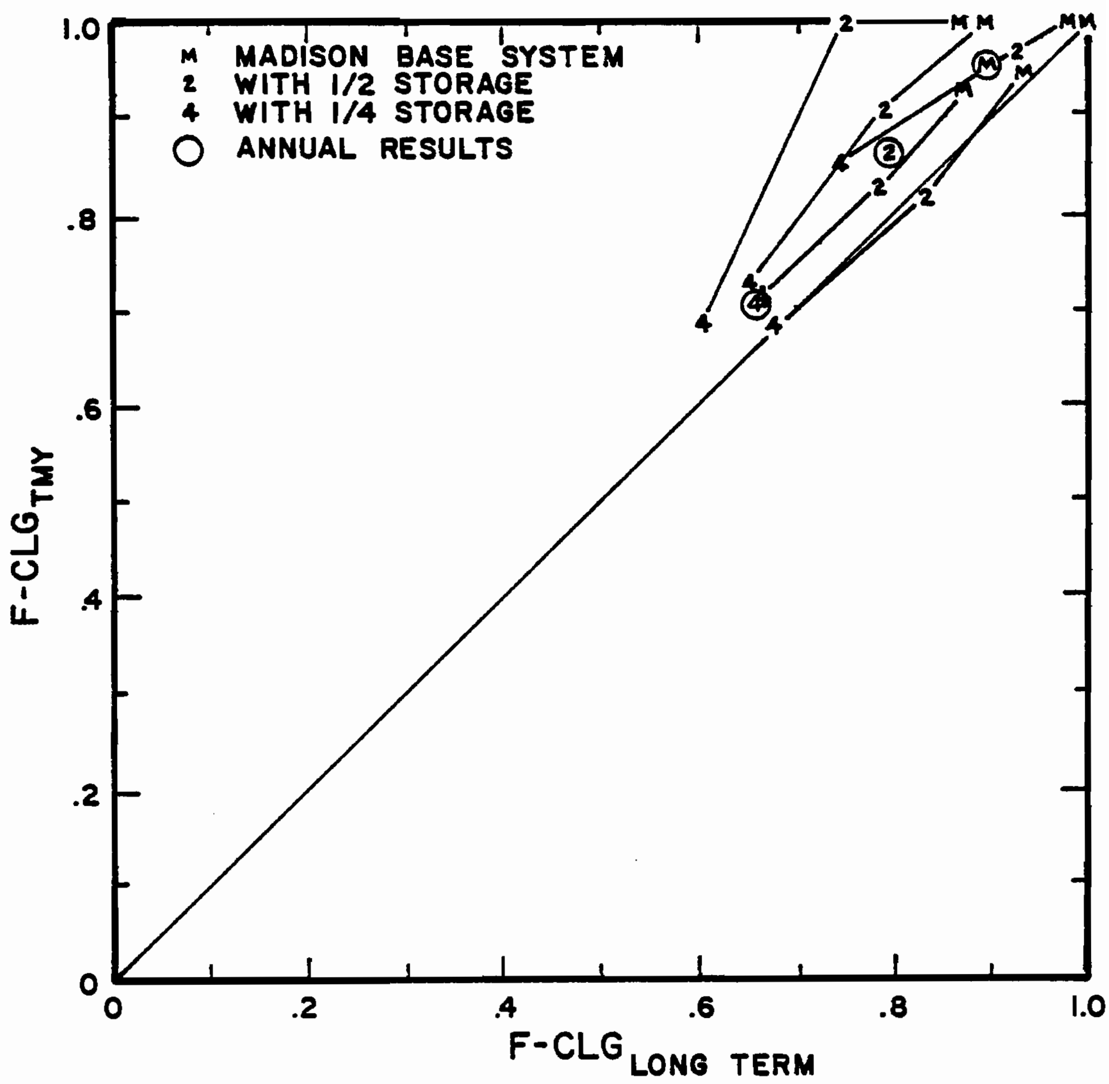

FIG. 10 SOLAR COOLING FRACTION DEVIATION FOR THREE STORAGE SIZES IN MADISON

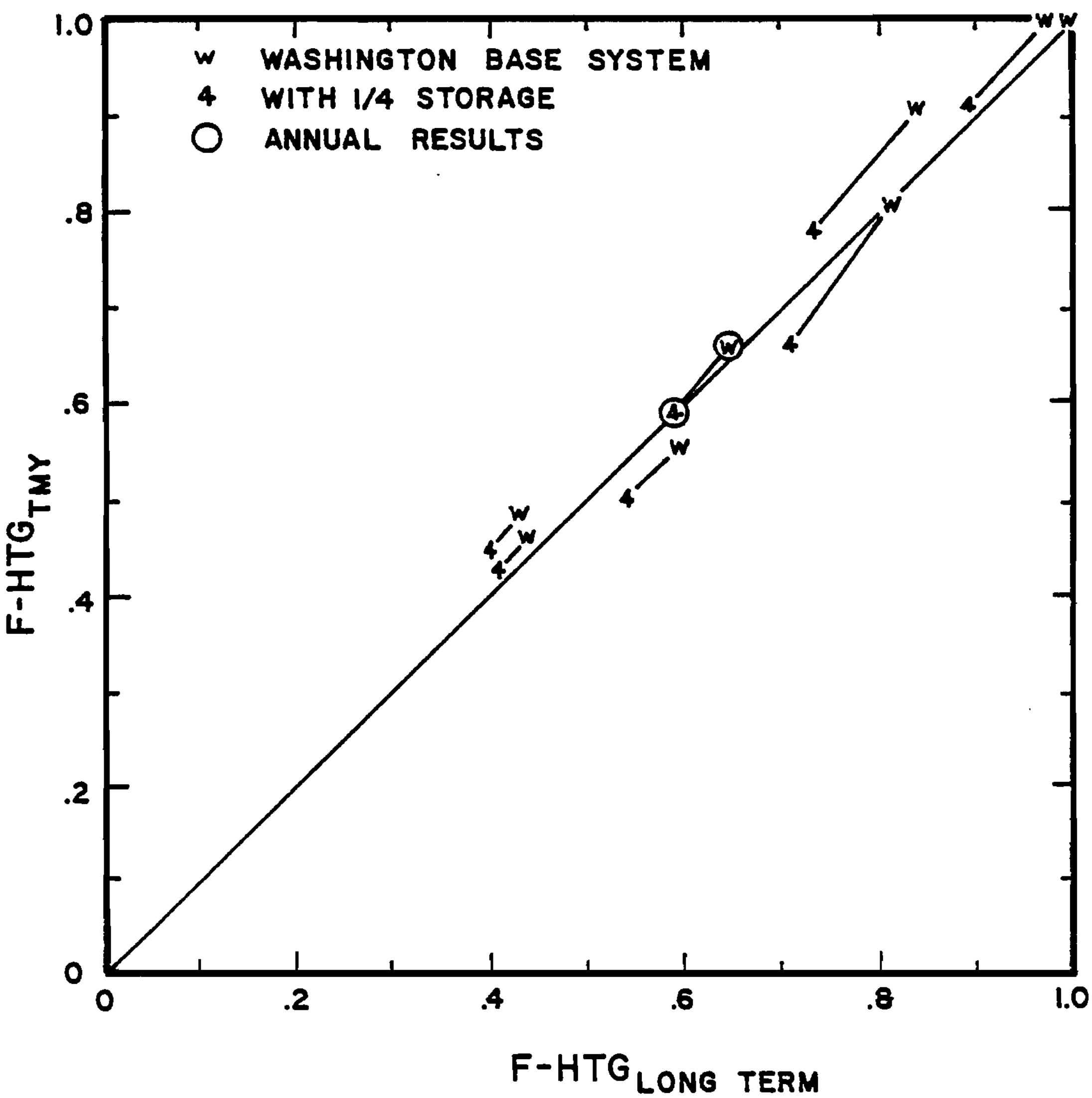

FIG. 11 SOLAR HEATING FRACTION DEVIATION FOR TWO STORAGE SIZES IN WASHINGTON

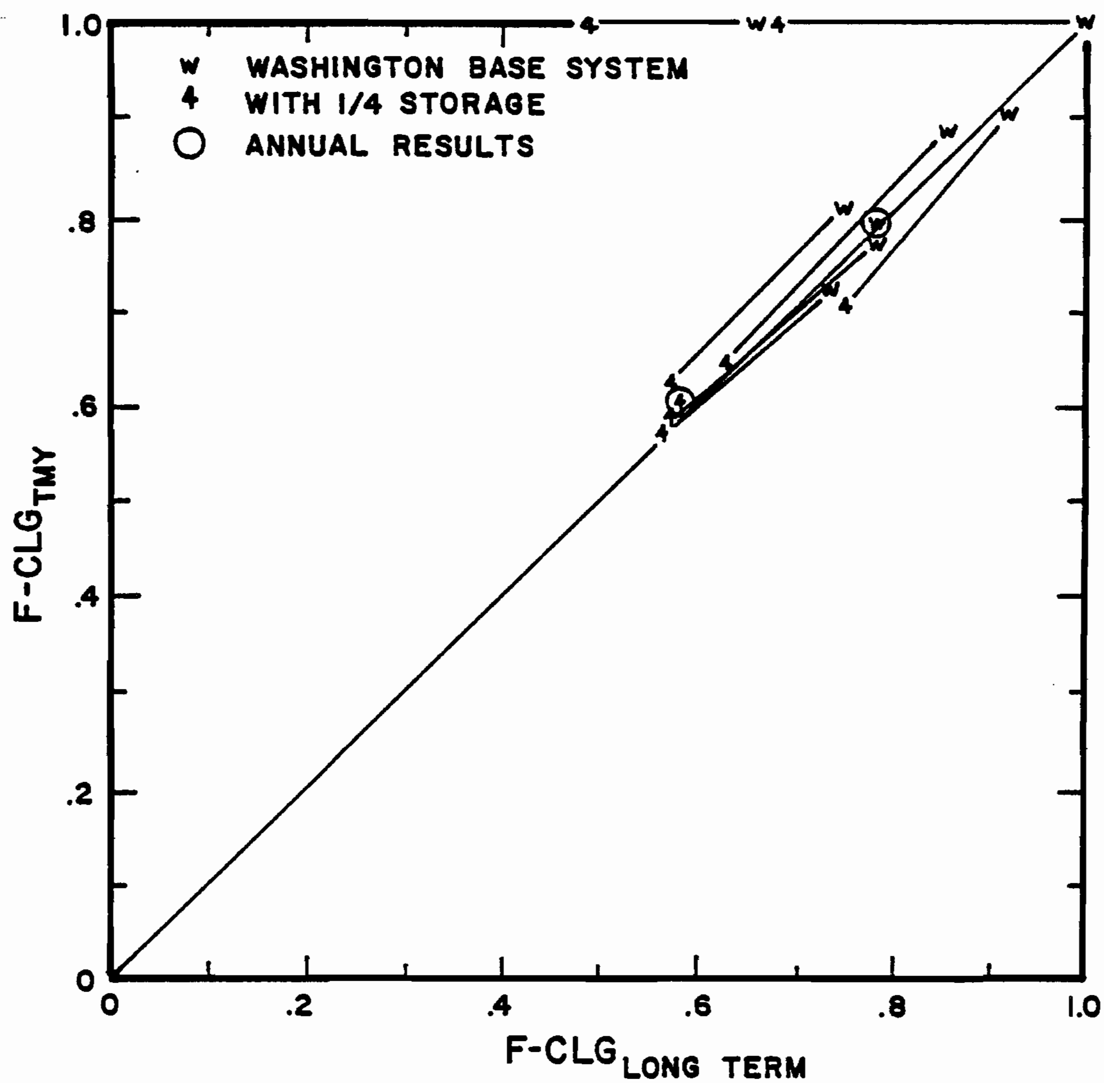

FIG. 12 SOLAR COOLING FRACTION DEVIATION
FOR TWO STORAGE SIZES IN WASHINGTON

5.0 SUMMARY AND CONCLUSION

One of the valuable by-products of this study has been the extensive spot checking of the integrity of the TMY and SOLMET data. It has been found that the long term average data published in micro-fiche in (3), and transcribed into Appendix A, agrees with the values calculated in the TRNSYS simulations. The "surface observations" in this data also agree closely, with the long term data published annually by NOAA in the Local Climatological Data publications (7). Furthermore, the near equivalence of each of the months in each TMY with the respective "source" month in the SOLMET format has been confirmed. The only differences are the slight changes made to the surface observations to smooth the discontinuities a few hours on either side of each monthly interface.

The high variability of the weather and solar system performance year to year has been noted. In Albuquerque, which has one of the least variable climates, annual solar heating fractions ranged from 0.54 to 0.72. In January they range from 0.35 to 0.72. With such a large range and with a sample size of only twenty four or less years, it is not very clear what the "long term performance" really is. It is quite possible that the weather of the next twenty years will be quite different from the data base used here. Certainly there is little reason to expect the coming year to be very much like the long term average or the TMY in the way it drives a solar system.

This work has provided ample opportunity for various checks on both TRNSYS and F-Chart. The ability of TRNSYS to perform multi-year simulations without problems, particularly with regard to the synchronization of the solar data with time and declination, has been established. Proof of this is that the same values of HTILT are obtained for the TMY months when located in the context of the original year and in the context of the TMY. Very good agreement has been obtained between TRNSYS and F-Chart for all test sites, although there is a slight tendency for F-Chart to over-predict the TRNSYS results. This may be partly due to the fact that F-Chart was established for combined space and domestic hot water systems and the base system here is strictly space heating. Most likely however, the error is due to an underestimation of the monthly average collector loss coefficient caused by assuming a constant 5 mph wind instead of using the monthly average windspeed values available in Appendix A.

Several observations have been made concerning typicality of the months in the TMYs. The TMY months are consistently among the five most representative from the twenty three or so available, in terms of total global insolation and temperature. This is enough to ensure that the solar system performance measures are fairly typical in months of high load. However, in months of low load, especially low cooling load, the performance of the solar system in the TMY month is likely to be considerably different from the long term. The reason is that performance in months of low load is more sensitive to joint distributions and persistence of meteorological data not adequately considered in the TMY selection process. In fact the method has a built-in bias to select low load months which will over-predict the long term solar contribution both in the heating and the cooling season. Fortunately these errors are usually not critical because they contribute little to the yearly or seasonal performance measures. However, for systems that are over-sized for a given climate and load, the TMY over-predictions can be become significant for the season.

Cooling system performance, and for that matter most high temperature solar applications, are more sensitive to weather data structure and hence more likely to be over-predicted by the TMY. Smaller storage sizes increase a solar system's sensitivity to extreme months but no serious seasonal performance differences between the TMY and the long term arise as a result.

The long term monthly diffuse radiation was found to be poorly represented by the TMY months due to lack of consideration in the selection process. The high weighting given to the total horizontal radiation did assure typicality of the TMY horizontal radiation but not always the diffuse component. In other words, a match of the long term-TMY total daily global radiation cumulative distribution functions did not guarantee a close match of the beam-diffuse components of the cumulative distribution functions. This is true because the model that generated the SOLMET beam-diffuse split can predict widely varying results for days of a given month having identical horizontal radiation totals, depending on how the hourly totals are distributed. It is left mostly to chance how well these differences cancel out over the course of a month. Not surprisingly they are observed to be largest in cloudy climates.

A simple analysis shows that this problem can be much more significant for collectors which utilize only beam radiation. Neglecting the contribution of ground reflected radiation, the energy incident on a collector within its acceptance angle over any time interval can be expressed as:

$$H_{in} = \bar{R}_B H_{BEAM} + \bar{R}_D H_{DIFF}$$

$$= H_{TOT} \bar{R}_B - H_{DIFF} (\bar{R}_B - \bar{R}_D)$$

where $\bar{R}_B$ (and $\bar{R}_D$) are the average ratios of beam (and diffuse) radiation on the collector aperature to beam (and diffuse) on the horizontal. ($\bar{R}_D$ is zero for a collector which can utilize only beam radiation.)

The sensitivity of the collector's radiative input energy, H_{in}, to the diffuse component, H_{DIFF}, for a given horizontal total, H_{TOT}, is:

$$\partial H_{in} / \partial H_{DIFF} = (\bar{R}_B - \bar{R}_D)$$

For simple flat plate collectors $\bar{R}_B$ is around 2 in a typical month and $\bar{R}_D$ is about 0.85 for a collector tilted at 45^o. Thus:

$$(\partial H_{in} / \partial H_{DIFF})_{flatplate} \approx -1.15$$

But for a tracking collector $\bar{R}_B$ can be around 5 easily and since $\bar{R}_D$ is zero,

$$(\partial H_{in} / \partial H_{DIFF})_{conc} \approx -5$$

For this particular case the collector input energy for the concentrator is 4 or 5 times more sensitive to the beam-diffuse split than for the flat plate collector. Results would vary month to month, but all the differences between the long term and TMY collector input energy for flat plate collectors seen in Appendix C would be several times larger for a concentrator. This would of course cause a large long term-TMY difference in collected energy and hence in performance throughout the system.

The long term-TMY differences in concentrating or tracking solar system performance arising from the atypicality of the TMY diffuse radiation would be largest for certain months having poor long term-TMY diffuse radiation matches, like February in Madison and May in New York. Over the course of the year, however, these differences tend to cancel. Even in Madison and New York, the annual collector radiative input is well within the standard deviation of the 23 year results.

The solar fraction taken by itself was found to be a misleading indication of weather typicality, especially when applied on a monthly basis. Over the course of a year however, many monthly errors tend to cancel. Thus a particular year chosen solely on the basis of its solar fractions for a particular solar system is quite likely to give typical yearly results for other systems. Such is the case for the Hedstrom years. Understandably, the month to month agreement of the Hedstrom year's performance with the long term is very poor.

The differences between the long term and the TMY heating performance predictions were found to be strongly correlated to differences in the gross monthly climate statistics in the high load months. One possible expedient to remedy this situation would have been to reprocess the TMY months after their final selection to adjust the hourly values of total and direct normal radiation, dry bulb and dew point temperature, and wind speed, to make the TMY monthly totals and averages identical to those in the long term. Although this would have altered the statistical structure of the original data somewhat it would have significantly reduced the differences in performance predictions between the TMY and the long term.

Several conclusions can be drawn from these observations concerning the validity of the TMY selection methodology. The process probably yielded as near "typical" a year as possible using twelve concatenated real months. The basic shortcoming of the method is that there is too small a population of months from which to pick a typical one. Typicality in important statistics is frequently sacrificed for typicality in others, and often, no month in the period of record adequately represents the long term in more than one or two statistics.

Fortunately, simulators are not often concerned that results for a particular month are representative of the long term as long as the yearly or seasonal results are representative. Due to the near random nature of the month to month atypicalities, the yearly and seasonal results are acceptably close to the long term for most solar heating and cooling system analysis work.

To significantly improve on the TMY's, it would be necessary to adopt a method which is not restricted to concatenating actual months. An improved TMY generation method would probably either manufacture artificial data or modify real data to ensure a closer match of important meteorological statistics.

6.0 RECOMMENDATIONS

The main value of the TMYs, as far as most researchers are concerned, is that they offer standardized hourly meteorological forcing functions for a wide variety of climates, enabling direct comparison of the results from different simulation studies. Since the selection of a simulation test location for a given study is often arbitrary within certain broad climatological constraints, it doesn't matter if the TMY is perfectly representative of a specific site. It is certain that the Albuquerque TMY is representative of an "arid continental" climate, that the Miami TMY is representative of a "subtropical marine" climate, etc. That is sufficient assurance for most needs. The existing TMYs are adequate for developing design and sizing procedures which operate on climate statistics. (The correlations for F-Chart were verified from simulations using the Hedstrom years as well as a number of other arbitrarily chosen years as input since the TMYs were not yet available). Given the difficulty in defining what the long term is, there is questionable need for more "accurate" typical meteorological years.

The value of the TMYs for specific solar system design and optimization in a particular city is very limited even if the selection methodology had no flaws. Hourly simulations are generally impractical for "fine tuning" a design because of time and cost constraints. Also, to be generally useful and practical, accurate TMYs would have to be available for hundreds if not thousands of sites. Various factors often contribute to significant micro-climate differences between the data measuring site and a proposed solar installation very nearby. Given the inherent shortcomings of the selection methodology and the above considerations the value of using the existing methodology to develop TMYs for 214 more stations where hourly solar radiation data have been modeled from cloud cover, sky condition and sun-shine data (1) is open to question.

If the existing methodology is used to generate more TMYs, it is recommended that consideration be given to these modifications. 1.) Bias the hourly values of the principal meteorological variables such that their monthly totals or averages are equal to those of the long term. This might be done by applying multiplicative correction factors to the solar radiation measurements and wind speed, and additive correction factors to the temperatures. 2.) Incorporate a means of representing the spring and fall months with atypical data structure that have so large an effect on long term performance in months of low load.

The question of the atypicality of the beam-diffuse radiation split should be resolved, particularly as it affects tracking or concentrating collectors. Though they are random and tend to cancel on an annual basis, there are substantial differences between the long term and the TMY in some months in some locations, particularly in cloudy climates. Care should be exercised in interpreting the results for tracking or concentrating systems over too short a time (i.e., monthly or even seasonally).

The lack of a sufficiently long data base would make it impractical to revise the TMY selection methodology to incorporate months having typical diffuse radiation. The model which was employed to estimate the beam-diffuse components for the SOLMET data should probably be checked by an independent party to ensure its accuracy. Finally, it might be worthwhile to develop and publish tables of long term and TMY monthly statistics for all the climate parameters in each TMY city for distribution with the TMY data. These tables should include global <u>and</u> diffuse (or direct normal radiation) degree days, temperature, etc. They would provide the analyst with some indication of how typical a particular period and location is. This would be particularly helpful for identifying and compensating for atypicalities in the diffuse radiation as well as for other weather statistics.

Post Script

After this study was completed ASHRAE technical committee TC4.2 which is responsible for developing and recommending weather data for usage by the HVAC industry in designing and sizing equipment, reviewed the TMY methodology and the results of the present study. The committee is concerned that the TMYs may not be appropriate for use in building heating and cooling load calculation and HVAC equipment sizing because an inordinate amount of weight in the selection process was given to solar radiation and too little weight given to dry bulb and wet bulb temperatures. The committee is presently sponsoring work to develop typical design years of their own for this purpose. The methodology is very similar to that used in the TMY development except for the weighting factors and the process of substituting days in the months finally selected in an effort to make the monthly averages and totals match the long term statistics. ASHRAE TC4.2 is reserving a final position statement on the TMYs until their typical years can be compared to the long term in a planned comparison exercise involving hourly loads programs. It is the opinion of the author that little difference will be found on an annual basis between the loads and HVAC performance found with the typical years developed by ASHRAE and by SANDIA.

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APPENDIX A

LONG-TERM AND TMY METEOROLOGICAL STATISTICS

TABLE A-1 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: ALBUQUERQUE

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m²-day)	MEAN	LONG TERM	11.54	15.23	20.06	25.29	28.81	30.40	28.18	25.93	22.36	17.47	12.89	11.54
		TMY	11.12	15.27	19.79	25.99	29.32	30.12	28.22	26.20	22.20	18.12	13.29	10.79
	AVRG ST DEV	LONG TERM	2.89	3.86	4.61	4.96	4.56	3.98	4.08	3.85	3.87	3.72	3.03	2.56
		TMY	3.17	4.01	4.86	3.50	4.18	3.94	4.31	3.33	4.02	3.90	2.24	2.35
	F-S		0.045	0.031	0.032	0.046	0.028	0.054	0.029	0.037	0.036	0.045	0.046	0.025
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	1.2	3.9	7.9	12.9	18.3	23.8	25.2	23.9	20.3	14.0	6.6	1.6
		TMY	1.4	3.4	6.8	12.6	18.6	22.9	25.5	24.0	19.5	14.1	6.5	2.1
	AVRG ST DEV	LONG TERM	4.0	3.7	4.1	3.7	3.5	2.8	2.2	1.9	2.7	3.6	3.4	3.4
		TMY	2.7	4.3	5.4	3.0	4.1	2.8	2.5	1.8	2.2	3.4	3.4	4.3
	F-S		0.100	0.039	0.057	0.076	0.048	0.092	0.032	0.055	0.111	0.039	0.029	0.039
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	-8.1	-7.7	-7.6	-6.9	-2.8	1.6	9.8	10.0	5.4	0.0	-5.0	-7.5
		TMY	-7.2	-8.6	-8.0	-6.9	-2.6	1.5	10.9	10.0	6.9	-1.0	-5.9	-8.6
	AVRG ST DEV	LONG TERM	4.4	3.7	3.9	4.4	5.2	5.2	3.1	2.9	4.3	4.6	3.9	3.6
		TMY	2.9	3.7	5.3	4.8	7.5	4.2	3.8	3.3	3.8	3.4	5.7	4.4
	F-S		0.060	0.050	0.036	0.024	0.070	0.070	0.122	0.073	0.104	0.096	0.093	0.081
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	3.4	3.9	4.4	4.8	4.6	4.4	4.0	3.6	3.8	3.7	3.4	3.4
		TMY	3.2	4.3	4.0	5.0	4.4	5.3	3.2	3.9	4.0	3.0	3.0	3.5
	AVRG ST DEV	LONG TERM	1.4	1.6	1.7	1.7	1.4	1.2	1.0	0.9	1.3	1.5	1.5	1.5
		TMY	1.3	1.9	1.6	1.8	1.6	1.7	0.9	0.8	1.2	1.2	1.2	1.9
	F-S		0.047	0.067	0.050	0.034	0.042	0.159	0.253	0.132	0.097	0.156	0.095	0.035

TABLE A-2 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: FORT WORTH

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m^2-day)	MEAN	LONG TERM	9.14	11.96	16.07	18.30	21.51	24.51	24.46	22.43	18.28	14.44	10.63	8.66
		TMY	8.84	12.00	16.62	17.34	21.20	24.72	25.15	23.20	19.19	14.44	10.84	8.64
	AVRG ST DEV	LONG TERM	4.21	5.49	6.59	7.54	6.90	5.29	4.95	4.33	5.19	5.07	4.37	3.80
		TMY	4.41	5.84	6.42	8.24	6.80	5.97	4.08	3.72	4.67	5.15	4.90	4.01
	F-S		0.030	0.025	0.033	0.051	0.056	0.050	0.041	0.042	0.035	0.039	0.046	0.032
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	6.6	9.0	13.1	18.7	22.7	27.1	29.4	28.9	25.2	19.5	12.9	8.5
		TMY	7.0	9.7	12.1	17.7	21.6	26.9	30.1	28.7	23.6	19.5	13.7	8.0
	AVRG ST DEV	LONG TERM	5.8	4.9	4.9	3.9	3.2	2.5	2.0	2.2	3.2	4.0	4.7	4.8
		TMY	5.9	5.6	5.7	3.0	3.9	2.3	1.5	2.1	3.9	3.8	4.9	4.9
	F-S		0.030	0.043	0.042	0.106	0.090	0.050	0.102	0.041	0.123	0.034	0.047	0.023
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	0.5	1.9	4.9	11.3	16.1	19.2	19.9	19.3	17.4	12.2	5.8	2.1
		TMY	1.5	4.7	3.0	10.9	16.1	20.1	18.1	19.0	16.1	12.7	7.3	2.7
	AVRG ST DEV	LONG TERM	6.9	5.8	6.2	5.8	3.6	2.1	1.6	2.1	3.6	5.4	6.2	6.0
		TMY	6.7	5.3	5.9	6.0	3.9	1.9	1.5	2.6	3.0	5.6	5.0	7.4
	F-S		0.050	0.125	0.085	0.034	0.081	0.105	0.262	0.042	0.147	0.030	0.078	0.063
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	5.3	5.5	6.1	6.0	5.3	5.1	4.5	4.2	4.4	4.5	4.9	5.1
		TMY	4.5	5.6	6.6	5.4	4.5	5.3	3.8	4.5	4.8	4.1	4.7	5.0
	AVRG ST DEV	LONG TERM	1.7	1.8	1.9	1.7	1.6	1.6	1.1	1.0	1.3	1.5	1.7	1.7
		TMY	1.6	1.6	2.0	1.6	1.7	1.9	1.0	0.9	1.3	1.3	1.5	1.5
	F-S		0.118	0.061	0.087	0.091	0.117	0.044	0.158	0.083	0.95	0.076	0.038	0.052

TABLE A-3 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: MADISON

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m^2-day)	MEAN	LONG TERM	5.85	9.13	12.89	15.88	19.79	22.11	21.91	19.47	14.71	10.26	5.69	4.44
		TMY	5.91	9.37	13.77	15.70	19.33	21.28	21.75	19.87	15.16	9.82	5.81	4.28
	AVRG ST DEV	LONG TERM	2.59	3.77	5.77	7.55	7.55	6.80	6.09	5.57	5.61	4.44	3.10	2.29
		TMY	3.04	3.77	6.22	6.99	8.02	6.81	6.70	5.44	4.93	4.79	3.72	2.29
	F-S		0.046	0.033	0.051	0.041	0.029	0.048	0.033	0.030	0.058	0.030	0.050	0.034
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	-8.1	-5.7	-0.3	7.7	14.1	19.7	21.8	20.8	15.8	10.5	2.3	-4.7
		TMY	-8.5	-6.2	-1.9	8.7	14.6	19.6	22.1	20.8	16.8	10.5	2.3	-3.7
	AVRG ST DEV	LONG TERM	6.6	5.5	4.7	4.9	4.6	3.7	2.9	3.1	4.4	4.8	5.0	5.5
		TMY	7.9	4.0	5.2	5.2	5.1	3.8	2.8	3.2	3.8	4.7	5.2	3.0
	F-S		0.022	0.087	0.074	0.067	0.029	0.030	0.029	0.064	0.086	0.029	0.022	0.068
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	-12.1	-10.1	-5.3	1.0	7.8	13.2	15.7	15.2	10.6	5.0	-1.7	-8.1
		TMY	-11.9	-9.9	-6.7	0.9	7.6	13.3	16.0	14.3	10.4	3.8	-1.1	-6.7
	AVRG ST DEV	LONG TERM	7.7	6.7	5.4	5.2	5.8	4.0	3.1	3.3	4.8	5.3	5.8	6.3
		TMY	9.4	4.6	5.8	5.4	4.2	4.1	2.5	3.3	4.6	5.4	6.1	3.4
	F-S		0.038	0.076	0.072	0.036	0.080	0.041	0.045	0.072	0.032	0.054	0.047	0.088
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	4.5	4.6	4.8	5.0	4.6	4.0	3.5	3.4	3.8	4.2	4.6	4.4
		TMY	4.5	4.9	5.5	5.5	4.7	4.8	3.8	3.1	4.2	3.8	4.7	3.8
	AVRG ST DEV	LONG TERM	1.6	1.8	1.8	1.8	1.5	1.3	1.2	1.2	1.3	1.5	1.8	1.6
		TMY	1.6	2.1	2.2	2.1	2.0	1.6	1.1	1.3	1.8	1.4	2.3	1.7
	F-S		0.027	0.041	0.086	0.052	0.042	0.145	0.064	0.101	0.066	0.072	0.041	0.138

TABLE A-4 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: MIAMI

Parameter	Statistic		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m^2-day)	MEAN	LONG TERM	12.01	14.91	18.20	21.90	20.92	19.38	20.03	18.54	16.51	14.93	12.70	11.54
		TMY	11.86	15.22	18.08	21.57	20.37	19.08	19.85	19.21	16.98	14.59	13.44	11.70
	AVRG ST DEV	LONG TERM	3.20	3.69	4.19	4.16	4.71	5.27	4.05	3.46	3.83	3.65	2.93	2.57
		TMY	3.57	3.26	5.20	3.64	5.81	5.54	3.71	2.87	3.45	5.15	2.31	2.32
	F-S		0.028	0.034	0.036	0.038	0.033	0.031	0.078	0.046	0.040	0.045	0.066	0.044
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	19.8	20.1	21.9	24.0	25.6	26.7	27.6	27.9	27.2	25.2	22.4	20.1
		TMY	20.8	20.7	22.5	23.7	25.4	26.9	27.2	27.9	27.4	25.1	22.9	19.4
	AVRG ST DEV	LONG TERM	3.4	3.1	2.8	1.8	1.2	1.2	1.0	1.1	1.0	1.7	2.5	3.4
		TMY	3.9	3.8	1.6	2.0	1.2	0.9	1.0	0.9	0.9	1.8	1.9	4.6
	F-S		0.051	0.055	0.077	0.041	0.076	0.060	0.132	0.069	0.068	0.049	0.044	0.058
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	14.6	14.4	15.7	17.6	20.0	22.2	22.8	23.1	23.0	20.4	17.1	14.6
		TMY	15.1	13.1	16.8	17.1	19.9	22.2	23.0	23.2	23.5	20.4	17.2	12.8
	AVRG ST DEV	LONG TERM	4.7	4.5	4.4	3.2	2.1	1.1	0.5	0.6	0.7	2.5	3.6	4.6
		TMY	5.1	5.8	2.9	3.5	2.4	1.2	0.5	0.5	0.9	2.6	2.7	6.4
	F-S		0.058	0.066	0.057	0.046	0.035	0.048	0.082	0.095	0.192	0.032	0.060	0.080
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	4.2	4.5	4.6	4.8	4.3	3.7	3.5	3.5	3.7	4.2	4.3	4.2
		TMY	4.3	4.2	4.7	3.7	3.5	4.4	2.9	3.9	3.3	3.5	4.1	3.9
	AVRG ST DEV	LONG TERM	1.3	1.4	1.2	1.3	1.2	1.1	0.9	0.9	1.1	1.4	1.3	1.2
		TMY	1.3	1.6	1.5	1.0	1.1	1.3	0.6	1.0	0.8	0.9	1.4	1.1
	F-S		0.039	0.056	0.023	0.206	0.174	0.176	0.163	0.113	0.084	0.154	0.041	0.063

TABLE A-5 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: NEW YORK

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m²-day)	MEAN	LONG TERM	5.68	8.18	11.77	15.48	18.57	19.41	19.05	16.91	13.75	10.15	6.07	4.60
		TMY	5.30	8.26	11.76	15.34	18.82	19.53	18.45	17.05	13.51	10.29	5.95	4.30
	AVRG ST DEV	LONG TERM	3.60	4.38	6.34	7.45	7.68	7.38	6.43	5.95	5.70	4.41	3.17	2.60
		TMY	3.09	4.44	6.55	7.85	7.92	7.34	7.20	4.99	6.47	4.94	3.21	2.76
	F-S		0.039	0.031	0.034	0.024	0.029	0.035	0.028	0.044	0.026	0.035	0.034	0.037
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	-.8	0.6	4.2	9.6	15.1	20.4	23.7	23.2	19.6	14.1	8.4	2.4
		TMY	0.1	0.1	4.0	11.1	15.3	19.9	23.8	23.5	19.1	14.1	8.6	2.8
	AVRG ST DEV	LONG TERM	4.2	4.0	3.4	3.4	3.3	2.9	2.2	2.2	3.2	3.6	4.0	4.1
		TMY	4.1	4.0	3.5	3.7	3.3	2.3	1.4	2.1	2.6	2.9	4.5	3.9
	F-S		0.027	0.038	0.039	0.117	0.036	0.085	0.086	0.063	0.068	0.044	0.045	0.036
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	-6.1	-5.6	-2.7	2.6	8.5	14.5	17.3	17.1	13.7	7.9	2.2	-3.4
		TMY	-5.8	-6.4	-3.4	4.5	8.4	14.4	16.3	17.1	12.9	8.6	1.9	-3.3
	AVRG ST DEV	LONG TERM	6.1	6.0	5.4	4.9	4.5	3.6	3.3	3.5	4.9	5.6	6.0	5.8
		TMY	6.4	6.8	5.6	4.6	5.4	3.4	3.2	3.9	4.4	4.8	6.6	5.0
	F-S		0.026	0.048	0.040	0.097	0.025	0.036	0.094	0.023	0.063	0.057	0.055	0.040
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	5.9	6.1	6.2	5.9	5.2	4.9	4.8	4.6	4.8	5.0	5.5	5.7
		TMY	4.9	6.4	7.3	6.1	5.4	5.1	4.8	4.6	4.5	5.2	5.7	5.2
	AVRG ST DEV	LONG TERM	2.1	2.0	2.0	1.7	1.3	1.2	1.0	1.1	1.3	1.7	2.0	2.1
		TMY	2.8	2.6	2.6	1.3	1.4	1.2	1.2	1.2	1.1	1.6	2.1	1.9
	F-S		0.138	0.047	0.105	0.090	0.049	0.077	0.037	0.037	0.058	0.047	0.024	0.062

TABLE A-6 LONG TERM AND TMY METEOROLOGICAL STATISTICS FOR: WASHINGTON, DC

			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY TOTAL HORIZONTAL RADIATION (MJ/m²-day)	MEAN	LONG TERM	6.51	9.22	12.77	16.57	19.56	21.58	20.31	18.38	15.02	11.24	7.38	5.46
		TMY	6.99	9.23	13.40	16.83	19.42	21.47	19.49	19.30	14.90	11.16	7.68	5.55
	AVRG ST DEV	LONG TERM	3.14	4.56	6.09	7.17	7.38	6.73	5.86	5.46	5.46	4.62	3.47	2.78
		TMY	3.36	4.88	6.00	7.49	7.63	6.85	5.97	4.84	5.35	4.85	3.64	2.84
	F-S		0.050	0.026	0.042	0.020	0.028	0.024	0.048	0.040	0.029	0.034	0.046	0.025
DAILY AVERAGE DRY BULB TEMPERATURE (°C)	MEAN	LONG TERM	0.4	1.6	6.1	12.4	17.5	22.2	24.6	23.7	20.0	13.7	7.8	2.3
		TMY	-.8	0.6	6.3	12.8	17.5	21.1	24.4	23.5	20.7	13.8	8.2	2.7
	AVRG ST DEV	LONG TERM	4.8	4.5	4.4	4.6	3.7	3.1	2.1	2.3	3.6	4.1	4.7	4.3
		TMY	5.7	4.2	4.6	4.9	4.3	3.0	1.8	2.9	3.3	3.9	5.0	3.6
	F-S		0.059	0.067	0.033	0.024	0.030	0.107	0.060	0.021	0.063	0.062	0.038	0.063
DAILY AVERAGE DEW POINT TEMPERATURE (°C)	MEAN	LONG TERM	-5.6	-4.9	-1.6	4.1	10.5	15.9	18.2	18.9	14.6	8.0	1.7	-3.4
		TMY	-6.8	-5.3	0.1	4.2	9.1	16.1	19.0	17.2	16.1	9.4	2.5	-4.1
	AVRG ST DEV	LONG TERM	6.1	6.1	5.6	5.7	5.0	3.6	2.9	2.9	4.4	5.4	6.1	5.7
		TMY	6.4	5.5	5.5	5.3	6.2	3.6	2.4	3.5	3.8	4.8	5.9	5.3
	F-S		0.058	0.053	0.030	0.048	0.059	0.031	0.075	0.070	0.085	0.101	0.043	0.044
DAILY AVERAGE WIND SPEED (m/sec)	MEAN	LONG TERM	4.0	4.3	4.5	4.4	3.8	3.4	3.2	3.2	3.2	3.4	3.7	3.8
		TMY	3.7	4.1	4.8	4.1	4.9	2.8	3.0	2.6	2.7	2.9	3.8	3.4
	AVRG ST DEV	LONG TERM	1.7	1.7	1.6	1.4	1.0	1.0	0.8	0.8	1.1	1.3	1.6	1.6
		TMY	1.6	1.3	1.8	1.3	0.8	1.0	0.6	0.8	0.7	1.1	1.7	1.5
	F-S		0.056	0.058	0.045	0.055	0.267	0.172	0.074	0.159	0.158	0.116	0.022	0.57

APPENDIX B

BASE SYSTEM DESIGN PARAMETERS

Appendix B

Base System Design Parameters

Collector

Area	Madison	$50m^2$
	Albuquerque	$20m^2$
	Fort Worth	$30m^2$
	Miami	$30m^2$
	Washington, DC	$50m^2$
	New York	$50m^2$
Collector Fluid Specific Heat	3.35 Kj/Kg ^{o}C	
Collector Fluid Flowrate	50 Kg/hr m_c^2	
Collector Efficiency Factor (F')	0.90	
$\tau\alpha$ (normal incidence)	0.77	
U_L (0 wind & 80 ^{o}C plate)	8.64 Kj/m^2 hr ^{o}C	

Collector Heat Exchanger

Effectiveness	0.75
Tank Side Fluid Specific Heat	4.19 Kj/Kg ^{o}C
Tank Side Fluid Flowrate	40 Kg/hr m_c^2

Storage Tank (mixed, water)

Volume	75 liters /m^2
Tank Heat Loss Coefficient	1.5 Kj/hr m^2 ^{o}C
Tank Height/Diameter	2
Initial Tank Temperature (January 1)	30 ^{o}C

Space Heating Coil

Effectiveness	0.40
Water Flowrate	25 Kg/hr m_c^2
Air Flowrate	75 Kg/hr m_c^2

Space Heating Auxiliary

Steady State Heat Output	30000 Kj/hr(commanded by second stage of heating thermostat)

House (Transfer Function Model)

Shape	Rectangular on slab with pitched roof
Orientation	Long dimensions facing north and south
Wall Construction	Frame wall with three inch insulation (ASHRAE Transfer Function Wall #36)
Roof Construction	Pitched roof frame construction with unheated attic and six inch insulation
Wall Size	$50m^2$N, $50m^2$S, $25m^2$E, $25m^2$W
Percent Wall Area in Double Glazed Window	6%N, 12%S, 6%E, 6%W
Percent Window Area Shaded	0
Wall Exterior and	0.5
Interior Volume	486 m^3
Air Changes per Hour	1
Floor Area	200 m^2
Construction Weight	Medium
Internal Thermal Capacitance	50000 Kj/Kg ^oC
Internal Generation Rate	1200 Kj/hr
Number of occupants	2
Internal Moisture Generation Rate	1.0 Kg/hr

Absorption Chiller

Type	Standard TRNSYS version 10 model of three ton Arkla Li-Br unit including cooling tower heat rejection and room cooling coil
Steady State Performance	Steady State heat input and cooling output interpolated from Arkla test data with firing water temperature and ambient wet bulb as inputs.
Transient Performance	Start-up time constant=0.133 hr Cool-down time constant=1.05 hr
Auxiliary	When auxiliary is commanded (by second stage of cooling thermostat), all heat to generator is provided by auxiliary at 90 °C
Minimum Temperature to Fire Generator	77 °C
Cooling Coil Apparatus Dew Point	7.2 °C

Thermostatic Controls

Temperature at which 1st stage (i.e. solar) Heat is Commanded	20°
Temperature at which 2nd stage (i.e. auxiliary) Heat is Commanded	18°
Temperature at which 1st stage (i.e. solar) Cooling is Commanded	24°
Temperature at which 2nd stage (i.e. auxiliary) Cooling is Commanded	25°
Minimum Tank Temperature for 1st Stage Heating	30 °C

APPENDIX C

LONG-TERM AND TMY SIMULATION RESULTS FOR BASE SYSTEM

TABLE C-1A LONG TERM AND TMY SUMMARY BY YEARS FOR ALBUQUERQUE

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	1.862	7.875	8.923	3.344	16.43	53.02	34.16	13.91	48.22	22.08	70.54	.236	1.133	.375	.690	.542	.708
1954	1.848	7.918	8.974	3.146	12.40	44.91	30.07	11.23	43.76	17.74	73.30	.233	1.133	.351	.724	.595	.687
1955	1.972	7.719	8.731	3.046	18.92	54.42	23.03	9.04	33.93	12.84	70.47	.255	1.131	.349	.652	.622	.679
1956	1.939	7.936	8.988	3.335	16.82	52.13	34.01	14.35	48.29	20.86	69.22	.244	1.133	.371	.677	.568	.704
1957	1.993	7.355	8.131	2.963	18.04	52.33	21.69	7.29	32.26	11.28	66.62	.271	1.105	.364	.655	.650	.672
1958	1.906	7.420	8.309	3.128	19.08	53.75	26.18	7.91	38.75	14.81	67.47	.257	1.120	.376	.645	.618	.676
1959	1.863	7.604	8.554	3.146	18.42	54.54	22.93	7.45	34.24	11.48	67.73	.245	1.125	.368	.662	.665	.670
1960	1.911	7.610	8.537	3.015	22.53	55.43	25.29	7.62	37.22	14.09	69.69	.251	1.122	.353	.594	.621	.679
1961	1.845	7.663	8.600	2.911	23.50	58.73	16.02	3.83	25.23	6.50	68.32	.241	1.122	.338	.600	.742	.635
1962	1.857	7.717	8.639	2.925	20.77	54.86	20.48	7.52	30.24	10.18	70.07	.241	1.119	.339	.621	.663	.677
1963	1.855	7.586	8.643	3.027	20.92	54.46	25.19	9.04	37.16	14.46	70.44	.245	1.139	.350	.616	.611	.678
1964	2.001	7.701	8.625	3.016	29.95	65.43	21.60	7.16	32.11	11.41	68.16	.260	1.120	.350	.542	.645	.673
1965	1.935	7.420	8.342	2.761	19.20	54.30	13.86	4.40	21.61	6.01	70.18	.261	1.124	.331	.646	.722	.641
1966	1.877	7.570	8.525	2.935	25.53	60.56	18.04	5.39	28.00	8.74	70.13	.248	1.126	.344	.578	.688	.644
1967	1.934	7.551	8.490	2.659	21.23	53.18	14.95	4.01	23.58	7.11	72.88	.256	1.124	.313	.601	.699	.634
1968	1.883	7.554	8.486	2.800	23.05	57.78	17.56	7.42	25.90	9.05	69.82	.249	1.123	.330	.601	.651	.678
1969	1.946	7.464	8.381	3.095	21.31	58.08	24.06	8.54	35.62	14.41	66.33	.261	1.123	.369	.633	.595	.675
1970	1.958	7.319	8.268	3.171	19.50	58.95	22.02	7.65	32.67	12.62	66.11	.268	1.130	.384	.669	.614	.674
1971	1.865	7.495	8.491	2.974	23.86	61.87	18.11	6.58	26.75	9.69	69.75	.249	1.133	.350	.614	.638	.677
1972	1.906	7.338	8.364	2.663	19.01	51.63	17.93	7.41	26.40	10.33	71.43	.260	1.140	.318	.632	.609	.679
1973	1.918	7.330	8.288	2.951	27.78	63.87	19.32	5.09	29.00	10.24	67.79	.262	1.131	.356	.565	.647	.666
1974	1.970	7.395	8.325	2.888	21.23	54.13	28.89	13.29	40.00	19.52	71.24	.266	1.126	.347	.608	.512	.722
1975	1.931	7.458	8.452	2.901	25.90	62.50	18.15	6.98	26.62	9.51	68.91	.259	1.133	.343	.586	.643	.682
23 YR MEAN	1.912	7.565	8.525	2.991	21.10	56.12	22.33	7.96	32.94	12.39	69.42	.253	1.127	.351	.624	.624	.678
23 YR ST DEV	.048	.184	.225	.178	3.91	4.67	5.60	2.89	7.42	4.38	1.91	.010	.008	.018	.043	.053	.021
TMY YEAR	1.951	7.625	8.610	2.968	20.06	56.29	19.92	6.65	29.37	10.52	68.97	.256	1.129	.345	.644	.642	.678
TMY-23 YR DEV	.039	.060	.085	.023	1.04	.17	2.41	1.31	3.57	1.87	.45	.003	.002	.006	.020	.018	.000

UNITS:

PRIMARY MEASURES:

HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]

TBAR: [DEGREES C]

ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-1B LONG TERM AND TMY SUMMARY BY MONTHS FOR ALBUQUERQUE

MO	STATISTIC	PRIMARY MEASURES HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	DERIVED MEASURES FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	23 YR MEAN	.0925	.3571	.5703	.2923	6.913	12.567	0.00	0.00	0.00	0.00	36.05	.259	1.597	.513	.450	1.000	0.000
	23 YR ST DEV	.0087	.0226	.0478	.0274	1.877	1.782	0.00	0.00	0.00	0.00	1.81	.038	.035	.008	.086	0.000	0.000
	TMY YEAR	.0931	.3446	.5469	.2805	6.870	12.310	0.00	0.00	0.00	0.00	35.03	.270	1.587	.513	.442	1.000	0.000
FEB	23 YR MEAN	.1139	.4254	.5922	.2999	3.678	9.429	0.00	0.00	0.00	0.00	43.96	.268	1.392	.506	.610	1.000	0.000
	23 YR ST DEV	.0094	.0269	.0467	.0235	1.775	1.791	0.00	0.00	0.00	0.00	7.44	.035	.024	.018	.123	0.000	0.000
	TMY YEAR	.1203	.4275	.5951	.3034	3.840	9.760	0.00	0.00	0.00	0.00	43.07	.281	1.392	.510	.607	1.000	0.000
MAR	23 YR MEAN	.1767	.6212	.7355	.3171	1.544	7.330	.00	.00	.00	0.00	60.42	.284	1.184	.431	.789	1.000	.576
	23 YR ST DEV	.0111	.0412	.0565	.0445	1.023	1.697	.01	.01	.02	0.00	12.77	.034	.014	.072	.103	0.000	.120
	TMY YEAR	.1795	.6135	.7245	.3436	2.167	8.351	0.00	0.00	0.00	0.00	49.90	.293	1.181	.474	.741	1.000	0.000
APR	23 YR MEAN	.2001	.7580	.7798	.1992	.187	3.553	.03	.03	.05	.02	85.39	.264	1.029	.255	.947	.600	.737
	23 YR ST DEV	.0114	.0288	.0313	.0459	.307	1.188	.15	.12	.19	.09	7.71	.022	.005	.065	.059	.096	.219
	TMY YEAR	.1965	.7797	.8079	.2033	0.000	3.562	0.00	0.00	0.00	0.00	89.07	.252	1.036	.252	1.000	1.000	0.000
MAY	23 YR MEAN	.2226	.8922	.8267	.1390	.012	.946	1.84	1.25	2.47	1.13	92.31	.249	.927	.168	.987	.542	.746
	23 YR ST DEV	.0148	.0380	.0343	.0321	.059	.599	1.49	1.14	1.87	1.15	2.97	.025	.004	.036	.055	.161	.085
	TMY YEAR	.2306	.9089	.8436	.1589	0.000	.988	1.95	1.02	2.76	1.11	92.00	.254	.928	.188	1.000	.597	.706
JUN	23 YR MEAN	.2148	.9113	.8039	.2510	0.000	.023	6.74	3.42	9.19	4.49	85.20	.236	.882	.312	1.000	.511	.734
	23 YR ST DEV	.0159	.0446	.0361	.0533	0.000	.062	2.51	1.54	3.15	2.20	2.70	.026	.005	.060	0.000	.084	.037
	TMY YEAR	.2253	.9035	.7923	.2016	0.000	0.000	5.15	2.75	6.97	3.26	88.16	.249	.877	.254	1.000	.532	.739
JUL	24 YR MEAN	.2187	.8748	.7938	.3180	0.000	0.000	6.25	1.43	9.54	3.54	81.57	.250	.907	.401	1.000	.629	.655
	24 YR ST DEV	.0117	.0385	.0323	.0235	0.000	.000	.98	.44	1.31	.95	1.03	.020	.005	.022	0.000	.057	.019
	TMY YEAR	.2285	.8747	.7968	.3347	0.000	0.000	6.85	1.69	10.15	3.78	81.12	.261	.911	.420	1.000	.628	.675
AUG	24 YR MEAN	.1966	.8050	.7978	.2982	0.000	0.000	5.07	1.14	7.88	2.31	82.66	.244	.991	.374	1.000	.707	.643
	24 YR ST DEV	.0087	.0374	.0367	.0453	0.000	0.000	1.34	.36	1.87	.95	1.94	.019	.004	.046	0.000	.070	.025
	TMY YEAR	.2004	.8120	.8041	.2987	0.000	0.000	5.05	1.08	7.81	2.21	82.40	.247	.990	.371	1.000	.717	.646
SEP	24 YR MEAN	.1645	.6707	.7598	.1768	.006	.195	2.44	.72	3.82	1.00	88.41	.245	1.133	.233	.971	.737	.640
	24 YR ST DEV	.0116	.0428	.0530	.0592	.028	.305	1.73	.90	2.34	1.14	4.13	.031	.009	.070	.020	.127	.060
	TMY YEAR	.1778	.6660	.7518	.1119	0.000	.034	.93	.12	1.67	.15	92.67	.267	1.129	.149	1.000	.909	.552
OCT	24 YR MEAN	.1308	.5435	.7255	.1376	.147	2.257	.10	.01	.21	.01	88.67	.241	1.335	.190	.935	.971	.507
	24 YR ST DEV	.0099	.0449	.0713	.0371	.251	.999	.15	.02	.29	.02	7.84	.038	.024	.064	.083	.034	.243
	TMY YEAR	.1222	.5617	.7555	.1243	.157	2.065	0.00	0.00	0.00	0.00	90.36	.218	1.345	.165	.924	1.000	0.000
NOV	24 YR MEAN	.0964	.3855	.5979	.2841	2.074	7.722	0.00	0.00	0.00	0.00	52.41	.250	1.551	.475	.731	1.000	0.000
	24 YR ST DEV	.0063	.0238	.0456	.0277	1.167	1.209	0.00	0.00	0.00	0.00	10.09	.027	.025	.039	.112	0.000	0.000
	TMY YEAR	.0961	.3987	.6223	.3157	1.200	7.669	0.00	0.00	0.00	0.00	47.82	.241	1.561	.507	.844	1.000	0.000
DEC	24 YR MEAN	.0832	.3258	.5469	.2794	6.682	12.157	0.00	0.00	0.00	0.00	35.90	.255	1.679	.511	.450	1.000	0.000
	24 YR ST DEV	.0091	.0224	.0511	.0303	1.721	1.361	0.00	0.00	0.00	0.00	2.67	.044	.045	.010	.090	0.000	0.000
	TMY YEAR	.0804	.3343	.5691	.2914	5.824	11.550	0.00	0.00	0.00	0.00	36.02	.241	1.702	.512	.496	1.000	0.000

TABLE C-2A LONG TERM AND TMY SUMMARY BY YEARS FOR FORT WORTH

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.156	6.431	6.981	2.383	3.92	27.08	58.71	20.78	87.58	46.04	77.26	.335	1.085	.341	.855	.474	.670
1954	2.169	6.584	7.174	2.425	5.69	26.15	66.42	21.86	97.43	52.22	79.09	.329	1.090	.338	.782	.464	.682
1955	2.227	6.568	7.101	2.638	6.48	30.44	61.00	23.36	92.46	43.22	73.48	.339	1.081	.371	.787	.533	.660
1956	2.119	6.623	7.152	2.578	9.35	30.07	63.95	19.27	93.76	44.23	75.73	.320	1.080	.360	.689	.528	.682
1957	2.221	5.785	6.120	2.223	8.32	33.32	49.08	19.04	73.76	37.65	72.07	.384	1.058	.363	.750	.490	.665
1958	2.211	5.954	6.328	2.363	12.12	38.65	55.35	22.45	83.70	45.18	69.15	.371	1.063	.373	.686	.460	.661
1959	2.217	6.130	6.591	2.325	9.72	34.06	54.87	23.08	83.94	44.64	71.81	.362	1.075	.353	.715	.468	.654
1960	2.183	6.169	6.543	2.318	16.30	37.83	57.07	22.73	86.42	44.37	70.79	.354	1.061	.354	.569	.487	.660
1961	2.200	6.209	6.685	2.226	9.93	33.57	47.97	19.87	73.65	37.15	74.16	.354	1.077	.333	.704	.495	.651
1962	2.180	6.049	6.556	2.309	10.63	33.09	58.83	23.64	89.24	48.82	74.11	.360	1.084	.352	.679	.453	.659
1963	2.249	6.317	6.873	2.556	14.11	35.66	65.54	23.67	98.20	49.27	73.96	.356	1.088	.372	.604	.498	.667
1964	2.196	6.132	6.727	2.288	6.58	33.05	52.06	19.67	78.24	43.19	75.89	.358	1.097	.340	.801	.448	.665
1965	2.271	5.881	6.333	2.262	5.14	29.40	53.27	20.40	80.22	42.57	72.82	.386	1.077	.357	.825	.469	.664
1966	2.226	5.917	6.418	2.065	11.82	34.26	48.16	20.53	74.01	40.93	74.52	.376	1.085	.322	.655	.447	.651
1967	2.219	6.053	6.586	2.187	5.83	27.97	46.93	17.97	71.77	34.80	75.26	.367	1.088	.332	.792	.515	.654
1968	2.237	5.711	6.175	2.105	10.97	34.76	45.08	20.00	69.90	36.85	72.33	.392	1.081	.341	.684	.473	.645
1969	2.229	5.939	6.337	2.244	7.07	31.80	53.04	22.29	80.65	44.30	72.79	.375	1.067	.354	.778	.451	.658
1970	2.315	5.783	6.272	2.155	8.40	33.92	53.01	22.63	81.14	48.56	73.40	.400	1.085	.344	.752	.402	.653
1971	2.305	5.873	6.385	2.029	5.32	27.51	48.29	20.34	73.98	42.39	77.48	.393	1.087	.318	.807	.427	.653
1972	2.310	6.069	6.583	2.216	10.96	31.95	56.30	22.95	85.73	46.83	73.84	.381	1.085	.337	.657	.454	.657
1973	2.277	5.839	6.317	2.082	7.87	30.73	50.48	23.44	78.61	45.35	74.98	.390	1.082	.330	.744	.423	.642
21 YR MEAN	2.225	6.096	6.583	2.284	8.88	32.15	54.54	21.43	82.59	43.74	74.04	.365	1.080	.347	.724	.470	.660
21 YR ST DEV	.051	.275	.318	.166	3.18	3.37	6.19	1.75	8.41	4.43	2.31	.022	.010	.016	.074	.033	.010
TMY YEAR	2.158	6.160	6.683	2.254	7.40	31.35	49.49	18.99	74.44	37.60	75.97	.350	1.085	.337	.764	.495	.665
TMY-21 YR DEV	.067	.064	.100	.031	1.48	.80	5.06	2.44	8.15	6.14	1.92	.015	.005	.010	.040	.024	.004

UNITS:

PRIMARY MEASURES:
- HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]
- TBAR: [DEGREES C]
- ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-28 LONG TERM AND TMY SUMMARY BY MONTHS FOR FORT WORTH

		PRIMARY MEASURES											DERIVED MEASURES					
MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	22 YR MEAN	.1062	.2616	.3988	.1793	3.965	8.988	0.00	0.00	0.00	0.00	44.77	.377	1.416	.450	.559	1.000	0.000
	22 YR ST DEV	.0082	.0425	.0729	.0329	1.814	1.584	0.00	0.00	0.00	0.00	8.26	.068	.054	.029	.156	0.000	0.000
	TMY YEAR	.1030	.2741	.3902	.1797	3.304	8.429	0.00	0.00	0.00	0.00	45.05	.376	1.424	.461	.608	1.000	0.000
FEB	22 YR MEAN	.1245	.3378	.4331	.1731	1.657	6.284	.01	.00	.01	0.00	57.33	.369	1.282	.400	.736	1.000	.567
	22 YR ST DEV	.0069	.0382	.0574	.0285	1.043	1.492	.02	.01	.03	0.00	13.18	.047	.027	.075	.133	0.000	.192
	TMY YEAR	.1259	.3359	.4295	.1744	1.549	5.908	0.00	0.00	0.00	0.00	62.42	.375	1.279	.406	.738	1.000	0.000
MAR	22 YR MEAN	.1886	.4975	.5618	.1515	.557	4.025	.28	.10	.46	.07	76.74	.379	1.129	.270	.862	.838	.613
	22 YR ST DEV	.0156	.0553	.0686	.0350	.871	1.925	.43	.16	.68	.15	13.37	.050	.016	.086	.124	.084	.296
	TMY YEAR	.1693	.5152	.5911	.1806	0.000	4.671	0.00	0.00	0.00	0.00	78.50	.329	1.147	.306	1.000	1.000	0.000
APR	22 YR MEAN	.2223	.5502	.5556	.1015	.009	.903	1.21	.48	2.00	.60	89.76	.404	1.010	.183	.991	.697	.606
	22 YR ST DEV	.0128	.0553	.0566	.0288	.030	.667	.98	.37	1.56	.56	4.14	.047	.007	.050	.016	.197	.037
	TMY YEAR	.2098	.5201	.5306	.0634	0.000	.694	.24	.10	.42	0.00	94.93	.403	1.020	.119	1.000	1.000	.569
MAY	22 YR MEAN	.2700	.6673	.6213	.1688	0.000	.116	4.57	1.93	7.24	2.83	85.61	.405	.931	.272	1.000	.609	.631
	22 YR ST DEV	.0165	.0634	.0591	.0440	0.000	.178	1.59	.59	2.39	1.19	2.88	.055	.004	.054	0.000	.072	.014
	TMY YEAR	.2722	.6573	.6110	.1377	0.000	.355	3.39	1.57	5.41	2.17	88.23	.414	.930	.225	1.000	.599	.627
JUN	22 YR MEAN	.2637	.7339	.6568	.2634	.000	-.002	9.85	4.02	14.98	7.91	77.75	.359	.895	.401	.801	.472	.658
	22 YR ST DEV	.0186	.0579	.0477	.0314	.002	.008	2.68	.98	3.92	2.32	12.06	.050	.006	.025	.042	.122	.351
	TMY YEAR	.2565	.7417	.6636	.2786	0.000	0.000	10.22	4.39	15.69	7.87	79.78	.346	.895	.420	1.000	.498	.651
JUL	22 YR MEAN	.2551	.7582	.6888	.2993	0.000	.000	13.99	5.39	20.79	12.41	79.24	.336	.908	.435	1.000	.403	.673
	22 YR ST DEV	.0101	.0497	.0435	.0273	0.000	.001	1.46	.62	1.90	1.57	.35	.030	.004	.013	0.000	.035	.016
	TMY YEAR	.2574	.7796	.7066	.3118	0.000	0.000	14.21	4.81	20.73	11.94	79.22	.330	.906	.441	1.000	.424	.685
AUG	22 YR MEAN	.2372	.6981	.6815	.2991	0.000	0.000	13.56	5.08	20.08	11.67	79.36	.340	.976	.439	1.000	.419	.675
	22 YR ST DEV	.0154	.0512	.0508	.0313	0.000	0.000	1.51	.53	1.92	1.46	.34	.047	.003	.015	0.000	.037	.015
	TMY YEAR	.2379	.7193	.7019	.3073	0.000	0.000	13.12	4.91	19.46	10.82	79.66	.331	.976	.438	1.000	.444	.674
SEP	22 YR MEAN	.2003	.5507	.5970	.2250	0.000	.013	8.25	3.16	12.52	6.39	81.28	.364	1.084	.377	1.000	.489	.659
	22 YR ST DEV	.0120	.0581	.0688	.0425	0.000	.035	1.68	.82	2.41	1.84	1.42	.052	.013	.039	0.000	.082	.015
	TMY YEAR	.1929	.5757	.6284	.2019	0.000	0.000	5.93	2.19	8.93	3.67	85.05	.335	1.092	.321	1.000	.589	.664
OCT	22 YR MEAN	.1524	.4514	.5616	.1233	0.000	.587	2.45	.94	3.87	1.45	87.65	.338	1.244	.220	1.000	.624	.634
	22 YR ST DEV	.0125	.0483	.0712	.0366	0.000	.489	1.23	.48	1.86	.99	4.52	.053	.028	.061	0.000	.154	.021
	TMY YEAR	.1384	.4476	.5683	.0990	0.000	.301	2.03	.87	3.21	1.07	91.50	.309	1.270	.174	1.000	.668	.632
NOV	22 YR MEAN	.1084	.3175	.4469	.1297	.435	3.764	.18	.07	.29	.08	77.40	.342	1.408	.290	.885	.731	.603
	22 YR ST DEV	.0071	.0352	.0590	.0274	.584	1.334	.27	.11	.43	.15	10.23	.048	.035	.063	.108	.296	.295
	TMY YEAR	.1046	.3250	.4595	.1326	.165	3.280	.34	.14	.58	.06	79.64	.322	1.414	.289	.950	.896	.594
DEC	22 YR MEAN	.0957	.2679	.3983	.1760	2.282	7.365	.01	.00	.02	.01	50.21	.357	1.487	.442	.690	.326	.601
	22 YR ST DEV	.0074	.0312	.0552	.0248	1.538	1.573	.03	.01	.06	.05	7.79	.051	.043	.027	.151	.213	.173
	TMY YEAR	.0900	.2680	.4024	.1867	2.385	7.712	0.00	0.00	0.00	0.00	47.60	.336	1.502	.464	.691	1.000	0.000

TABLE C-3A LONG TERM AND TMY SUMMARY BY YEARS FOR MADISON

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.066	4.984	5.527	1.423	50.64	96.43	12.66	4.95	20.18	2.74	64.72	.414	1.109	.257	.475	.864	.627
1954	2.035	4.638	5.122	1.502	49.09	100.58	11.16	4.68	18.16	2.26	63.61	.439	1.104	.293	.512	.875	.615
1955	2.053	5.053	5.589	1.536	58.12	105.60	17.36	7.03	27.48	6.18	64.83	.406	1.106	.275	.450	.775	.632
1956	2.041	4.748	5.265	1.416	54.94	104.69	9.05	3.72	14.58	1.48	64.83	.430	1.109	.269	.475	.898	.620
1957	2.006	4.609	5.110	1.407	55.19	105.76	8.98	3.90	14.50	2.16	61.66	.435	1.109	.275	.478	.851	.619
1958	2.137	5.119	5.779	1.445	52.05	105.16	6.96	2.74	11.30	.72	67.49	.418	1.129	.250	.505	.937	.616
1959	2.136	4.843	5.338	1.558	60.36	112.21	14.09	6.08	22.78	4.05	61.40	.441	1.102	.292	.462	.822	.619
1960	2.066	4.931	5.492	1.438	57.71	109.93	8.34	4.03	13.68	1.89	63.61	.419	1.114	.262	.475	.862	.610
1961	2.064	5.028	5.498	1.465	56.64	108.12	9.64	4.45	15.74	1.30	61.42	.410	1.093	.266	.476	.918	.612
1962	2.139	4.909	5.376	1.390	63.25	113.33	7.17	3.05	11.84	.04	63.04	.436	1.095	.259	.442	.997	.606
1963	2.126	5.200	5.752	1.460	64.07	111.09	11.38	4.95	18.36	.95	67.53	.409	1.106	.254	.423	.948	.620
1964	2.122	5.162	5.726	1.639	46.68	102.93	12.49	5.16	19.80	2.10	65.09	.411	1.109	.286	.546	.894	.631
1965	2.092	4.921	5.406	1.405	56.56	110.97	5.07	2.16	8.31	.40	63.33	.425	1.099	.260	.490	.951	.611
1966	2.068	5.224	5.827	1.628	52.68	114.53	8.11	3.48	13.09	1.00	62.67	.396	1.115	.279	.540	.923	.620
1967	2.111	4.797	5.264	1.383	58.02	113.90	3.38	1.49	5.63	.02	62.25	.440	1.097	.263	.491	.996	.600
1968	2.057	5.165	5.758	1.511	48.58	103.03	9.00	4.10	14.49	1.84	66.98	.398	1.115	.262	.529	.873	.621
1969	2.202	4.894	5.477	1.545	54.66	113.89	6.36	2.87	10.62	.45	63.70	.450	1.119	.282	.520	.958	.599
1970	2.078	5.121	5.721	1.563	52.35	109.47	8.80	3.81	14.34	1.24	64.54	.406	1.117	.273	.522	.914	.614
1971	2.142	5.158	5.749	1.539	55.00	107.59	10.80	4.51	17.48	1.36	66.09	.415	1.115	.268	.489	.922	.618
1972	2.175	4.669	5.129	1.402	65.50	118.87	6.26	2.80	10.20	1.13	62.09	.466	1.098	.273	.449	.889	.613
1973	2.063	4.646	5.150	1.438	48.65	98.89	8.97	3.82	14.68	.86	63.88	.444	1.109	.279	.508	.941	.611
1974	2.075	4.730	5.206	1.388	53.44	105.95	6.19	2.42	10.06	1.00	63.72	.439	1.101	.267	.496	.900	.615
1975	2.118	4.853	5.348	1.512	54.41	104.36	11.86	4.70	19.06	1.50	65.46	.436	1.102	.283	.479	.921	.622
23 YR MEAN	2.095	4.931	5.461	1.478	55.15	107.71	9.31	3.95	15.06	1.59	64.08	.425	1.108	.271	.488	.894	.618
23 YR ST DEV	.048	.198	.241	.077	5.00	5.51	3.16	1.28	4.95	1.35	1.81	.018	.009	.012	.032	.052	.008
TMY YEAR	2.144	4.930	5.442	1.462	55.41	107.89	7.99	3.31	13.10	.55	65.38	.435	1.104	.269	.486	.958	.610
TMY-23 YR DEV	.050	.001	.019	.015	.25	.18	1.32	.64	1.96	1.04	1.29	.010	.004	.002	.001	.064	.008

UNITS:

PRIMARY MEASURES:

HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]

TBAR: [DEGREES C]

ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-3B LONG TERM AND TMY SUMMARY BY MONTHS FOR MADISON

		PRIMARY MEASURES											DERIVED MEASURES					
MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	23 YR MEAN	.0875	.1807	.2967	.1199	15.913	21.690	0.000	0.000	0.000	0.000	31.26	.484	1.642	.404	.266	1.000	0.000
	23 YR ST DEV	.0052	.0198	.0460	.0243	2.161	2.150	0.000	0.000	0.000	0.000	.62	.058	.082	.025	.057	0.000	0.000
	TMY YEAR	.0868	.1833	.3003	.1215	16.820	22.690	0.000	0.000	0.000	0.000	31.81	.474	1.638	.405	.259	1.000	0.000
FEB	23 YR MEAN	.1128	.2538	.3677	.1610	10.272	18.073	0.000	0.000	0.000	0.000	33.29	.444	1.449	.438	.432	1.000	0.000
	23 YR ST DEV	.0078	.0244	.0480	.0246	1.897	1.865	0.000	0.000	0.000	0.000	1.27	.053	.059	.016	.068	0.000	0.000
	TMY YEAR	.1287	.2557	.3518	.1493	11.230	18.440	0.000	0.000	0.000	0.000	32.98	.503	1.376	.424	.391	1.000	0.000
MAR	23 YR MEAN	.1757	.3990	.4829	.2160	5.311	15.561	0.000	0.000	0.000	0.000	40.29	.440	1.210	.447	.659	1.000	0.000
	23 YR ST DEV	.0122	.0406	.0594	.0323	1.635	2.086	0.000	0.000	0.000	0.000	4.92	.048	.032	.024	.085	0.000	0.000
	TMY YEAR	.1763	.4267	.5279	.2428	5.287	16.940	0.000	0.000	0.000	0.000	39.26	.413	1.237	.460	.688	1.000	0.000
APR	23 YR MEAN	.2111	.4754	.4931	.1668	1.110	8.415	.009	.004	.017	0.000	64.56	.444	1.037	.338	.868	1.000	.528
	23 YR ST DEV	.0121	.0403	.0474	.0186	.793	1.461	.026	.011	.048	0.000	11.22	.048	.015	.055	.081	0.000	.180
	TMY YEAR	.2240	.4710	.4887	.1617	.512	7.583	0.000	0.000	0.000	0.000	71.58	.476	1.038	.331	.932	1.000	0.000
MAY	23 YR MEAN	.2577	.6125	.5730	.1044	.142	3.514	.277	.108	.467	.008	86.70	.421	.936	.182	.960	.984	.593
	23 YR ST DEV	.0163	.0712	.0671	.0203	.249	1.307	.381	.150	.626	.036	6.56	.048	.005	.040	.064	.019	.270
	TMY YEAR	.2592	.5989	.5544	.1043	.237	3.324	.408	.148	.663	0.000	85.32	.433	.926	.188	.929	1.000	.616
JUN	23 YR MEAN	.2733	.6625	.5927	.0877	0.000	.542	1.961	.811	3.172	.211	93.45	.413	.895	.148	1.000	.933	.618
	23 YR ST DEV	.0146	.0558	.0505	.0303	0.000	.461	1.290	.536	2.038	.323	2.85	.051	.004	.047	0.000	.056	.022
	TMY YEAR	.2761	.6383	.5715	.0799	0.000	.376	1.643	.664	2.666	.136	94.51	.433	.895	.140	1.000	.949	.616
JUL	24 YR MEAN	.2667	.6797	.6210	.1257	0.000	.063	3.613	1.535	5.844	.747	90.83	.392	.914	.202	1.000	.872	.618
	24 YR ST DEV	.0148	.0519	.0478	.0365	0.000	.116	1.587	.662	2.448	.654	2.90	.045	.004	.053	0.000	.062	.014
	TMY YEAR	.2665	.6742	.6177	.1270	0.000	0.000	3.596	1.480	5.829	.415	89.84	.395	.916	.206	1.000	.929	.617
AUG	24 YR MEAN	.2331	.6002	.6013	.1024	0.000	.145	2.747	1.192	4.429	.493	92.28	.388	1.002	.170	1.000	.889	.620
	24 YR ST DEV	.0117	.0413	.0444	.0299	0.000	.229	1.446	.613	2.245	.773	2.77	.036	.008	.049	0.000	.085	.018
	TMY YEAR	.2380	.6159	.6177	.0948	0.000	.116	2.040	.882	3.384	0.000	93.72	.386	1.003	.153	1.000	1.000	.603
SEP	24 YR MEAN	.1821	.4418	.5081	.0806	0.000	1.972	.706	.307	1.136	.154	92.53	.412	1.150	.159	1.000	.864	.622
	24 YR ST DEV	.0100	.0398	.0530	.0156	0.000	.647	.773	.346	1.214	.365	3.26	.042	.021	.035	0.000	.102	.129
	TMY YEAR	.1913	.4548	.5224	.0530	0.000	1.105	.301	.135	.556	0.000	96.34	.421	1.149	.101	1.000	1.000	.540
OCT	24 YR MEAN	.1345	.3199	.4387	.1169	.567	6.091	.034	.013	.058	0.000	75.65	.420	1.372	.266	.907	1.000	.584
	24 YR ST DEV	.0082	.0380	.0635	.0275	.764	1.663	.085	.034	.139	0.000	10.81	.052	.045	.062	.098	0.000	.244
	TMY YEAR	.1424	.3043	.4018	.1380	.038	6.187	0.000	0.000	0.000	0.000	74.32	.468	1.320	.343	.994	1.000	0.000
NOV	24 YR MEAN	.0877	.1712	.2631	.1107	6.950	12.569	0.000	0.000	0.000	0.000	37.72	.512	1.537	.421	.447	1.000	0.000
	24 YR ST DEV	.0069	.0200	.0383	.0188	1.794	1.394	0.000	0.000	0.000	0.000	6.95	.050	.060	.024	.095	0.000	0.000
	TMY YEAR	.0857	.1742	.2708	.0989	7.025	12.510	0.000	0.000	0.000	0.000	43.73	.492	1.554	.365	.438	1.000	0.000
DEC	24 YR MEAN	.0723	.1363	.2278	.0901	14.738	19.053	0.000	0.000	0.000	0.000	30.76	.530	1.671	.396	.226	1.000	0.000
	24 YR ST DEV	.0077	.0181	.0392	.0191	1.990	1.977	0.000	0.000	0.000	0.000	.40	.053	.092	.024	.051	0.000	0.000
	TMY YEAR	.0690	.1327	.2169	.0913	14.260	18.620	0.000	0.000	0.000	0.000	31.13	.520	1.635	.421	.234	1.000	0.000

TABLE C-4A LONG TERM AND TMY SUMMARY BY YEARS FOR MIAMI

YEAR	PRIMARY MEASURES HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	DERIVED MEASURES FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.679	6.086	6.330	2.178	0.00	.74	94.64	45.46	149.5	91.97	81.78	.440	1.040	.344	1.000	.385	.633
1954	2.708	6.136	6.509	2.049	0.00	.94	89.37	42.34	140.3	87.04	83.97	.441	1.061	.315	1.000	.380	.637
1955	2.707	6.291	6.612	2.208	0.00	.93	83.59	39.74	132.5	74.51	83.23	.430	1.051	.334	1.000	.438	.631
1956	2.814	6.330	6.677	2.163	0.00	2.03	88.30	41.70	139.0	83.27	82.90	.445	1.055	.324	1.000	.401	.635
1957	2.874	5.982	6.295	2.119	0.00	.76	91.45	45.15	145.3	89.44	81.85	.481	1.052	.337	1.000	.384	.629
1958	2.654	6.051	6.303	2.111	0.00	3.61	87.28	42.59	137.6	85.28	82.64	.439	1.042	.335	1.000	.380	.634
1959	2.762	5.974	6.265	2.182	0.00	1.28	90.94	44.90	144.7	87.55	81.61	.462	1.049	.348	1.000	.395	.628
1960	2.723	6.137	6.463	2.032	0.00	1.86	89.35	43.31	141.5	89.51	83.31	.444	1.053	.314	1.000	.367	.632
1961	2.680	6.498	6.833	2.380	0.00	1.41	92.73	42.95	145.6	82.86	82.79	.412	1.052	.348	1.000	.431	.637
1962	2.756	6.177	6.497	2.098	0.00	2.23	81.23	38.73	128.3	74.91	83.57	.446	1.052	.323	1.000	.416	.633
1963	2.765	6.201	6.464	2.110	0.00	1.28	83.49	40.47	132.2	77.37	83.29	.446	1.042	.326	1.000	.415	.632
1964	2.873	5.986	6.206	2.190	0.00	.95	96.70	46.84	153.2	95.28	81.43	.480	1.037	.353	1.000	.378	.631
1965	2.769	6.066	6.339	2.231	0.00	.87	86.89	41.01	138.1	78.96	81.72	.456	1.045	.352	1.000	.428	.629
1966	2.910	5.695	5.963	1.783	0.00	1.41	72.83	36.72	117.5	72.90	84.00	.511	1.047	.299	1.000	.380	.620
1967	2.795	6.119	6.409	2.239	0.00	.57	85.54	40.46	136.2	76.71	81.64	.457	1.047	.349	1.000	.437	.628
1968	2.687	5.988	6.337	1.955	0.00	2.27	82.88	39.38	130.7	81.52	83.87	.449	1.058	.309	1.000	.377	.634
1969	2.878	5.785	6.067	1.834	0.00	.87	88.29	41.63	138.8	92.00	83.84	.497	1.049	.302	1.000	.337	.636
1970	2.748	6.112	6.436	2.227	0.00	2.11	96.67	45.76	152.1	94.57	82.14	.450	1.053	.346	1.000	.378	.635
1971	2.720	6.253	6.556	2.277	0.00	.82	98.72	47.04	156.2	95.68	81.55	.435	1.048	.347	1.000	.388	.632
1972	2.653	6.080	6.380	2.231	0.00	.30	91.27	44.15	145.1	85.38	81.48	.436	1.049	.350	1.000	.412	.629
1973	2.799	5.967	6.278	2.181	0.00	1.57	97.68	47.40	155.5	99.74	81.79	.469	1.052	.347	1.000	.358	.628
1974	2.677	6.152	6.456	2.344	0.00	.36	103.59	48.14	162.6	99.40	80.89	.435	1.049	.363	1.000	.389	.637
1975	2.754	6.266	6.600	2.418	0.00	.63	104.30	50.16	164.7	99.58	81.19	.440	1.053	.366	1.000	.395	.633
23 YR MEAN	2.756	6.101	6.403	2.154	0.00	1.29	90.34	43.31	142.9	86.76	82.46	.452	1.049	.336	1.000	.393	.632
23 YR ST DEV	.075	.173	.192	.153	0.00	.78	7.37	3.38	11.3	8.44	1.01	.023	.006	.019	0.000	.026	.004
TMY YEAR	2.756	6.142	6.475	2.249	0.00	1.36	90.14	43.02	143.7	84.94	81.67	.449	1.054	.347	1.000	.409	.627
TMY-23 YR DEV	.000	.041	.072	.095	0.00	.07	.19	.29	.7	1.82	.78	.003	.005	.011	0.000	.016	.005

UNITS:

PRIMARY MEASURES:

HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]

TBAR: [DEGREES C]

ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-4B LONG TERM AND TMY SUMMARY BY MONTHS FOR MIAMI

MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	KBAR	FCOL	F-HTG	F-CLG	COP
		PRIMARY MEASURES											DERIVED MEASURES					
JAN	23 YR MEAN	.1526	.3714	.4632	.1161	0.000	.481	2.36	1.11	3.87	1.60	86.98	.411	1.247	.251	1.000	.588	.610
	23 YR ST DEV	.0122	.0328	.0509	.0322	0.000	.407	1.65	.75	2.61	1.47	3.97	.059	.030	.060	0.000	.159	.023
	TMY YEAR	.1575	.3676	.4544	.1435	0.000	.552	2.51	1.18	4.16	1.63	77.83	.428	1.236	.316	1.000	.608	.602
FEB	23 YR MEAN	.1761	.4164	.4833	.1103	0.000	.310	2.29	1.06	3.77	1.37	88.89	.423	1.161	.228	1.000	.636	.607
	23 YR ST DEV	.0114	.0290	.0405	.0354	0.000	.435	1.55	.71	2.46	1.21	3.96	.054	.020	.065	0.000	.146	.022
	TMY YEAR	.1607	.4263	.5013	.1189	0.000	.243	2.75	1.18	4.54	1.73	87.71	.377	1.176	.237	1.000	.619	.606
MAR	23 YR MEAN	.2422	.5634	.6023	.1611	0.000	.096	4.06	1.86	6.64	2.51	86.92	.430	1.069	.268	1.000	.622	.612
	23 YR ST DEV	.0123	.0482	.0560	.0403	0.000	.125	1.53	.69	2.40	1.34	3.06	.052	.010	.055	0.000	.099	.015
	TMY YEAR	.2206	.5604	.6043	.1837	0.000	0.000	4.03	1.77	6.69	1.76	86.06	.394	1.078	.304	1.000	.737	.602
APR	23 YR MEAN	.2688	.6323	.6258	.2158	0.000	0.000	6.05	2.71	9.86	3.92	83.22	.425	.990	.345	1.000	.602	.613
	23 YR ST DEV	.0182	.0387	.0397	.0280	0.000	0.000	1.32	.60	2.01	1.59	2.35	.052	.004	.040	0.000	.095	.014
	TMY YEAR	.2510	.6476	.6438	.2276	0.000	0.000	5.62	2.47	9.25	2.92	84.72	.388	.994	.354	1.000	.684	.608
MAY	23 YR MEAN	.2970	.6479	.6077	.2338	0.000	0.000	8.85	4.14	14.14	7.70	79.85	.458	.938	.385	1.000	.455	.625
	23 YR ST DEV	.0196	.0502	.0457	.0255	0.000	0.000	1.03	.51	1.48	1.49	.98	.057	.003	.018	0.000	.067	.009
	TMY YEAR	.3178	.6314	.5941	.2275	0.000	0.000	8.52	3.97	13.83	7.56	80.03	.503	.941	.383	1.000	.453	.616
JUN	23 YR MEAN	.2929	.5808	.5340	.2049	0.000	0.000	10.68	5.37	17.15	11.55	78.41	.504	.920	.384	1.000	.327	.635
	23 YR ST DEV	.0162	.0421	.0365	.0217	0.000	0.000	.95	.42	1.36	1.03	.28	.053	.005	.016	0.000	.028	.006
	TMY YEAR	.2960	.5700	.5261	.1992	0.000	0.000	11.17	5.45	17.59	12.15	78.46	.519	.923	.379	1.000	.309	.635
JUL	24 YR MEAN	.2998	.6197	.5759	.2308	0.000	.000	13.01	6.35	20.23	13.89	78.39	.484	.929	.401	1.000	.314	.643
	24 YR ST DEV	.0197	.0346	.0308	.0180	0.000	.001	.84	.35	1.17	1.01	.25	.046	.004	.010	0.000	.024	.006
	TMY YEAR	.3216	.6152	.5715	.2270	0.000	0.000	12.29	6.12	19.39	13.13	78.32	.523	.929	.397	1.000	.323	.634
AUG	24 YR MEAN	.2717	.5728	.5553	.2246	0.000	0.000	13.49	6.61	20.97	14.78	78.37	.474	.969	.405	1.000	.295	.644
	24 YR ST DEV	.0135	.0271	.0263	.0156	0.000	0.000	.89	.41	1.27	1.02	.19	.040	.002	.010	0.000	.017	.006
	TMY YEAR	.2715	.5955	.5771	.2354	0.000	0.000	13.64	6.70	21.30	14.78	78.47	.456	.969	.408	1.000	.306	.640
SEP	24 YR MEAN	.2500	.4952	.5095	.2029	0.000	0.000	12.43	6.15	19.36	13.81	78.32	.505	1.029	.398	1.000	.287	.642
	24 YR ST DEV	.0187	.0394	.0445	.0267	0.000	0.000	.95	.44	1.37	1.12	.26	.064	.010	.018	0.000	.034	.006
	TMY YEAR	.2690	.5095	.5242	.2094	0.000	0.000	12.96	6.50	20.35	14.65	78.48	.528	1.029	.399	1.000	.280	.637
OCT	24 YR MEAN	.2055	.4577	.5138	.1948	0.000	0.000	9.42	4.48	14.77	9.51	79.12	.449	1.123	.379	1.000	.356	.637
	24 YR ST DEV	.0121	.0348	.0442	.0248	0.000	0.000	1.33	.71	2.01	1.93	.73	.051	.014	.021	0.000	.059	.007
	TMY YEAR	.1902	.4524	.5114	.1988	0.000	0.000	9.02	4.27	14.24	8.82	79.27	.420	1.130	.389	1.000	.381	.634
NOV	24 YR MEAN	.1568	.3803	.4655	.1455	0.000	.058	4.92	2.27	7.92	4.26	82.96	.412	1.224	.313	1.000	.463	.622
	24 YR ST DEV	.0078	.0219	.0330	.0271	0.000	.081	1.62	.75	2.50	1.82	3.16	.038	.018	.053	0.000	.088	.012
	TMY YEAR	.1530	.4033	.5012	.1724	0.000	0.000	5.17	2.26	8.31	3.90	82.01	.379	1.243	.344	1.000	.530	.623
DEC	24 YR MEAN	.1399	.3579	.4606	.1098	0.000	.350	2.55	1.17	4.18	1.93	88.04	.391	1.287	.238	1.000	.539	.608
	24 YR ST DEV	.0090	.0255	.0417	.0328	0.000	.311	1.50	.69	2.40	1.45	4.21	.048	.027	.065	0.000	.132	.022
	TMY YEAR	.1474	.3626	.4654	.1058	0.000	.567	2.46	1.15	4.02	1.91	88.72	.407	1.283	.227	1.000	.525	.613

TABLE C-5A LONG TERM AND TMY SUMMARY BY YEARS FOR NEW YORK

YEAR	PRIMARY MEASURES: HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	DERIVED MEASURES: FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.099	4.845	5.242	1.406	22.00	62.07	15.59	6.41	25.38	3.44	67.63	.433	1.082	.268	.646	.864	.614
1954	2.097	4.685	5.011	1.327	28.96	70.19	11.27	4.70	18.95	2.28	67.79	.448	1.070	.265	.587	.880	.595
1955	2.136	4.780	5.213	1.472	30.09	73.79	18.54	8.42	29.97	8.40	67.18	.447	1.091	.282	.592	.720	.619
1956	2.100	4.502	4.840	1.365	29.71	74.31	11.35	4.88	18.90	3.33	65.82	.466	1.075	.282	.600	.824	.601
1957	2.134	4.738	5.067	1.372	28.44	69.55	13.21	5.58	22.26	2.85	66.21	.450	1.069	.271	.591	.872	.593
1958	2.069	4.387	4.800	1.364	34.40	78.68	11.70	5.15	19.43	3.39	64.47	.472	1.094	.284	.563	.826	.602
1959	2.129	4.499	4.922	1.461	29.86	71.45	20.20	9.15	32.85	9.33	65.38	.473	1.094	.297	.582	.716	.615
1960	2.193	4.609	5.072	1.420	25.34	72.42	11.61	5.02	19.51	3.70	66.32	.476	1.100	.280	.650	.810	.595
1961	2.160	4.405	4.868	1.480	29.47	76.04	17.46	8.05	28.25	8.83	65.40	.490	1.105	.304	.612	.687	.618
1962	2.264	4.619	4.967	1.316	37.70	80.54	9.17	3.86	15.62	.78	65.98	.490	1.075	.265	.532	.950	.587
1963	2.220	4.710	5.100	1.251	36.02	75.54	10.61	4.05	17.36	3.00	68.66	.471	1.083	.245	.523	.827	.611
1964	2.097	4.800	5.276	1.463	25.26	72.52	12.08	5.13	20.27	2.98	68.09	.437	1.099	.277	.652	.853	.596
1965	2.239	4.746	5.122	1.351	30.65	75.98	9.48	4.40	16.14	2.02	66.38	.472	1.079	.264	.597	.875	.588
1966	2.180	4.633	5.015	1.521	26.13	75.77	14.00	5.67	22.96	4.35	64.73	.470	1.082	.303	.655	.810	.610
1967	2.123	4.346	4.670	1.286	37.40	83.89	6.48	3.06	11.35	1.25	63.48	.488	1.075	.275	.554	.890	.571
1968	2.127	4.738	5.176	1.413	36.39	78.85	16.24	6.94	26.83	6.92	66.59	.449	1.092	.273	.538	.742	.605
1969	2.110	4.634	5.056	1.371	30.87	72.95	16.87	7.45	27.51	9.11	65.76	.455	1.091	.271	.577	.669	.613
1970	2.118	4.379	4.706	1.366	35.40	74.78	18.08	7.75	29.70	8.67	64.62	.484	1.075	.290	.527	.708	.609
1971	2.138	4.488	4.827	1.466	27.52	69.84	20.59	8.70	33.61	10.55	65.40	.476	1.076	.304	.606	.686	.613
1972	2.013	4.178	4.494	1.278	29.33	67.64	15.04	6.70	24.71	7.01	64.74	.482	1.076	.284	.566	.716	.609
1973	2.084	4.324	4.742	1.348	22.39	64.90	13.53	6.18	22.34	5.65	66.53	.482	1.097	.284	.655	.747	.605
1974	2.070	4.366	4.718	1.343	28.12	68.66	14.61	6.27	24.04	5.76	66.96	.474	1.081	.285	.590	.760	.608
1975	2.168	4.255	4.581	1.266	25.85	65.64	12.05	5.49	19.95	4.94	67.94	.509	1.077	.276	.606	.752	.604
23 YR MEAN	2.133	4.551	4.934	1.378	29.88	72.87	13.90	6.04	22.95	5.15	66.18	.469	1.084	.279	.590	.775	.606
23 YR ST DEV	.058	.192	.218	.075	4.54	5.22	3.65	1.65	5.72	2.90	1.32	.019	.011	.014	.041	.079	.012
TMY YEAR	2.111	4.526	4.915	1.271	30.26	70.47	11.21	4.89	18.79	3.75	67.48	.466	1.086	.259	.571	.800	.597
TMY-23 YR DEV	.023	.024	.019	.107	.38	2.40	2.69	1.16	4.16	1.41	1.30	.002	.002	.021	.019	.025	.009

UNITS:

PRIMARY MEASURES:

HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]

TBAR: [DEGREES C]

ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-5B LONG TERM AND TMY SUMMARY BY MONTHS FOR NEW YORK

MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
		PRIMARY MEASURES											DERIVED MEASURES					
JAN	23 YR MEAN	.0886	.1755	.2650	.1153	9.583	15.123	0.00	0.00	0.00	0.00	31.54	.505	1.510	.435	.366	1.000	0.000
	23 YR ST DEV	.0078	.0181	.0347	.0178	1.774	1.710	0.00	0.00	0.00	0.00	.52	.046	.060	.017	.067	0.000	0.000
	TMY YEAR	.0777	.1643	.2581	.1118	9.437	14.830	0.00	0.00	0.00	0.00	31.76	.473	1.571	.433	.364	1.000	0.000
FEB	23 YR MEAN	.1133	.2282	.3042	.1365	6.624	13.180	0.00	0.00	0.00	0.00	33.50	.497	1.333	.449	.497	1.000	0.000
	23 YR ST DEV	.0078	.0230	.0359	.0200	1.622	1.360	0.00	0.00	0.00	0.00	1.59	.043	.034	.017	.086	0.000	0.000
	TMY YEAR	.1150	.2312	.3097	.1395	6.675	13.460	0.00	0.00	0.00	0.00	32.98	.497	1.339	.450	.504	1.000	0.000
MAR	23 YR MEAN	.1738	.3643	.4228	.1865	2.940	11.657	0.00	0.00	0.00	0.00	43.24	.477	1.161	.441	.748	1.000	0.000
	23 YR ST DEV	.0138	.0401	.0523	.0240	1.252	1.369	0.00	0.00	0.00	0.00	4.51	.036	.021	.015	.087	0.000	0.000
	TMY YEAR	.1681	.3644	.4247	.1824	3.037	11.790	0.00	0.00	0.00	0.00	45.85	.461	1.166	.429	.742	1.000	0.000
APR	23 YR MEAN	.2141	.4637	.4756	.1509	.322	6.736	0.00	0.00	0.00	0.00	69.74	.462	1.026	.317	.952	1.000	0.000
	23 YR ST DEV	.0154	.0474	.0524	.0204	.332	1.114	0.00	0.00	0.00	0.00	9.25	.052	.013	.050	.045	0.000	0.000
	TMY YEAR	.2152	.4603	.4679	.1350	.587	5.579	0.00	0.00	0.00	0.00	67.93	.468	1.016	.289	.895	1.000	0.000
MAY	23 YR MEAN	.2574	.5749	.5385	.0792	.023	2.439	.12	.04	.20	.00	91.00	.448	.937	.147	.991	.995	.575
	23 YR ST DEV	.0193	.0684	.0651	.0204	.090	1.121	.18	.07	.31	.00	5.08	.042	.005	.046	.028	.004	.285
	TMY YEAR	.2518	.5833	.5519	.0655	0.000	1.990	.07	.03	.13	0.00	95.84	.397	.946	.119	1.000	1.000	.533
JUN	23 YR MEAN	.2691	.5816	.5240	.0693	0.000	.123	1.62	.67	2.71	.25	94.23	.463	.901	.132	1.000	.908	.599
	23 YR ST DEV	.0143	.0642	.0572	.0229	0.000	.119	.82	.35	1.34	.24	1.62	.058	.005	.039	0.000	.063	.024
	TMY YEAR	.2874	.5859	.5287	.0409	0.000	.023	.71	.32	1.17	0.00	96.53	.491	.902	.077	1.000	1.000	.602
JUL	24 YR MEAN	.2751	.5930	.5436	.1548	0.000	.003	5.41	2.32	8.87	2.08	85.90	.464	.917	.285	1.000	.766	.609
	24 YR ST DEV	.0186	.0620	.0568	.0296	0.000	.012	1.51	.66	2.31	1.18	2.51	.058	.004	.038	0.000	.094	.015
	TMY YEAR	.2711	.5719	.5247	.1344	0.000	0.000	4.03	1.65	6.82	1.13	86.77	.474	.917	.256	1.000	.834	.591
AUG	24 YR MEAN	.2351	.5211	.5170	.1403	0.000	.003	5.00	2.21	8.22	2.15	86.45	.451	.992	.271	1.000	.738	.608
	24 YR ST DEV	.0104	.0410	.0439	.0243	0.000	.010	1.64	.72	2.51	1.45	2.79	.041	.008	.042	0.000	.109	.017
	TMY YEAR	.2555	.5287	.5250	.1526	0.000	0.000	5.52	2.47	9.13	2.46	86.28	.483	.993	.291	1.000	.731	.605
SEP	24 YR MEAN	.1899	.4126	.4588	.0748	0.000	.294	1.78	.81	2.96	.74	91.97	.460	1.112	.163	1.000	.751	.601
	24 YR ST DEV	.0097	.0464	.0596	.0228	0.000	.280	1.28	.61	2.03	.93	2.67	.055	.023	.043	0.000	.163	.123
	TMY YEAR	.1857	.4052	.4484	.0541	0.000	.149	.88	.41	1.53	.16	93.63	.453	1.107	.121	1.000	.897	.574
OCT	24 YR MEAN	.1437	.3144	.4077	.0740	.028	2.899	.07	.03	.12	.01	89.35	.457	1.297	.181	.990	.935	.558
	24 YR ST DEV	.0070	.0264	.0436	.0176	.115	.902	.17	.09	.31	.03	4.36	.046	.035	.041	.028	.028	.245
	TMY YEAR	.1340	.3191	.4181	.0720	0.000	2.626	0.00	0.00	0.00	0.00	91.10	.420	1.310	.172	1.000	1.000	0.000
NOV	24 YR MEAN	.0950	.1810	.2607	.1064	1.897	7.525	0.00	0.00	0.00	0.00	45.06	.525	1.441	.408	.748	1.000	0.000
	24 YR ST DEV	.0100	.0210	.0364	.0153	.966	1.050	0.00	0.00	0.00	0.00	8.92	.048	.058	.042	.104	0.000	0.000
	TMY YEAR	.1014	.1786	.2511	.0946	2.156	7.383	0.00	0.00	0.00	0.00	48.96	.568	1.406	.377	.708	1.000	0.000
DEC	24 YR MEAN	.0767	.1417	.2171	.0924	8.422	12.879	0.00	0.00	0.00	0.00	31.37	.542	1.533	.426	.346	1.000	0.000
	24 YR ST DEV	.0110	.0203	.0359	.0172	1.556	1.846	0.00	0.00	0.00	0.00	.79	.052	.071	.019	.063	0.000	0.000
	TMY YEAR	.0698	.1334	.2064	.0887	8.369	12.640	0.00	0.00	0.00	0.00	32.08	.523	1.547	.430	.338	1.000	0.000

TABLE C-6A LONG TERM AND TMY SUMMARY BY YEARS FOR WASHINGTON

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1954	2.220	5.173	5.596	1.655	18.22	58.95	26.42	10.10	42.15	8.73	70.36	.429	1.082	.296	.691	.793	.627
1955	2.204	4.972	5.433	1.576	20.19	61.06	27.47	12.04	43.25	14.04	70.28	.443	1.093	.290	.669	.675	.635
1956	2.152	4.832	5.153	1.497	21.34	60.85	20.36	8.58	32.74	5.70	67.67	.445	1.066	.290	.649	.826	.622
1957	2.215	4.967	5.303	1.594	20.79	58.66	27.58	10.95	43.69	10.13	68.32	.446	1.068	.301	.646	.768	.631
1958	2.194	4.983	5.462	1.524	24.61	66.57	21.31	9.56	34.35	8.79	69.46	.440	1.096	.279	.630	.744	.621
1959	2.242	5.068	5.501	1.740	16.39	57.52	36.30	15.76	57.07	19.45	68.31	.442	1.085	.316	.715	.659	.636
1960	2.257	5.136	5.570	1.656	22.49	65.21	25.37	10.56	40.98	9.31	68.75	.439	1.084	.297	.655	.773	.619
1961	2.188	4.927	5.391	1.635	21.79	63.04	29.49	13.85	46.69	15.17	69.57	.444	1.094	.303	.654	.675	.632
1962	2.165	4.958	5.400	1.581	28.23	69.21	22.57	9.14	36.35	6.62	68.28	.437	1.089	.293	.592	.818	.621
1963	2.194	5.487	6.030	1.543	27.23	72.93	15.86	6.08	25.24	2.92	72.03	.400	1.099	.256	.627	.884	.628
1964	2.224	5.020	5.503	1.621	20.80	70.23	18.72	7.90	29.89	7.01	68.83	.443	1.096	.295	.704	.765	.626
1965	2.213	5.127	5.610	1.658	21.18	70.20	19.15	8.29	30.65	5.03	68.18	.432	1.094	.296	.698	.836	.625
1966	2.215	5.142	5.544	1.652	27.01	79.51	16.55	6.71	26.18	4.14	66.71	.431	1.078	.298	.660	.842	.632
1967	2.232	4.905	5.398	1.538	23.03	74.99	11.76	5.38	19.24	2.84	68.65	.455	1.101	.285	.693	.852	.611
1968	2.240	5.149	5.602	1.539	27.06	73.45	16.73	7.76	26.77	4.97	69.60	.435	1.088	.275	.632	.814	.625
1969	2.234	5.012	5.447	1.476	32.79	77.24	18.38	8.49	29.40	8.26	66.81	.446	1.087	.271	.575	.719	.625
1970	2.198	5.045	5.390	1.460	32.66	76.29	13.52	6.10	21.87	.52	65.89	.436	1.068	.271	.572	.976	.618
1971	2.236	4.819	5.160	1.495	23.82	67.78	16.74	7.85	27.11	4.75	68.41	.464	1.071	.290	.649	.825	.617
1972	2.196	4.714	5.083	1.465	24.58	71.79	13.70	6.48	21.93	4.01	66.42	.466	1.078	.288	.658	.817	.625
1973	2.250	4.669	5.083	1.544	24.40	66.64	21.30	9.92	34.09	7.42	67.51	.482	1.089	.304	.634	.782	.625
1974	2.253	4.854	5.225	1.406	24.31	67.82	12.58	5.96	20.40	2.26	69.55	.464	1.076	.269	.642	.889	.617
1975	2.233	4.753	5.122	1.473	28.12	70.55	16.51	8.02	26.96	4.31	68.98	.470	1.078	.288	.601	.840	.612
22 YR MEAN	2.216	4.987	5.409	1.560	24.14	68.20	20.38	8.89	32.59	7.11	68.57	.444	1.085	.288	.646	.782	.625
22 YR ST DEV	.028	.183	.222	.084	4.18	6.31	6.24	2.61	9.72	4.53	1.43	.017	.011	.014	.039	.075	.007
TMY YEAR	2.199	5.037	5.489	1.528	23.29	67.90	18.18	8.17	29.12	6.11	70.25	.437	1.090	.278	.657	.790	.624
TMY-22 YR DEV	.017	.050	.080	.033	.85	.31	2.20	.72	3.47	1.00	1.68	.008	.005	.010	.011	.008	.001

UNITS:

PRIMARY MEASURES:

HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]

TBAR: [DEGREES C]

ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE C-6B LONG TERM AND TMY SUMMARY BY MONTHS FOR WASHINGTON

		PRIMARY MEASURES											DERIVED MEASURES					
MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	22 YR MEAN	.0965	.2011	.2995	.1335	8.208	14.665	0.000	0.000	0.000	0.000	32.89	.480	1.489	.446	.440	1.000	0.000
	22 YR ST DEV	.0076	.0178	.0357	.0192	1.698	1.692	0.000	0.000	0.000	0.000	1.43	.055	.062	.014	.073	0.000	0.000
	TMY YEAR	.0934	.2141	.3301	.1481	8.375	15.530	0.000	0.000	0.000	0.000	33.61	.436	1.542	.449	.461	1.000	0.000
FEB	22 YR MEAN	.1202	.2573	.3408	.1551	5.084	12.458	0.000	0.000	0.000	0.000	36.73	.467	1.325	.455	.592	1.000	0.000
	22 YR ST DEV	.0097	.0273	.0436	.0226	1.517	1.692	0.000	0.000	0.000	0.000	4.35	.050	.040	.017	.094	0.000	0.000
	TMY YEAR	.1181	.2585	.3422	.1561	5.962	13.340	0.000	0.000	0.000	0.000	36.55	.457	1.324	.456	.553	1.000	0.000
MAR	22 YR MEAN	.1815	.3953	.4548	.1858	1.627	10.074	0.000	0.000	0.000	0.000	53.00	.459	1.151	.408	.839	1.000	0.000
	22 YR ST DEV	.0134	.0430	.0554	.0205	1.151	1.559	0.000	0.000	0.000	0.000	8.34	.047	.020	.033	.091	0.000	0.000
	TMY YEAR	.1861	.4154	.4774	.1946	.913	9.921	0.000	0.000	0.000	0.000	56.13	.448	1.149	.408	.908	1.000	0.000
APR	22 YR MEAN	.2230	.4963	.5066	.1223	.119	4.704	.169	.051	.289	0.000	81.59	.449	1.021	.241	.975	1.000	.586
	22 YR ST DEV	.0131	.0569	.0625	.0203	.221	1.326	.300	.085	.496	0.000	8.66	.058	.011	.054	.036	0.000	.286
	TMY YEAR	.2206	.5048	.5166	.1219	0.000	4.395	.104	.026	.206	0.000	86.78	.437	1.023	.236	1.000	1.000	.508
MAY	22 YR MEAN	.2662	.6055	.5648	.0765	.005	1.353	.783	.320	1.297	.052	93.42	.440	.933	.135	.996	.960	.604
	22 YR ST DEV	.0149	.0593	.0566	.0172	.017	.886	.805	.331	1.314	.173	2.85	.044	.004	.032	.015	.081	.177
	TMY YEAR	.2667	.6021	.5608	.0635	0.000	1.163	.683	.264	1.041	.048	95.26	.443	.931	.113	1.000	.954	.656
JUN	22 YR MEAN	.2729	.6465	.5797	.1217	0.000	.080	3.737	1.592	6.001	.839	90.21	.422	.897	.210	1.000	.860	.623
	22 YR ST DEV	.0171	.0538	.0471	.0357	0.000	.124	1.589	.657	2.467	.707	2.83	.044	.003	.059	0.000	.071	.014
	TMY YEAR	.2608	.6442	.5791	.0907	0.000	0.000	2.421	1.138	4.013	.446	92.25	.405	.899	.157	1.000	.889	.603
JUL	22 YR MEAN	.2788	.6287	.5754	.1792	0.000	0.000	6.931	3.011	10.985	2.892	84.65	.443	.915	.312	1.000	.737	.631
	22 YR ST DEV	.0170	.0494	.0452	.0239	0.000	0.000	1.808	.780	2.695	1.805	2.38	.052	.003	.034	0.000	.102	.011
	TMY YEAR	.2875	.6041	.5502	.1745	0.000	0.000	6.730	3.075	10.680	2.895	83.06	.476	.911	.317	1.000	.729	.630
AUG	23 YR MEAN	.2453	.5694	.5630	.1644	0.000	.002	6.012	2.662	9.591	2.338	85.81	.431	.989	.292	1.000	.756	.627
	23 YR ST DEV	.0124	.0393	.0412	.0300	0.000	.006	1.879	.865	2.877	1.565	2.65	.041	.008	.050	0.000	.091	.009
	TMY YEAR	.2376	.5984	.5891	.1727	0.000	0.000	5.832	2.523	9.309	1.857	85.99	.397	.984	.293	1.000	.801	.626
SEP	23 YR MEAN	.1958	.4528	.5010	.0940	0.000	.383	2.523	1.125	4.050	.873	90.51	.432	1.107	.188	1.000	.784	.623
	23 YR ST DEV	.0107	.0501	.0631	.0289	0.000	.362	1.671	.789	2.607	1.115	2.87	.052	.020	.053	0.000	.117	.024
	TMY YEAR	.1873	.4470	.4951	.0831	0.000	.113	2.408	1.142	3.874	.860	93.06	.419	1.108	.168	1.000	.778	.622
OCT	23 YR MEAN	.1466	.3497	.4521	.0869	.015	3.280	.243	.107	.397	.135	88.97	.419	1.293	.192	.995	.660	.612
	23 YR ST DEV	.0076	.0373	.0582	.0267	.074	1.374	.643	.287	1.023	.450	5.82	.048	.036	.057	.021	.124	.286
	TMY YEAR	.1490	.3458	.4461	.0785	0.000	2.967	0.000	0.000	0.000	0.000	94.03	.431	1.290	.176	1.000	1.000	0.000
NOV	23 YR MEAN	.1020	.2214	.3238	.1267	1.543	8.051	.006	.003	.010	0.000	53.21	.461	1.463	.391	.808	1.000	.612
	23 YR ST DEV	.0070	.0216	.0400	.0147	1.033	1.169	.026	.013	.041	0.000	11.07	.050	.049	.044	.108	0.000	.157
	TMY YEAR	.1101	.2303	.3323	.1223	1.562	7.850	0.000	0.000	0.000	0.000	53.00	.478	1.443	.368	.801	1.000	0.000
DEC	23 YR MEAN	.0857	.1687	.2564	.1135	7.408	12.930	0.000	0.000	0.000	0.000	32.78	.508	1.520	.443	.427	1.000	0.000
	23 YR ST DEV	.0066	.0177	.0344	.0174	1.752	2.093	0.000	0.000	0.000	0.000	1.33	.050	.062	.014	.068	0.000	0.000
	TMY YEAR	.0815	.1722	.2704	.1218	6.475	12.620	0.000	0.000	0.000	0.000	33.27	.473	1.570	.450	.487	1.000	0.000

APPENDIX D

MONTHLY PERFORMANCE FOR EVERY MONTH IN THE PERIOD OF RECORD FOR MADISON

TABLE D-1 SELECTED MONTHLY PERFORMANCE MEASURES FOR EVERY MONTH IN THE PERIOD OF RECORD FOR MADISON

JAN

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1953	.1378	19.150	0.	.194	1.000
	1954	.1673	20.840	0.	.245	1.000
	1955	.1839	21.110	0.	.281	1.000
	1956	.1818	20.440	0.	.311	1.000
	1957	.1892	23.730	0.	.276	1.000
	1958	.1936	20.260	0.	.356	1.000
	1959	.1766	23.740	0.	.217	1.000
	1960	.1498	20.020	0.	.196	1.000
H	1961	.2019	22.020	0.	.318	1.000
	1962	.1802	23.510	0.	.219	1.000
	1963	.1743	25.350	0.	.185	1.000
	1964	.1908	18.030	0.	.374	1.000
T	1965	.1828	22.260	0.	.265	1.000
	1966	.2263	24.740	0.	.350	1.000
	1967	.1791	19.730	0.	.279	1.000
	1968	.1667	19.980	0.	.264	1.000
	1969	.1663	22.750	0.	.219	1.000
	1970	.2063	24.570	0.	.282	1.000
	1971	.2040	24.860	0.	.279	1.000
	1972	.1869	22.560	0.	.238	1.000
	1973	.1925	19.000	0.	.358	1.000
	1974	.1644	20.490	0.	.248	1.000
	1975	.1544	19.720	0.	.198	1.000
	TMY	.1833	22.690	0.	.259	1.000
	L.T.	.1807	21.690	0.	.266	1.000

FEB

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1953	.2297	16.470	0.	.411	1.000
	1954	.2242	13.090	0.	.525	1.000
	1955	.2331	18.190	0.	.383	1.000
	1956	.2586	17.850	0.	.450	1.000
	1957	.2101	15.560	0.	.388	1.000
	1958	.2905	20.000	0.	.504	1.000
	1959	.2577	19.640	0.	.416	1.000
T	1960	.2552	18.380	0.	.398	1.000
H	1961	.2440	15.280	0.	.479	1.000
	1962	.2063	19.810	0.	.253	1.000
	1963	.2561	21.060	0.	.369	1.000
	1964	.2560	16.800	0.	.477	1.000
	1965	.2735	18.940	0.	.465	1.000
	1966	.2652	17.770	0.	.475	1.000
	1967	.2804	20.580	0.	.431	1.000
	1968	.2921	19.170	0.	.516	1.000
	1969	.2649	17.030	0.	.484	1.000
	1970	.2946	18.130	0.	.542	1.000
	1971	.2279	18.430	0.	.340	1.000
	1972	.2559	19.970	0.	.364	1.000
	1973	.2444	16.850	0.	.464	1.000
	1974	.2694	18.740	0.	.452	1.000
	1975	.2485	17.950	0.	.401	1.000
	TMY	.2557	18.440	0.	.391	1.000
	L.T.	.2538	18.073	0.	.432	1.000

MAR

	YEAR	HHOR	QLH	QLH	F-HTG	F-CLG
	1953	.3565	14.390	0.	.579	1.000
	1954	.3862	15.700	0.	.701	1.000
	1955	.4444	15.870	0.	.683	1.000
	1956	.4123	16.400	0.	.699	1.000
	1957	.3872	14.950	0.	.693	1.000
	1958	.3878	14.750	0.	.561	1.000
	1959	.4104	16.660	0.	.638	1.000
	1960	.4469	20.930	0.	.586	1.000
H	1961	.3268	14.360	0.	.570	1.000
	1962	.3881	16.250	0.	.612	1.000
	1963	.3686	13.890	0.	.535	1.000
	1964	.4177	15.590	0.	.735	1.000
	1965	.3782	18.400	0.	.523	1.000
	1966	.3778	13.710	0.	.711	1.000
	1967	.3581	14.680	0.	.590	1.000
	1968	.4460	11.620	0.	.781	1.000
	1969	.4830	16.910	0.	.829	1.000
	1970	.4575	15.900	0.	.804	1.000
	1971	.4265	16.580	0.	.687	1.000
T	1972	.4261	16.840	0.	.709	1.000
	1973	.3415	10.990	0.	.727	1.000
	1974	.3464	14.950	0.	.608	1.000
	1975	.4034	17.590	0.	.639	1.000
	TMY	.4267	16.940	0.	.688	1.000
	L.T.	.3990	15.561	0.	.659	1.000

APR

	YEAR	HHOR	QLH	QLH	F-HTG	F-CLG
	1953	.4124	9.899	0.	.821	1.000
	1954	.4438	6.871	0.	.812	1.000
	1955	.5117	4.944	0.	1.000	1.000
	1956	.4475	9.674	0.	.871	1.000
	1957	.4694	7.768	0.	.759	1.000
	1958	.5145	7.901	0.	.942	1.000
	1959	.4871	8.257	0.	.926	1.000
	1960	.4775	7.433	.105	.825	1.000
H	1961	.4476	10.640	0.	.709	1.000
	1962	.5301	8.922	.060	.857	1.000
	1963	.5585	7.027	0.	1.000	1.000
T	1964	.4703	7.542	0.	.925	1.000
	1965	.4597	9.607	0.	.811	1.000
	1966	.4611	10.220	0.	.832	1.000
	1967	.4180	8.760	0.	.942	1.000
	1968	.4766	7.613	0.	1.000	1.000
	1969	.4870	7.380	0.	.906	1.000
	1970	.5148	7.584	.046	.904	1.000
	1971	.5560	8.074	0.	.954	1.000
	1972	.4591	10.580	0.	.876	1.000
	1973	.4348	8.687	0.	.747	1.000
	1974	.4696	7.320	0.	.892	1.000
	1975	.4272	10.840	0.	.824	1.000
	TMY	.4710	7.583	0.	.932	1.000
	L.T.	.4754	8.415	.009	.868	1.000

H = HEDSTROM YEAR
T = SOURCE YEAR OF TMY MONTH

NOTE: UNITS ARE SAME AS THOSE IN APPENDIX C

TABLE D-1 (cont.)

MAY

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
T	1953	.5982	3.264	.412	.795	1.000
	1954	.5984	5.093	0.	.938	1.000
	1955	.6486	1.866	.254	1.000	1.000
	1956	.5228	3.783	.023	.948	1.000
	1957	.4641	4.266	0.	.884	1.000
	1958	.7521	2.219	0.	1.000	1.000
	1959	.6063	1.763	.781	1.000	1.000
	1960	.5318	3.875	0.	.791	1.000
H	1961	.6688	4.278	.076	1.000	1.000
	1962	.6137	2.397	1.211	1.000	1.000
	1963	.6303	3.826	.098	1.000	1.000
	1964	.7130	1.309	.928	1.000	1.000
	1965	.6216	2.378	.327	1.000	1.000
	1966	.7014	5.659	.046	.909	1.000
	1967	.6896	6.119	.081	1.000	1.000
	1968	.5841	4.413	0.	1.000	1.000
	1969	.6220	3.598	.278	1.000	1.000
	1970	.6155	3.241	.268	1.000	1.000
	1971	.6591	3.757	0.	1.000	1.000
	1972	.6104	2.766	.399	1.000	1.000
	1973	.4905	4.558	0.	1.000	1.000
	1974	.5217	4.708	.022	.943	1.000
	1975	.6242	1.692	1.162	1.000	.909
	TMY	.5989	3.324	.409	.929	1.000
	L.T.	.6125	3.514	.277	.960	.984

JUN

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1953	.7021	.029	2.881	1.000	.932
	1954	.6249	.741	4.301	1.000	.828
	1955	.6103	.995	1.083	1.000	1.000
	1956	.6974	.338	3.871	1.000	.901
T	1957	.6376	.417	1.646	1.000	.938
	1958	.5804	.728	.432	1.000	1.000
	1959	.6475	.072	2.562	1.000	.804
	1960	.6156	.425	.361	1.000	1.000
H	1961	.7684	.258	1.856	1.000	.961
	1962	.6794	.453	1.530	1.000	1.000
	1963	.7395	.259	3.556	1.000	.948
	1964	.7000	.575	3.130	1.000	.978
	1965	.7193	.504	.791	1.000	1.000
	1966	.7258	.745	2.610	1.000	1.000
	1967	.6047	.365	1.086	1.000	.987
	1968	.6838	.510	1.715	1.000	1.000
	1969	.5382	2.208	.275	1.000	1.000
	1970	.6933	.579	2.029	1.000	.938
	1971	.7073	.172	4.414	1.000	.900
	1972	.6593	1.074	.555	1.000	1.000
	1973	.6514	.029	1.363	1.000	.990
	1974	.6440	.755	.484	1.000	1.000
	1975	.6063	.231	2.581	1.000	.933
	TMY	.6383	.376	1.643	1.000	.949
	L.T.	.6625	.542	1.961	1.000	.933

JUL

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.7103	.017	5.507	1.000	.796
	1953	.6390	0.	4.265	1.000	.787
	1954	.6320	0.	4.177	1.000	.903
	1955	.7065	0.	8.305	1.000	.781
	1956	.6021	0.	2.189	1.000	.909
	1957	.6483	0.	4.594	1.000	.813
	1958	.6385	0.	2.048	1.000	.944
	1959	.7109	.172	3.175	1.000	.896
	1960	.7492	.029	2.309	1.000	.994
H	1961	.7081	0.	2.817	1.000	.927
	1962	.6167	.049	1.600	1.000	.985
	1963	.7499	0.	5.341	1.000	.923
	1964	.6663	.029	5.186	1.000	.848
	1965	.7132	.029	2.203	1.000	.908
	1966	.7129	0.	4.236	1.000	.852
	1967	.6830	.473	1.804	1.000	1.000
	1968	.7800	.057	2.987	1.000	.853
	1969	.6178	0.	2.514	1.000	.910
	1970	.6872	.054	3.941	1.000	.837
	1971	.6247	.111	1.932	1.000	.872
	1972	.5920	.313	2.559	1.000	.881
T	1973	.6734	0.	3.512	1.000	.924
	1974	.7061	0.	4.418	1.000	.857
	1975	.7453	.170	5.091	1.000	.929
	TMY	.6742	0.	3.596	1.000	.929
	L.T.	.6797	.063	3.613	1.000	.872

AUG

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.5424	.029	1.588	1.000	.992
	1953	.6409	0.	3.876	1.000	.909
	1954	.5880	0.	1.803	1.000	.870
	1955	.6193	0.	6.700	1.000	.690
	1956	.5596	.143	2.834	1.000	.880
	1957	.5476	.025	2.240	1.000	.877
	1958	.6326	.111	4.199	1.000	.921
	1959	.5485	0.	5.870	1.000	.751
	1960	.5984	.076	2.764	1.000	.956
H	1961	.6326	.029	2.869	1.000	.976
	1962	.6461	0.	2.485	1.000	1.000
T	1963	.6152	.116	2.175	1.000	1.000
	1964	.6490	.257	2.408	1.000	.835
	1965	.5934	.557	1.683	1.000	.973
	1966	.6225	.229	.979	1.000	1.000
	1967	.5904	1.007	.326	1.000	1.000
	1968	.6608	.341	4.053	1.000	.826
	1969	.6462	0.	3.031	1.000	.985
	1970	.6372	0.	2.146	1.000	1.000
	1971	.6172	.086	1.917	1.000	.968
	1972	.5242	.249	2.720	1.000	.853
	1973	.5952	.083	3.318	1.000	.930
	1974	.5650	.143	1.010	1.000	1.000
	1975	.5324	0.	2.931	1.000	.899
	TMY	.6159	.116	2.040	1.000	1.000
	L.T.	.6002	.145	2.747	1.000	.889

TABLE D-1 (cont.)

SEP

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.4664	1.541	.912	1.000	1.000
	1953	.5437	1.286	1.174	1.000	.772
	1954	.4034	1.307	.884	1.000	.984
	1955	.4837	1.056	1.020	1.000	.956
	1956	.4794	1.860	.131	1.000	1.000
	1957	.4651	1.837	.500	1.000	.791
T	1958	.4542	1.063	.279	1.000	1.000
	1959	.4397	1.470	1.705	1.000	.864
	1960	.4290	1.110	2.806	1.000	.621
H	1961	.4039	2.031	2.022	1.000	.775
	1962	.4223	3.135	.287	1.000	1.000
	1963	.4364	1.951	.160	1.000	1.000
	1964	.4134	2.393	.840	1.000	.909
	1965	.3552	2.913	.070	1.000	1.000
	1966	.4763	2.704	.241	1.000	1.000
	1967	.4587	2.629	0.	1.000	1.000
	1968	.4551	1.359	.034	1.000	1.000
	1969	.4326	2.283	.260	1.000	1.000
	1970	.4015	2.285	.368	1.000	1.000
	1971	.4891	1.505	2.172	1.000	.961
	1972	.4089	1.834	.024	1.000	1.000
	1973	.3878	2.020	.774	1.000	.982
	1974	.4574	2.931	.252	1.000	1.000
	1975	.4394	2.821	.037	1.000	1.000
	TMY	.4548	1.105	.301	1.000	1.000
	L.T.	.4418	1.972	.706	1.000	.864

OCT

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.3743	8.804	0.	1.000	1.000
	1953	.3858	4.004	.055	1.000	1.000
	1954	.2765	6.445	0.	.972	1.000
	1955	.3002	5.678	0.	.914	1.000
	1956	.3706	3.378	0.	1.000	1.000
	1957	.3067	7.441	0.	.835	1.000
	1958	.3428	4.793	0.	.984	1.000
	1959	.2329	8.133	0.	.670	1.000
	1960	.3202	6.169	0.	.821	1.000
H	1961	.3122	5.884	0.	.871	1.000
	1962	.3046	5.603	0.	.937	1.000
	1963	.3451	2.716	.047	1.000	1.000
	1964	.3496	7.910	0.	.965	1.000
	1965	.3266	6.843	0.	.976	1.000
	1966	.3519	7.236	0.	.987	1.000
	1967	.2600	7.511	.083	.709	1.000
	1968	.3106	6.156	.211	.966	1.000
	1969	.2963	8.034	0.	.794	1.000
	1970	.3050	5.767	0.	.920	1.000
	1971	.3199	3.588	.369	1.000	1.000
	1972	.2890	8.197	0.	.813	1.000
	1973	.3080	4.592	0.	.974	1.000
T	1974	.3037	6.155	0.	.994	1.000
	1975	.3844	5.159	.055	1.000	1.000
	TMY	.3043	6.187	0.	.994	1.000
	L.T.	.3199	6.091	.034	.907	1.000

NOV

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.1966	11.470	0.	.587	1.000
	1953	.2023	10.740	0.	.620	1.000
	1954	.1611	11.910	0.	.458	1.000
	1955	.1712	14.870	0.	.353	1.000
	1956	.1303	12.810	0.	.319	1.000
	1957	.1427	12.960	0.	.364	1.000
	1958	.1669	11.750	0.	.487	1.000
	1959	.1871	16.590	0.	.371	1.000
	1960	.1790	11.730	0.	.515	1.000
H	1961	.1746	12.730	0.	.469	1.000
	1962	.1714	13.080	0.	.442	1.000
	1963	.1734	10.680	0.	.557	1.000
	1964	.2067	11.480	0.	.602	1.000
T	1965	.1737	12.560	0.	.441	1.000
	1966	.1658	12.420	0.	.453	1.000
	1967	.1510	14.000	0.	.324	1.000
	1968	.1777	12.650	0.	.469	1.000
	1969	.1868	14.100	0.	.447	1.000
	1970	.1551	12.490	0.	.361	1.000
	1971	.1883	13.000	0.	.509	1.000
	1972	.1329	13.190	0.	.259	1.000
	1973	.1896	12.280	0.	.511	1.000
	1974	.1532	12.110	0.	.423	1.000
	1975	.1711	10.050	0.	.552	1.000
	TMY	.1742	12.510	0.	.438	1.000
	L.T.	.1712	12.569	0.	.447	1.000

DEC

	YEAR	HHOR	QLH	QAC	F-HTG	F-CLG
	1952	.1180	17.550	0.	.202	1.000
	1953	.1356	17.200	0.	.249	1.000
T	1954	.1323	18.580	0.	.236	1.000
	1955	.1405	21.020	0.	.211	1.000
	1956	.0857	18.010	0.	.114	1.000
	1957	.1407	16.810	0.	.283	1.000
	1958	.1646	21.590	0.	.257	1.000
	1959	.1382	15.710	0.	.328	1.000
	1960	.1787	19.750	0.	.343	1.000
H	1961	.1394	20.610	0.	.181	1.000
	1962	.1497	20.120	0.	.262	1.000
	1963	.1525	24.220	0.	.218	1.000
	1964	.1288	21.010	0.	.187	1.000
	1965	.1235	15.980	0.	.231	1.000
	1966	.1368	19.100	0.	.257	1.000
	1967	.1243	18.050	0.	.230	1.000
	1968	.1312	19.160	0.	.211	1.000
	1969	.1534	19.600	0.	.232	1.000
	1970	.1525	18.870	0.	.253	1.000
	1971	.1381	17.430	0.	.257	1.000
	1972	.1246	21.300	0.	.152	1.000
	1973	.1368	19.800	0.	.187	1.000
	1974	.1293	17.650	0.	.216	1.000
	1975	.1168	18.140	0.	.169	1.000
	TMY	.1327	18.620	0.	.234	1.000
	L.T.	.1363	19.053	0.	.226	1.000

APPENDIX E

LONG-TERM AND TMY SIMULATION RESULTS FOR DIFFERENT STORAGE SIZES

TABLE E-1A LONG TERM AND TMY SUMMARY BY YEARS FOR ALBUQUERQUE
WITH 1/2 BASE SYSTEM STORAGE

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	1.862	7.875	8.923	2.908	17.48	52.87	34.57	14.07	48.48	28.11	71.12	.236	1.133	.326	.669	.420	.713
1954	1.848	7.918	8.974	2.689	13.64	44.80	30.60	11.47	43.78	23.75	74.10	.233	1.133	.300	.696	.458	.699
1955	1.972	7.719	8.731	2.642	20.52	54.49	23.45	9.16	34.09	17.80	71.43	.255	1.131	.303	.624	.478	.688
1956	1.939	7.936	8.988	2.856	18.33	52.13	34.63	14.56	48.84	27.91	70.08	.244	1.133	.318	.648	.429	.709
1957	1.993	7.355	8.131	2.586	19.36	52.20	22.02	7.36	32.31	15.81	67.50	.271	1.105	.318	.629	.511	.682
1958	1.906	7.420	8.309	2.741	20.45	53.61	26.49	7.96	38.77	19.48	68.63	.257	1.120	.330	.618	.498	.683
1959	1.863	7.604	8.554	2.727	20.07	54.47	23.32	7.53	34.45	16.75	68.90	.245	1.125	.319	.632	.514	.677
1960	1.911	7.610	8.537	2.646	23.72	55.48	25.72	7.78	37.56	18.90	70.12	.251	1.122	.310	.573	.497	.685
1961	1.845	7.663	8.600	2.533	25.06	58.76	16.29	3.81	25.11	10.71	69.08	.241	1.122	.295	.574	.574	.649
1962	1.857	7.717	8.639	2.538	21.91	54.89	20.90	7.66	30.27	15.10	70.82	.241	1.119	.294	.601	.501	.690
1963	1.855	7.586	8.643	2.634	22.26	54.51	25.39	9.06	36.98	19.10	71.18	.245	1.139	.305	.592	.483	.687
1964	2.001	7.701	8.625	2.651	31.32	65.60	21.82	7.24	31.86	15.61	68.75	.260	1.120	.307	.523	.510	.685
1965	1.935	7.420	8.342	2.415	20.61	54.26	14.25	4.52	21.80	9.86	70.93	.261	1.124	.289	.620	.548	.653
1966	1.877	7.570	8.525	2.576	26.64	60.59	18.42	5.47	28.03	13.03	70.40	.248	1.126	.302	.560	.535	.657
1967	1.934	7.551	8.490	2.335	22.60	53.16	15.16	4.01	23.64	10.35	73.39	.256	1.124	.275	.575	.562	.641
1968	1.883	7.554	8.486	2.460	24.39	57.78	17.78	7.45	26.04	12.87	70.15	.249	1.123	.290	.578	.506	.683
1969	1.946	7.464	8.381	2.759	22.83	58.12	24.35	8.66	35.81	18.25	67.22	.261	1.123	.329	.607	.490	.680
1970	1.958	7.319	8.268	2.790	21.26	58.85	22.36	7.76	32.79	16.94	67.50	.268	1.130	.337	.639	.483	.682
1971	1.865	7.495	8.491	2.587	25.54	61.62	18.41	6.70	26.74	13.71	70.55	.249	1.133	.305	.586	.487	.688
1972	1.906	7.338	8.364	2.335	20.34	51.70	18.09	7.42	26.38	13.79	71.93	.260	1.140	.279	.607	.477	.686
1973	1.918	7.330	8.288	2.617	29.29	63.91	19.59	5.16	29.17	13.93	68.43	.262	1.131	.316	.542	.523	.671
1974	1.970	7.395	8.325	2.543	22.26	54.05	29.24	13.45	40.18	23.72	71.78	.266	1.126	.305	.588	.410	.728
1975	1.931	7.458	8.452	2.550	27.50	62.55	18.53	7.08	26.94	13.57	69.51	.259	1.133	.302	.560	.496	.688
23 YR MEAN	1.912	7.565	8.525	2.614	22.49	56.10	22.67	8.06	33.04	16.92	70.15	.253	1.127	.307	.599	.488	.686
23 YR ST DEV	.048	.184	.225	.147	3.94	4.70	5.66	2.93	7.48	5.07	1.78	.010	.008	.016	.041	.041	.020
TMY YEAR	1.951	7.625	8.610	2.608	21.47	56.31	20.17	6.70	29.45	14.72	69.99	.256	1.129	.303	.619	.500	.685
TMY-23 YR DEV	.039	.060	.085	.006	1.02	.20	2.50	1.36	3.59	2.20	.16	.003	.002	.004	.020	.012	.001

UNITS:

PRIMARY MEASURES:
- HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]
- TBAR: [DEGREES C]
- ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE E-1B LONG TERM AND TMY SUMMARY BY MONTHS FOR ALBUQUERQUE
WITH 1/2 BASE SYSTEM STORAGE

MO	STATISTIC	PRIMARY MEASURES											DERIVED MEASURES					
		HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	23 YR MEAN	.0925	.3571	.5703	.2813	7.138	12.625	0.00	0.00	0.00	0.00	38.11	.259	1.597	.493	.435	1.000	0.000
	23 YR ST DEV	.0087	.0226	.0478	.0257	1.875	1.786	0.00	0.00	0.00	0.00	2.65	.038	.035	.008	.082	0.000	0.000
	TMY YEAR	.0931	.3446	.5469	.2705	7.072	12.380	0.00	0.00	0.00	0.00	36.59	.270	1.587	.495	.429	1.000	0.000
FEB	23 YR MEAN	.1139	.4254	.5922	.2853	3.909	9.448	0.00	0.00	0.00	0.00	47.59	.268	1.392	.482	.586	1.000	0.000
	23 YR ST DEV	.0094	.0269	.0467	.0230	1.779	1.826	0.00	0.00	0.00	0.00	7.82	.035	.024	.022	.118	0.000	0.000
	TMY YEAR	.1203	.4275	.5951	.2909	4.057	9.753	0.00	0.00	0.00	0.00	46.97	.281	1.392	.489	.584	1.000	0.000
MAR	23 YR MEAN	.1767	.6212	.7355	.2908	1.811	7.307	.00	.00	.00	.00	63.21	.284	1.184	.395	.752	.642	.631
	23 YR ST DEV	.0111	.0412	.0565	.0424	1.058	1.716	.01	.01	.02	.01	11.32	.034	.014	.070	.099	.075	.132
	TMY YEAR	.1795	.6135	.7245	.3178	2.430	8.388	0.00	0.00	0.00	0.00	55.14	.293	1.181	.439	.710	1.000	0.000
APR	23 YR MEAN	.2001	.7580	.7798	.1783	.281	3.503	.04	.03	.05	.03	84.68	.264	1.029	.229	.920	.388	.744
	23 YR ST DEV	.0114	.0288	.0313	.0430	.363	1.177	.15	.12	.19	.13	6.87	.022	.005	.060	.070	.163	.232
	TMY YEAR	.1965	.7797	.8079	.1882	0.000	3.490	0.00	0.00	0.00	0.00	86.89	.252	1.036	.233	1.000	1.000	0.000
MAY	23 YR MEAN	.2226	.8922	.8267	.1063	.021	.936	1.86	1.26	2.47	1.57	91.47	.249	.927	.129	.978	.363	.752
	23 YR ST DEV	.0148	.0380	.0343	.0265	.087	.591	1.51	1.16	1.89	1.41	2.76	.025	.004	.031	.083	.165	.097
	TMY YEAR	.2306	.9089	.8436	.1251	0.000	.980	1.95	1.01	2.75	1.57	91.10	.254	.928	.148	1.000	.430	.708
JUN	23 YR MEAN	.2148	.9113	.8039	.1942	0.000	.023	6.82	3.46	9.24	5.56	85.21	.236	.882	.242	1.000	.398	.738
	23 YR ST DEV	.0159	.0446	.0361	.0486	0.000	.062	2.53	1.56	3.19	2.27	2.43	.026	.005	.056	0.000	.052	.032
	TMY YEAR	.2253	.9035	.7923	.1523	0.000	.010	5.23	2.78	7.07	4.24	87.99	.249	.877	.192	1.000	.399	.740
JUL	24 YR MEAN	.2187	.8748	.7938	.2565	0.000	0.000	6.33	1.44	9.54	4.59	81.73	.250	.907	.323	1.000	.519	.664
	24 YR ST DEV	.0117	.0385	.0323	.0255	0.000	.000	.97	.44	1.31	.90	.90	.020	.005	.028	0.000	.039	.018
	TMY YEAR	.2285	.8747	.7968	.2716	0.000	0.000	6.89	1.69	10.10	4.82	81.26	.261	.911	.341	1.000	.523	.682
AUG	24 YR MEAN	.1966	.8050	.7978	.2307	0.000	0.000	5.17	1.16	7.90	3.49	82.49	.244	.991	.289	1.000	.558	.654
	24 YR ST DEV	.0087	.0374	.0367	.0407	0.000	0.000	1.35	.37	1.86	1.05	1.51	.019	.004	.043	0.000	.042	.024
	TMY YEAR	.2004	.8120	.8041	.2212	0.000	0.000	5.17	1.10	7.86	3.63	82.22	.247	.990	.275	1.000	.538	.658
SEP	24 YR MEAN	.1645	.6707	.7598	.1291	.013	.192	2.50	.74	3.84	1.73	87.45	.245	1.133	.170	.933	.548	.652
	24 YR ST DEV	.0116	.0428	.0530	.0405	.063	.294	1.77	.92	2.36	1.52	3.71	.031	.009	.049	.048	.112	.063
	TMY YEAR	.1778	.6660	.7518	.0823	0.000	.033	.93	.12	1.68	.46	91.69	.267	1.129	.110	1.000	.729	.556
OCT	24 YR MEAN	.1308	.5435	.7255	.1207	.247	2.218	.11	.01	.21	.06	87.79	.241	1.335	.166	.889	.726	.512
	24 YR ST DEV	.0099	.0449	.0713	.0356	.324	.979	.16	.03	.29	.10	7.30	.038	.024	.060	.106	.144	.239
	TMY YEAR	.1222	.5617	.7555	.1039	.322	2.043	0.00	0.00	0.00	0.00	90.86	.218	1.345	.138	.842	1.000	0.000
NOV	24 YR MEAN	.0964	.3855	.5979	.2715	2.316	7.703	0.00	0.00	0.00	0.00	54.28	.250	1.551	.454	.699	1.000	0.000
	24 YR ST DEV	.0063	.0238	.0456	.0256	1.170	1.230	0.00	0.00	0.00	0.00	9.04	.027	.025	.038	.109	0.000	0.000
	TMY YEAR	.0961	.3987	.6223	.3029	1.552	7.649	0.00	0.00	0.00	0.00	51.05	.241	1.561	.487	.797	1.000	0.000
DEC	24 YR MEAN	.0832	.3258	.5469	.2694	6.893	12.202	0.00	0.00	0.00	0.00	37.78	.255	1.679	.493	.435	1.000	0.000
	24 YR ST DEV	.0091	.0224	.0511	.0287	1.701	1.374	0.00	0.00	0.00	0.00	3.52	.044	.045	.009	.086	0.000	0.000
	TMY YEAR	.0804	.3343	.5691	.2808	6.037	11.580	0.00	0.00	0.00	0.00	38.11	.241	1.702	.493	.479	1.000	0.000

TABLE E-2A LONG TERM AND TMY SUMMARY BY YEARS FOR MADISON
WITH 1/2 BASE SYSTEM STORAGE

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.066	4.984	5.527	1.267	53.21	96.13	12.78	5.00	20.39	4.71	65.00	.414	1.109	.229	.447	.769	.627
1954	2.035	4.638	5.122	1.361	50.69	100.37	11.23	4.71	18.05	4.20	63.45	.439	1.104	.266	.495	.767	.622
1955	2.053	5.053	5.589	1.377	59.81	105.32	17.50	7.10	27.48	8.87	64.32	.406	1.106	.246	.432	.677	.637
1956	2.041	4.748	5.265	1.272	57.28	104.36	9.08	3.74	14.65	2.97	65.15	.430	1.109	.242	.451	.797	.620
1957	2.006	4.609	5.110	1.286	56.88	105.54	9.08	3.94	14.68	3.58	61.71	.435	1.109	.252	.461	.756	.618
1958	2.137	5.119	5.779	1.311	53.89	104.65	7.01	2.75	11.47	1.83	67.55	.418	1.129	.227	.485	.840	.611
1959	2.136	4.843	5.338	1.406	62.76	111.75	14.15	6.12	22.89	5.96	61.44	.441	1.102	.263	.438	.740	.618
1960	2.066	4.931	5.492	1.287	60.37	109.71	8.38	4.05	13.66	3.43	63.43	.419	1.114	.234	.450	.749	.613
1961	2.064	5.028	5.498	1.325	58.77	107.79	9.67	4.47	15.62	2.87	61.53	.410	1.093	.241	.455	.816	.619
1962	2.139	4.909	5.376	1.272	64.67	112.95	7.12	3.03	11.74	1.01	63.00	.436	1.095	.237	.427	.914	.606
1963	2.126	5.200	5.752	1.319	65.27	110.63	11.44	4.99	18.46	2.89	66.82	.409	1.106	.229	.410	.843	.620
1964	2.122	5.162	5.726	1.491	49.04	102.66	12.58	5.20	20.11	3.94	65.25	.411	1.109	.260	.522	.804	.625
1965	2.092	4.921	5.406	1.280	58.74	110.69	5.05	2.15	8.26	1.02	62.85	.425	1.099	.237	.469	.876	.611
1966	2.068	5.224	5.827	1.486	55.15	114.11	8.15	3.50	13.21	2.34	62.85	.396	1.115	.255	.517	.823	.617
1967	2.111	4.797	5.264	1.261	60.32	113.54	3.27	1.45	5.48	.34	62.86	.440	1.097	.240	.469	.938	.596
1968	2.057	5.165	5.758	1.367	50.68	102.80	9.07	4.14	14.57	3.33	66.58	.398	1.115	.237	.507	.771	.622
1969	2.202	4.894	5.477	1.417	56.89	113.75	6.38	2.89	10.58	1.29	63.22	.450	1.119	.259	.500	.878	.603
1970	2.078	5.121	5.721	1.417	54.65	108.84	8.75	3.79	14.29	2.33	64.31	.406	1.117	.248	.498	.837	.612
1971	2.142	5.158	5.749	1.399	56.63	107.30	10.79	4.50	17.48	3.04	65.82	.415	1.115	.243	.472	.826	.617
1972	2.175	4.669	5.129	1.278	67.28	118.53	6.26	2.80	10.14	2.09	62.11	.466	1.098	.249	.432	.794	.618
1973	2.063	4.646	5.150	1.292	50.66	98.52	8.99	3.83	14.70	2.63	63.62	.444	1.109	.251	.486	.821	.611
1974	2.075	4.730	5.206	1.248	56.00	105.51	6.16	2.42	9.96	1.89	64.14	.439	1.101	.240	.469	.810	.618
1975	2.118	4.853	5.348	1.373	56.27	104.29	11.93	4.74	19.28	3.48	65.77	.436	1.102	.257	.460	.820	.619
23 YR MEAN	2.095	4.931	5.461	1.339	57.21	107.38	9.34	3.97	15.09	3.05	64.03	.425	1.108	.245	.467	.798	.619
23 YR ST DEV	.048	.198	.241	.072	4.86	5.49	3.20	1.30	5.01	1.80	1.73	.018	.009	.011	.030	.058	.008
TMY YEAR	2.144	4.930	5.442	1.320	57.87	107.72	7.98	3.31	13.15	1.79	65.27	.435	1.104	.243	.463	.864	.607
TMY-23 YR DEV	.050	.001	.019	.019	.66	.34	1.36	.66	1.95	1.25	1.24	.010	.004	.003	.004	.065	.012

UNITS:
PRIMARY MEASURES:
HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]
TBAR: [DEGREES C]
ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE E-2B LONG TERM AND TMY SUMMARY BY MONTHS FOR MADISON
WITH 1/2 BASE SYSTEM STORAGE

MO	STATISTIC	PRIMARY MEASURES											DERIVED MEASURES					
		HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	23 YR MEAN	.0875	.1807	.2967	.1164	15.986	21.658	0.000	0.000	0.000	0.000	31.77	.484	1.642	.392	.262	1.000	0.000
	23 YR ST DEV	.0052	.0198	.0460	.0234	2.106	2.115	0.000	0.000	0.000	0.000	.92	.058	.082	.024	.054	0.000	0.000
	TMY YEAR	.0868	.1833	.3003	.1171	16.990	22.710	0.000	0.000	0.000	0.000	32.41	.474	1.638	.390	.252	1.000	0.000
FEB	23 YR MEAN	.1128	.2538	.3677	.1550	10.513	18.083	0.000	0.000	0.000	0.000	34.78	.444	1.449	.422	.419	1.000	0.000
	23 YR ST DEV	.0078	.0244	.0480	.0234	1.841	1.854	0.000	0.000	0.000	0.000	1.83	.053	.059	.014	.064	0.000	0.000
	TMY YEAR	.1287	.2557	.3518	.1434	11.480	18.520	0.000	0.000	0.000	0.000	34.01	.503	1.376	.408	.380	1.000	0.000
MAR	23 YR MEAN	.1757	.3990	.4829	.2022	5.769	15.526	0.000	0.000	0.000	0.000	44.10	.440	1.210	.419	.628	1.000	0.000
	23 YR ST DEV	.0122	.0406	.0594	.0320	1.591	2.118	0.000	0.000	0.000	0.000	5.45	.048	.032	.030	.079	0.000	0.000
	TMY YEAR	.1763	.4267	.5279	.2308	5.781	16.950	0.000	0.000	0.000	0.000	43.08	.413	1.237	.437	.659	1.000	0.000
APR	23 YR MEAN	.2111	.4754	.4931	.1464	1.557	8.307	.009	.003	.017	0.000	65.88	.444	1.037	.297	.813	1.000	.507
	23 YR ST DEV	.0121	.0403	.0474	.0168	.846	1.451	.025	.010	.048	0.000	8.87	.048	.015	.050	.082	0.000	.171
	TMY YEAR	.2240	.4710	.4887	.1440	.712	7.557	0.000	0.000	0.000	0.000	71.90	.476	1.038	.295	.906	1.000	0.000
MAY	23 YR MEAN	.2577	.6125	.5730	.0889	.241	3.472	.266	.103	.451	.033	85.48	.421	.936	.155	.931	.926	.589
	23 YR ST DEV	.0163	.0712	.0671	.0183	.343	1.293	.375	.147	.624	.075	6.27	.048	.005	.036	.085	.050	.269
	TMY YEAR	.2592	.5989	.5544	.0868	.538	3.262	.402	.146	.676	.022	83.95	.433	.926	.157	.835	.967	.594
JUN	23 YR MEAN	.2733	.6625	.5927	.0735	.002	.540	1.968	.816	3.181	.535	92.05	.413	.895	.124	.996	.832	.619
	23 YR ST DEV	.0146	.0558	.0505	.0271	.011	.461	1.310	.545	2.075	.536	3.45	.051	.004	.042	.012	.079	.022
	TMY YEAR	.2761	.6383	.5715	.0644	0.000	.358	1.672	.675	2.747	.490	93.67	.433	.895	.113	1.000	.822	.609
JUL	24 YR MEAN	.2667	.6797	.6210	.1058	0.000	.061	3.631	1.545	5.874	1.287	89.34	.392	.914	.170	1.000	.781	.618
	24 YR ST DEV	.0148	.0519	.0478	.0317	0.000	.116	1.622	.676	2.497	.926	2.80	.045	.004	.046	0.000	.068	.015
	TMY YEAR	.2665	.6742	.6177	.1077	0.000	0.000	3.577	1.474	5.795	.960	87.93	.395	.916	.174	1.000	.834	.617
AUG	24 YR MEAN	.2331	.6002	.6013	.0847	0.000	.147	2.760	1.198	4.433	.945	90.86	.388	1.002	.141	1.000	.787	.623
	24 YR ST DEV	.0117	.0413	.0444	.0266	0.000	.228	1.471	.623	2.273	.937	2.84	.036	.008	.044	0.000	.088	.023
	TMY YEAR	.2380	.6159	.6177	.0792	0.000	.114	2.052	.892	3.414	.321	91.84	.386	1.003	.128	1.000	.906	.601
SEP	24 YR MEAN	.1821	.4418	.5081	.0691	.005	1.977	.711	.309	1.145	.281	90.44	.412	1.150	.136	.998	.755	.620
	24 YR ST DEV	.0100	.0398	.0530	.0138	.019	.651	.780	.349	1.224	.446	4.04	.042	.021	.032	.009	.131	.133
	TMY YEAR	.1913	.4548	.5224	.0435	0.000	1.117	.278	.127	.513	0.000	95.17	.421	1.149	.083	1.000	1.000	.542
OCT	24 YR MEAN	.1345	.3199	.4387	.1068	.938	5.994	.034	.013	.059	.001	73.93	.420	1.372	.244	.843	.984	.571
	24 YR ST DEV	.0082	.0380	.0635	.0259	.902	1.643	.083	.033	.135	.005	10.34	.052	.045	.059	.118	.008	.243
	TMY YEAR	.1424	.3043	.4018	.1210	.550	6.010	0.000	0.000	0.000	0.000	75.36	.468	1.320	.301	.908	1.000	0.000
NOV	24 YR MEAN	.0877	.1712	.2631	.1056	7.248	12.538	0.000	0.000	0.000	0.000	38.94	.512	1.537	.401	.422	1.000	0.000
	24 YR ST DEV	.0069	.0200	.0383	.0172	1.707	1.422	0.000	0.000	0.000	0.000	7.07	.050	.060	.025	.085	0.000	0.000
	TMY YEAR	.0857	.1742	.2708	.0938	7.450	12.460	0.000	0.000	0.000	0.000	42.44	.492	1.554	.346	.402	1.000	0.000
DEC	24 YR MEAN	.0723	.1363	.2278	.0876	14.802	19.052	0.000	0.000	0.000	0.000	31.12	.530	1.671	.385	.223	1.000	0.000
	24 YR ST DEV	.0077	.0181	.0392	.0184	1.960	1.965	0.000	0.000	0.000	0.000	.59	.053	.092	.022	.049	0.000	0.000
	TMY YEAR	.0690	.1327	.2169	.0883	14.370	18.660	0.000	0.000	0.000	0.000	31.53	.520	1.635	.407	.230	1.000	0.000

TABLE E-3A LONG TERM AND TMY SUMMARY BY YEARS FOR MADISON WITH 1/4 BASE SYSTEM STORAGE

	PRIMARY MEASURES											DERIVED MEASURES					
YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
1953	2.066	4.984	5.527	1.127	55.55	96.01	12.91	5.04	20.40	7.18	64.37	.414	1.109	.204	.421	.648	.633
1954	2.035	4.638	5.122	1.223	52.84	100.08	11.40	4.77	18.16	6.76	62.38	.439	1.104	.239	.472	.628	.628
1955	2.053	5.053	5.589	1.237	62.03	105.37	17.72	7.16	27.69	11.77	63.59	.406	1.106	.221	.411	.575	.640
1956	2.041	4.748	5.265	1.135	59.78	104.43	9.25	3.79	14.59	5.23	64.60	.430	1.109	.216	.428	.642	.634
1957	2.006	4.609	5.110	1.168	58.90	105.52	9.15	3.96	14.61	5.40	61.41	.435	1.109	.229	.442	.631	.627
1958	2.137	5.119	5.779	1.202	55.79	104.93	7.18	2.82	11.52	3.53	66.57	.418	1.129	.208	.468	.694	.623
1959	2.136	4.843	5.338	1.266	64.91	111.64	14.29	6.17	22.88	8.73	61.02	.441	1.102	.237	.419	.619	.624
1960	2.066	4.931	5.492	1.168	62.67	110.06	8.53	4.11	13.77	5.50	62.87	.419	1.114	.213	.431	.601	.620
1961	2.064	5.028	5.498	1.183	61.24	107.68	9.78	4.51	15.60	5.39	61.37	.410	1.093	.215	.431	.654	.627
1962	2.139	4.909	5.376	1.150	66.57	112.71	7.25	3.08	11.72	3.06	62.32	.436	1.095	.214	.409	.739	.619
1963	2.126	5.200	5.752	1.195	66.76	110.91	11.61	5.05	18.38	5.62	65.85	.409	1.106	.208	.398	.694	.632
1964	2.122	5.162	5.726	1.344	51.81	102.48	12.73	5.24	20.11	6.35	65.02	.411	1.109	.235	.494	.684	.633
1965	2.092	4.921	5.406	1.165	61.02	110.49	5.12	2.18	8.27	2.23	62.09	.425	1.099	.216	.448	.730	.619
1966	2.068	5.224	5.827	1.357	57.63	113.89	8.26	3.53	13.23	4.16	62.10	.396	1.115	.233	.494	.685	.624
1967	2.111	4.797	5.264	1.157	62.67	113.59	3.38	1.49	5.58	1.37	62.14	.440	1.097	.220	.448	.755	.604
1968	2.057	5.165	5.758	1.230	53.21	102.53	9.17	4.17	14.52	5.14	65.47	.398	1.115	.214	.481	.646	.632
1969	2.202	4.894	5.477	1.279	59.83	113.48	6.41	2.89	10.50	2.84	62.71	.450	1.119	.234	.473	.730	.610
1970	2.078	5.121	5.721	1.272	57.48	108.63	8.87	3.84	14.24	4.40	63.26	.406	1.117	.222	.471	.691	.623
1971	2.142	5.158	5.749	1.257	58.79	107.33	11.03	4.60	17.60	6.04	64.80	.415	1.115	.219	.452	.657	.626
1972	2.175	4.669	5.129	1.154	70.03	118.37	6.35	2.83	10.19	3.53	61.54	.466	1.098	.225	.408	.654	.623
1973	2.063	4.646	5.150	1.153	53.27	98.34	9.13	3.89	14.70	4.71	62.70	.444	1.109	.224	.458	.680	.621
1974	2.075	4.730	5.206	1.123	58.85	105.42	6.25	2.44	10.00	3.21	63.63	.439	1.101	.216	.442	.679	.625
1975	2.118	4.853	5.348	1.239	58.17	104.35	12.12	4.81	19.40	6.29	64.67	.436	1.102	.232	.442	.676	.625
23 YR MEAN	2.095	4.931	5.461	1.208	59.56	107.31	9.47	4.02	15.11	5.15	63.33	.425	1.108	.221	.445	.659	.627
23 YR ST DEV	.048	.198	.241	.066	4.75	5.49	3.24	1.31	5.03	2.24	1.57	.018	.009	.010	.028	.045	.008
TMY YEAR	2.144	4.930	5.442	1.181	60.72	107.69	8.16	3.38	13.19	3.77	64.55	.435	1.104	.217	.436	.714	.619
TMY-23 YR DEV	.050	.001	.019	.027	1.17	.38	1.31	.63	1.92	1.38	1.22	.010	.004	.004	.009	.055	.008

UNITS:

PRIMARY MEASURES:
- HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]
- TBAR: [DEGREES C]
- ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE E-38 LONG TERM AND TMY SUMMARY BY MONTHS FOR MADISON
WITH 1/4 BASE SYSTEM STORAGE

		PRIMARY MEASURES											DERIVED MEASURES					
MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	23 YR MEAN	.0875	.1807	.2967	.1122	16.109	21.634	0.000	0.000	0.000	0.000	32.26	.484	1.642	.378	.255	1.000	0.000
	23 YR ST DEV	.0052	.0198	.0460	.0223	2.047	2.098	0.000	0.000	0.000	0.000	1.33	.058	.082	.021	.051	0.000	0.000
	TMY YEAR	.0868	.1853	.3003	.1117	17.210	22.740	0.000	0.000	0.000	0.000	32.92	.474	1.638	.372	.243	1.000	0.000
FEB	23 YR MEAN	.1128	.2538	.3677	.1470	10.802	18.055	0.000	0.000	0.000	0.000	36.49	.444	1.449	.400	.402	1.000	0.000
	23 YR ST DEV	.0078	.0244	.0480	.0218	1.777	1.857	0.000	0.000	0.000	0.000	2.13	.053	.059	.012	.058	0.000	0.000
	TMY YEAR	.1267	.2557	.3518	.1358	11.800	18.530	0.000	0.000	0.000	0.000	35.44	.503	1.376	.386	.363	1.000	0.000
MAR	23 YR MEAN	.1757	.3990	.4829	.1843	6.396	15.423	0.000	0.000	0.000	0.000	46.23	.440	1.210	.382	.585	1.000	0.000
	23 YR ST DEV	.0122	.0406	.0594	.0298	1.507	2.136	0.000	0.000	0.000	0.000	4.52	.048	.032	.030	.070	0.000	0.000
	TMY YEAR	.1763	.4267	.5279	.2058	6.675	16.820	0.000	0.000	0.000	0.000	46.48	.413	1.237	.390	.603	1.000	0.000
APR	23 YR MEAN	.2111	.4754	.4931	.1302	2.032	8.239	.008	.003	.017	.002	63.80	.444	1.037	.264	.753	.878	.501
	23 YR ST DEV	.0121	.0403	.0474	.0153	.904	1.428	.025	.010	.047	.010	7.60	.048	.015	.044	.080	.052	.167
	TMY YEAR	.2240	.4710	.4887	.1287	1.150	7.400	0.000	0.000	0.000	0.000	69.06	.476	1.038	.263	.845	1.000	0.000
MAY	23 YR MEAN	.2577	.6125	.5730	.0791	.376	3.536	.278	.108	.462	.118	83.09	.421	.936	.138	.894	.744	.602
	23 YR ST DEV	.0163	.0712	.0671	.0179	.391	1.290	.389	.152	.630	.186	5.99	.048	.005	.034	.091	.143	.277
	TMY YEAR	.2592	.5989	.5544	.0771	.675	3.371	.438	.159	.735	.105	81.09	.433	.926	.139	.800	.857	.597
JUN	23 YR MEAN	.2733	.6625	.5927	.0605	.010	.591	2.001	.826	3.182	1.026	90.64	.413	.895	.102	.983	.678	.629
	23 YR ST DEV	.0146	.0558	.0505	.0218	.032	.457	1.322	.548	2.057	.790	3.82	.051	.004	.034	.038	.086	.028
	TMY YEAR	.2761	.6383	.5715	.0521	0.000	.379	1.687	.681	2.710	.864	92.71	.433	.895	.091	1.000	.681	.623
JUL	24 YR MEAN	.2667	.6797	.6210	.0856	0.000	.074	3.672	1.559	5.869	2.019	87.82	.392	.914	.138	1.000	.656	.626
	24 YR ST DEV	.0148	.0519	.0478	.0272	0.000	.133	1.646	.684	2.514	1.145	2.55	.045	.004	.040	0.000	.058	.014
	TMY YEAR	.2665	.6742	.6177	.0881	0.000	0.000	3.644	1.497	5.806	1.717	86.81	.395	.916	.143	1.000	.704	.628
AUG	24 YR MEAN	.2331	.6002	.6013	.0679	.000	.170	2.795	1.210	4.437	1.567	89.54	.388	1.002	.113	.998	.647	.630
	24 YR ST DEV	.0117	.0413	.0444	.0227	.002	.248	1.483	.627	2.279	1.076	2.86	.036	.008	.038	.003	.082	.028
	TMY YEAR	.2380	.6159	.6177	.0611	0.000	.152	2.075	.901	3.377	.905	90.61	.386	1.003	.099	1.000	.732	.614
SEP	24 YR MEAN	.1821	.4418	.5081	.0612	.043	2.055	.724	.314	1.150	.445	87.77	.412	1.150	.120	.979	.612	.630
	24 YR ST DEV	.0100	.0398	.0530	.0110	.067	.626	.790	.353	1.231	.559	4.47	.042	.021	.026	.031	.156	.136
	TMY YEAR	.1913	.4548	.5224	.0376	0.000	1.181	.317	.145	.567	.179	93.23	.421	1.149	.072	1.000	.684	.560
OCT	24 YR MEAN	.1345	.3199	.4387	.0990	1.225	5.968	.036	.014	.063	.014	71.25	.420	1.372	.226	.795	.781	.570
	24 YR ST DEV	.0082	.0380	.0635	.0231	.996	1.580	.084	.034	.135	.034	9.65	.052	.045	.053	.131	.126	.246
	TMY YEAR	.1424	.3043	.4018	.1073	.950	5.967	0.000	0.000	0.000	0.000	72.95	.468	1.320	.267	.841	1.000	0.000
NOV	24 YR MEAN	.0877	.1712	.2631	.0993	7.528	12.492	0.000	0.000	0.000	0.000	39.89	.512	1.537	.378	.397	1.000	0.000
	24 YR ST DEV	.0069	.0200	.0383	.0157	1.633	1.439	0.000	0.000	0.000	0.000	6.28	.050	.060	.024	.077	0.000	0.000
	TMY YEAR	.0857	.1742	.2708	.0909	7.725	12.430	0.000	0.000	0.000	0.000	41.33	.492	1.554	.336	.379	1.000	0.000
DEC	24 YR MEAN	.0723	.1363	.2278	.0845	14.900	19.050	0.000	0.000	0.000	0.000	31.55	.530	1.671	.371	.218	1.000	0.000
	24 YR ST DEV	.0077	.0181	.0392	.0177	1.930	1.958	0.000	0.000	0.000	0.000	.89	.053	.092	.020	.047	0.000	0.000
	TMY YEAR	.0690	.1327	.2169	.0845	14.540	18.720	0.000	0.000	0.000	0.000	31.93	.520	1.635	.389	.223	1.000	0.000

TABLE E-4A LONG TERM AND TMY SUMMARY BY YEARS FOR WASHINGTON
WITH 1/4 BASE SYSTEM STORAGE

YEAR	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
	PRIMARY MEASURES											DERIVED MEASURES					
1954	2.220	5.173	5.596	1.264	21.80	58.49	27.14	10.33	42.50	18.65	69.34	.429	1.082	.226	.627	.561	.639
1955	2.204	4.972	5.433	1.242	23.77	60.73	28.01	12.24	43.73	21.45	70.14	.443	1.093	.229	.609	.509	.641
1956	2.152	4.832	5.153	1.136	25.27	60.33	20.97	8.82	33.06	14.04	67.58	.445	1.066	.220	.581	.575	.634
1957	2.215	4.967	5.303	1.243	23.44	58.01	28.28	11.20	44.15	19.09	67.29	.446	1.068	.234	.596	.568	.641
1958	2.194	4.983	5.462	1.196	28.72	66.27	21.72	9.72	34.56	15.15	68.42	.440	1.096	.219	.567	.562	.628
1959	2.242	5.068	5.501	1.385	19.88	57.08	37.11	16.05	57.81	28.44	68.47	.442	1.085	.252	.652	.508	.642
1960	2.257	5.136	5.570	1.305	25.88	64.93	25.91	10.75	41.20	17.71	68.78	.439	1.084	.234	.601	.570	.629
1961	2.188	4.927	5.391	1.298	25.44	62.73	30.19	14.14	47.45	22.78	69.20	.444	1.094	.241	.594	.520	.636
1962	2.165	4.958	5.400	1.248	31.67	68.86	23.12	9.35	36.72	14.16	67.67	.437	1.089	.231	.540	.614	.630
1963	2.194	5.487	6.030	1.243	30.54	72.96	16.17	6.19	25.44	8.75	70.91	.400	1.099	.206	.581	.656	.635
1964	2.224	5.020	5.503	1.295	25.56	69.56	19.23	8.10	30.24	12.36	67.84	.443	1.096	.235	.632	.591	.636
1965	2.213	5.127	5.610	1.326	25.34	69.90	19.56	8.46	30.95	11.81	68.01	.432	1.094	.236	.637	.618	.632
1966	2.215	5.142	5.544	1.331	31.58	78.75	16.85	6.82	26.38	9.62	66.55	.431	1.078	.240	.599	.635	.639
1967	2.232	4.905	5.398	1.246	27.51	74.40	12.01	5.49	19.30	6.72	67.89	.455	1.101	.231	.630	.652	.622
1968	2.240	5.149	5.602	1.261	30.27	73.28	17.08	7.91	27.01	9.93	68.85	.435	1.088	.225	.587	.632	.632
1969	2.234	5.012	5.447	1.228	35.74	77.19	18.78	8.65	29.71	12.55	66.55	.446	1.087	.225	.537	.577	.632
1970	2.198	5.045	5.390	1.156	36.54	75.92	13.66	6.16	21.89	6.13	65.39	.436	1.068	.215	.519	.720	.624
1971	2.236	4.819	5.160	1.197	27.64	67.50	16.95	7.93	26.94	9.69	67.16	.464	1.071	.232	.590	.640	.629
1972	2.196	4.714	5.083	1.182	28.92	71.33	14.11	6.66	22.37	8.59	67.75	.466	1.078	.233	.595	.616	.631
1973	2.250	4.669	5.083	1.223	28.32	65.78	21.71	10.08	34.43	13.44	67.41	.482	1.089	.241	.570	.610	.630
1974	2.253	4.854	5.225	1.114	28.19	67.50	12.83	6.07	20.41	7.01	69.70	.464	1.076	.213	.582	.657	.629
1975	2.233	4.753	5.122	1.192	31.34	70.61	16.88	8.20	27.23	9.68	67.61	.470	1.078	.233	.556	.644	.620
22 YR MEAN	2.216	4.987	5.409	1.241	27.88	67.82	20.83	9.06	32.89	13.53	68.11	.444	1.085	.229	.589	.588	.633
22 YR ST DEV	.028	.183	.222	.066	4.13	6.35	6.40	2.67	9.88	5.78	1.27	.017	.011	.010	.034	.053	.006
TMY YEAR	2.199	5.037	5.489	1.202	27.69	67.32	18.53	8.31	29.37	11.68	69.75	.437	1.090	.219	.589	.602	.631
TMY-22 YR DEV	.017	.050	.080	.039	.19	.50	2.30	.75	3.52	1.85	1.63	.008	.005	.010	.000	.014	.002

UNITS:
PRIMARY MEASURES:
HDIF, HHOR, HTILT, QU: [GJ/SQ. METER]
TBAR: [DEGREES C]
ALL OTHERS: [GJ]

DERIVED MEASURES: [DIMENSIONLESS]

TABLE E-4B LONG TERM AND TMY SUMMARY BY MONTHS FOR WASHINGTON
WITH 1/4 BASE SYSTEM STORAGE

		PRIMARY MEASURES											DERIVED MEASURES					
MO	STATISTIC	HDIF	HHOR	HTILT	QU	QAUXH	QLH	QAC	QLAT	QLC	QAUXC	TBAR	FDIF	RBAR	FCOL	F-HTG	F-CLG	COP
JAN	22 YR MEAN	.0965	.2011	.2995	.1215	8.670	14.653	0.000	0.000	0.000	0.000	36.56	.480	1.489	.405	.408	1.000	0.000
	22 YR ST DEV	.0076	.0178	.0357	.0170	1.614	1.714	0.000	0.000	0.000	0.000	2.75	.055	.062	.011	.062	0.000	0.000
	TMY YEAR	.0934	.2141	.3301	.1332	8.975	15.570	0.000	0.000	0.000	0.000	38.40	.436	1.542	.404	.424	1.000	0.000
FEB	22 YR MEAN	.1202	.2573	.3408	.1365	5.734	12.402	0.000	0.000	0.000	0.000	42.73	.467	1.325	.400	.538	1.000	0.000
	22 YR ST DEV	.0097	.0273	.0436	.0194	1.517	1.722	0.000	0.000	0.000	0.000	4.44	.050	.040	.018	.084	0.000	0.000
	TMY YEAR	.1181	.2585	.3422	.1368	6.687	13.310	0.000	0.000	0.000	0.000	43.27	.457	1.324	.400	.498	1.000	0.000
MAR	22 YR MEAN	.1815	.3953	.4548	.1495	2.618	9.858	0.000	0.000	0.000	0.000	57.33	.459	1.151	.329	.734	1.000	0.000
	22 YR ST DEV	.0134	.0430	.0554	.0204	1.178	1.582	0.000	0.000	0.000	0.000	6.82	.047	.020	.037	.087	0.000	0.000
	TMY YEAR	.1861	.4154	.4774	.1510	2.137	9.622	0.000	0.000	0.000	0.000	59.65	.448	1.149	.316	.778	1.000	0.000
APR	22 YR MEAN	.2230	.4963	.5066	.0951	.495	4.663	.175	.053	.293	.072	76.83	.449	1.021	.188	.894	.753	.597
	22 YR ST DEV	.0131	.0569	.0625	.0176	.481	1.258	.310	.087	.498	.155	7.23	.058	.011	.044	.079	.135	.278
	TMY YEAR	.2206	.5048	.5166	.0909	.387	4.252	.109	.028	.204	.060	77.46	.437	1.023	.176	.909	.705	.537
MAY	22 YR MEAN	.2662	.6055	.5648	.0538	.049	1.414	.797	.326	1.293	.392	89.62	.440	.933	.095	.965	.697	.616
	22 YR ST DEV	.0149	.0593	.0566	.0123	.099	.864	.831	.342	1.316	.484	3.91	.044	.004	.025	.073	.140	.183
	TMY YEAR	.2667	.6021	.5608	.0422	0.000	1.257	.713	.272	1.045	.522	93.13	.443	.931	.075	1.000	.501	.682
JUN	22 YR MEAN	.2729	.6465	.5797	.0841	0.000	.094	3.829	1.628	6.048	2.197	87.95	.422	.897	.145	1.000	.637	.633
	22 YR ST DEV	.0171	.0538	.0471	.0263	0.000	.136	1.636	.674	2.509	1.140	2.77	.044	.003	.044	0.000	.051	.015
	TMY YEAR	.2608	.6442	.5791	.0584	0.000	0.000	2.466	1.159	3.989	1.413	90.24	.405	.899	.101	1.000	.646	.618
JUL	22 YR MEAN	.2788	.6287	.5754	.1308	0.000	0.000	7.081	3.068	11.110	4.807	82.61	.443	.915	.227	1.000	.567	.637
	22 YR ST DEV	.0170	.0494	.0452	.0201	0.000	0.000	1.851	.793	2.782	1.886	1.46	.052	.003	.032	0.000	.063	.009
	TMY YEAR	.2875	.6041	.5502	.1288	0.000	0.000	6.855	3.125	10.800	4.584	81.93	.476	.911	.234	1.000	.576	.635
AUG	23 YR MEAN	.2453	.5694	.5630	.1165	0.000	.004	6.138	2.712	9.688	4.130	83.36	.431	.989	.207	1.000	.574	.634
	23 YR ST DEV	.0124	.0393	.0412	.0245	0.000	.018	1.928	.882	2.951	1.837	1.87	.041	.008	.041	0.000	.066	.007
	TMY YEAR	.2376	.5984	.5891	.1241	0.000	0.000	5.923	2.555	9.361	3.503	83.78	.397	.984	.211	1.000	.626	.633
SEP	23 YR MEAN	.1958	.4528	.5010	.0624	.010	.409	2.580	1.148	4.083	1.745	87.88	.432	1.107	.125	.975	.573	.632
	23 YR ST DEV	.0107	.0501	.0631	.0209	.038	.380	1.709	.805	2.645	1.450	3.41	.052	.020	.039	.031	.082	.028
	TMY YEAR	.1873	.4470	.4951	.0573	0.000	.140	2.466	1.171	3.972	1.598	90.07	.419	1.108	.116	1.000	.598	.621
OCT	23 YR MEAN	.1466	.3497	.4521	.0732	.133	3.326	.247	.108	.395	.202	83.49	.419	1.293	.162	.960	.489	.625
	23 YR ST DEV	.0076	.0373	.0582	.0236	.173	1.334	.658	.291	1.024	.595	6.46	.048	.036	.051	.045	.206	.291
	TMY YEAR	.1490	.3458	.4461	.0656	0.000	3.016	0.000	0.000	0.000	0.000	87.81	.431	1.290	.147	1.000	1.000	0.000
NOV	23 YR MEAN	.1020	.2214	.3238	.1129	2.273	7.865	.006	.003	.010	.003	54.13	.461	1.463	.349	.711	.681	.586
	23 YR ST DEV	.0070	.0216	.0400	.0142	1.031	1.185	.027	.013	.041	.015	7.70	.050	.049	.040	.102	.077	.139
	TMY YEAR	.1101	.2303	.3323	.1037	2.562	7.563	0.000	0.000	0.000	0.000	54.04	.478	1.443	.312	.661	1.000	0.000
DEC	23 YR MEAN	.0857	.1687	.2564	.1037	7.781	12.908	0.000	0.000	0.000	0.000	35.92	.508	1.520	.404	.397	1.000	0.000
	23 YR ST DEV	.0066	.0177	.0344	.0161	1.748	2.115	0.000	0.000	0.000	0.000	2.38	.050	.062	.013	.060	0.000	0.000
	TMY YEAR	.0815	.1722	.2704	.1105	6.937	12.590	0.000	0.000	0.000	0.000	37.20	.473	1.570	.409	.449	1.000	0.000

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report is a summary of an evaluation of the weather data set, generated at Sandia Laboratories, known as the "Typical Meteorological Year" (TMY) Data. The purpose of the evaluation is to determine how well the TMY data represent actual long-term weather data in affecting the performance of solar heating and cooling systems. The two data sets are compared through detailed SHAC simulation.

17. Document Analysis

a. Descriptors Solar Heating Systems ; Solar Cooling Systems ; Temperature ; Wind Speed ; Insolation ; Weather ; Typical Meteorological Year ; Simulations ; Hedstrom Year ; F-Chart ; TRNSYS ; SOLMET

b. Identifiers/Open-Ended Terms National Oceanic and Atmospheric Administration. National Climatic Center.

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