Solar House
Design Program Validation

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REVIEW OF PRESENT DESIGN PROCEDURES

It is important that the designer of solar heating and/or cooling systems be able to perform rapid and approximate calculations for determining the size of the various components that constitute a solar heating and/or cooling system. These approximation techniques may be used to provide quick checks against more detailed analyses to ensure against possible gross errors, and may also be used to provide information to a potential client.

DESIGN GUIDELINES

The primary information required for quick sizing of a solar system is the mean daily solar insolation and the average ambient temperature or the average degree days for the given location. By knowing the degree days for the location, or the average ambient temperature, and by knowing the design heat load for the structure, the average heat load may be readily determined. The percentage of this heat load that may be supplied by a solar system may be approximated by knowing the mean daily solar insolation on a horizontal surface at the selected location. The mean solar insolation on the horizontal surface may then be converted to mean radiation on a tilted surface by means of approximate rules or charts. The percentage of the radiation on the tilted surface that is collected by the collector is then determined. This is usually accomplished by referring to manufacturer's literature regarding performance specifications for selected collectors.

Once the size of the collector array has been determined, the storage volume may be determined by assuming one half cubic foot of rocks per square foot of collector for air systems with pebble bed storage or by assuming 1.5 gallons of water per square foot of collector for water systems. The flow rates of transport medium through the collectors may be assumed to be 2 CFM per square foot of collector for air systems or 0.03 gallons per minute per square foot for water systems. Additional components such as pumps, blowers, and heat exchangers may then be sized from the above flow rate information.

Economic analyses are conducted after the preliminary sizing studies are performed. The system costs may be estimated on the basis of the preliminary sizing calculations. These system costs are then used in economic analyses in order to provide the client with enough information that decisions regarding that design may be made. There are available a number of algorithms for performing economic investigations. The details of these are the subject of a separate investigation and will not be further discussed here.

The design procedure described above is outlined below in more specific terms as follows.

1. Determine the design heat load for the building in Btu/dd (British Thermal Units per degree day).
2. Determine the number of degree days for the given location.
3. Multiply the heat load determined in Step 1 by the degree days determined in Step 2 to determine the heating load for the building.

4. Determine the monthly average solar radiation on a horizontal surface, $\bar{H}_O$, at the given location.
5. Convert the monthly average radiation on a horizontal surface to monthly average radiation on the desired tilted surface to obtain $\bar{H}_T$.
6. Multiply $\bar{H}_T$, determined in Step 5, by an average efficiency for the month to obtain the average amount of energy collected per square foot of collector.
7. Select a collector size.
8. Multiply the collector size by the number obtained in Step 6 to determine the average energy collected.
9. Determine storage size (gallons) for water systems by multiplying the collector size (ft^2) by 1.5 gallons/ ft^2 . For air systems using pebble storage multiply the collector size by 0.5 ft^3 rocks/ ft^2 of collector.
10. Size pumps or blowers from the requirements that for water systems the collector flow rate should be about 0.03 gallons per minute per square foot of collector and for air systems the collector flow rate should be about 2 CFM per square foot of collector.
11. Conduct economic analysis to determine inputs required for final design purposes.

SIMPLIFIED ANALYSIS

For standard air or water systems that may be represented as shown on Figures 1 and 2, respectively, a simplification in the above procedure results. The design curves shown on Figure 3 may be used to estimate the collector size required in order that the solar system provide a specified percentage of the annual load.

FIGURE 1. SCHEMATIC OF AIR SYSTEM

Figure 2 (a)
(from Ref. 1)

FIGURE 3-A. FRACTION OF ANNUAL LOAD
SUPPLIED BY SOLAR AS A FUNCTION OF JANUARY
(AIR SYSTEM)

FIGURE 3B. FRACTION OF ANNUAL LOAD
 SUPPLIED BY SOLAR AS A FUNCTION OF JANUARY
 (WATER SYSTEM)

These design charts are the result of many simulations performed for systems represented as shown in Figures 1 and 2 to be located in a large number of different climatological regions. Consequently, the curves are shown as a band rather than a single line. The ordinate on each figure represents the percentage of the annual load supplied by the solar system. This load may also include service hot water if desired. The abscissa represents the January climatological conditions. That is, S is equal to the total solar insolation on a horizontal surface for the month of January at the location in question. L represents the total heating load for the structure for the month of January. The required collector area is represented by A . Consequently, in order to use these curves, one has only to determine the January insolation on a horizontal surface, S , and the January load for the building, L , and specify the desired percentage of annual load to be supplied by solar, f . For example, if it is desired that the solar system provide 75% of the annual heating and service hot water load, we see from Figure 3 for air systems that the value of SA/L is approximately 0.6. Consequently, the collector area, A , may be readily determined.

It should be emphasized that these curves should be used for preliminary design purposes only and that more accurate results would ordinarily be obtained by conducting a monthly analysis as described earlier. In addition, these curves are limited to the design of solar systems that would be represented by the configurations shown on Figures 1 and 2.

DESIGN CHARTS

The simplified design techniques presented earlier are not usually adequate for final design purposes because the collector is not adequately accounted for in those procedures. This section takes into consideration the design parameters of the collector itself in determining system performance.

This material is based upon the work presented in Reference 1. In that paper, a general design procedure for solar heating systems was developed based upon information obtained from many simulations of solar heating systems utilizing a detailed simulation program. The result was a simple graphical method using monthly average meteorological data which may be used for the design of solar heating systems.

The Approach

The approach taken in Reference 1 was to use a simulation program to develop a generalized performance chart. This generalized performance chart correlates long-term performance of solar heating systems with system design parameters, building construction, and weather. This chart may then be combined with cost figures to provide a method by which architects and heating engineers may determine the economic optimal design of residential space and water heating systems using liquid heat transport.

The system considered was that shown on Figure 2. This following discussion is applicable to systems using liquid as the transport medium and for storage. The mathematical models

for the system components that were used in the simulation studies are presented below.

Collector Model

The method of Hottel and Whillier (Ref. 5) was used to model the collector. The equation for the useful energy collected is

$$Q_u = F_R A [H_T \tau \alpha - U_L (T_i - T_a)] = (\dot{m} C_p)_c (T_o - T_i)$$

where

$$F_R = \frac{(\dot{m} C_p)_c}{AU_L} \left[1 - \exp \left(\frac{F' U_L A}{(\dot{m} C_p)_c} \right) \right]$$

The terms in this equation are defined below:

F' = collector efficiency factor

A = collector area

H_T = radiation on the collector

$\tau \alpha$ = product of cover transmittance and collector plate absorptance

U_L = collector loss coefficient

T_i = collector inlet temperature

T_a = ambient temperature

$(\dot{m} C_p)_c$ = collector fluid capacitance rate

T_o = collector outlet temperature

Storage Model

The heat balance equation for the storage system is

$$C_S \frac{dT_S}{dt} = Q_D - (Q_L - E_L) - (Q_W - E_W)$$

where

- C_S = heat capacity of storage
- T_S = storage temperature
- Q_L = space heating load
- E_L = auxiliary energy required to meet the space heating load
- Q_W = service hot water heating load
- E_W = auxiliary energy required to meet the service hot water load
- Q_D = energy transferred to storage tank

Heat Exchanger Model

The thermal performance of the heat exchanger was modeled according to the equation

$$Q_{hx} = E_c (\dot{m} Cp)_{\min} (T_o - T_s) = (\dot{m} Cp)_s (T_1 - T_s)$$

where

- T_s = temperature of water in storage
- $(\dot{m} Cp)_{\min} = \min [(\dot{m} Cp)_c, (\dot{m} Cp)_s]$

T_o and T_1 are the temperatures at the outlets of the heat exchanger. Thermal losses in the piping were neglected in the analysis. This is valid if pipes are well-insulated and not excessively long.

The equations for the heat exchanger and collector were combined to give

$$Q_u = F_R' A [H_T \tau - U_L (T_s - T_a)]$$

where

$$F_R' = F_R \left\{ 1 + \left[\frac{F_R U_L A}{(\dot{m} Cp)_c} \right] \left[\frac{(\dot{m} Cp)_c}{\epsilon_c (\dot{m} Cp)_{\min}} - 1 \right] \right\}^{-1}$$

The term, F_R'/F_R , is considered to be a "heat exchanger factor." Its value lies between 0 and 1 and represents a penalty paid for the use of the heat exchanger.

The term in the storage model, Q_D , was then expressed in terms of the above relations according to

$$Q_D = \begin{cases} F_R' A [H_T \tau - U_L (T_s - T_a)], & T_1 \leq T_{\max} \\ (\dot{m} Cp)_s (T_{\max} - T_s), & \text{otherwise} \end{cases}$$

where $T_{\max}$ is the boiling temperature.

Load Model

The house heating load was modeled as

$$Q_L = UA (T_R - T_a)$$

where T_R is the room temperature and UA is the space heating load at design conditions divided by the design temperature difference.

The service water heating load was modeled by

$$Q_w = (\dot{m} Cp)_w (T_w - T_m)$$

where T_w represented the minimum acceptable hot water temperature and T_m represented the temperature from the cold water return lines.

Auxiliary Energy

The auxiliary energy was modeled in two parts. The first represented the amount of energy required for service hot water, E_w , while the second represented the amount required for space heating, E_L . These were modeled according to

$$E_w = (\dot{m} C_p)_w (T_w - T_s)$$

and

$$E_L = [Q_L - Q_{\max} - (UA)_s (T_s - T_{\text{env}})]$$

where

$$Q_{\max} = E_L C_{\min} (T_s - T_R).$$

The term $C_{\min}$ represents the minimum of the two fluid flow capacitances through the load heat exchanger and is usually that of air. The term $E_L C_{\min}/UA$ provides a measure for sizing the load heat exchanger.

Sensitivity Analysis

The development of the general design procedure for solar heating systems began with an extensive study of the effects of various design parameters on the long-term system performance. The sensitivity study indicated three parameters upon which the performance was highly sensitive whereas additional system parameters had negligible affect on performance relative to these three highly sensitive parameters. These parameters are summarized as follows:

Collector Fluid Capacitance Rate

The product of the mass flow rate and the specific heat of the transport medium through the collector strongly affects the heating system performance. Duffie and Beckman [Ref. 2] have shown that the optimal collector fluid capacitance rate is infinitely large. However, the dependence of system performance on the collector capacity rate is asymptotic and only a small gain in energy collection rate is realized if the collector fluid capacitance rate per unit area is increased when the collector flow factor (defined below) exceeds 10.

$$F'' = F_R/F' = \frac{(\dot{m} C_p)_c}{U_L A F'} \left[1 - \exp\left(\frac{-U_L F' A}{(\dot{m} C_p)_c}\right) \right]$$

Low collector fluid capacitance rates, that is, rates for which F' is less than 5, also result in reductions of energy collection; the nominal value for collector fluid capacitance rate was selected as $210 \text{ kJ hr}^{-1} \text{ C}^{-1} \text{ m}^{-2}$ ($33.32 \text{ Btu-hr}^{-1} \text{ } ^\circ\text{F}^{-1} \text{ } \text{ft}^2$) for the study.

Storage Capacity

In an economic study of solar heating systems, Löff and Tybout [Ref. 3] concluded that the storage tank capacity that resulted in minimum cost solar heating was in the range of 200 to $300 \text{ kJ/}^\circ\text{C}$ (50-75 kg of stored water) per square meter of collector area. That is the equivalent of 1.25 to 1.75 gallons of water per square foot of collector area. They also indicated

that the performance of solar heating systems is rather insensitive to the amount of storage capacity within this general range. These results are valid so long as one is not considering seasonal storage, that is, storing summer heat for use in the winter. Results from simulations for several different storage capacities are in general agreement with the Löff and Tybout study and are shown in Figure 4. Consequently, a storage capacity of 75 kg water/sq. meter (1.86 gallons water/sq. ft.) was used in the study to develop the generalized performance curves.

Load Heat Exchanger Size

A dimensional parameter ($\epsilon_1 c_{\min}/UA$) where ϵ_1 is the effectiveness of the space heating load heat exchanger, $c_{\min}$ is the minimum capacitance rate in the load heat exchanger, and UA represents a constant characterizing space heating load, was found to provide a measure of the size of heat exchanger needed in order to supply heat to a specified building. Figure 5 indicates how the performance of a space heating system is related to this parameter. For values of this parameter less than 1, the reduction in system performance due to having too small of a heat exchanger will be appreciable. Values for this parameter between 1 and 3 should be used for optimal performance. Consequently, the generalized performance charts were developed utilizing a value of this parameter equal to 2.

Figure 4
(from Ref. 1)

Figure 5.2
(from Ref. 1)

Correlation of System Performance

The correlation of f , the fraction of the load supplied by solar, to various system parameters was investigated by making more than 300 simulation studies, each of which estimated month by month system performance by performing calculations at half hour intervals using meteorological data for an average year for Madison, Wisconsin. The results of these studies are shown graphically on Figure 6. This chart may be used to estimate the performance of a solar heating system, month by month, as a function of the system design and local weather conditions.

Although the f curves shown on Figure 6 were developed using simulation results for Madison, Wisconsin, climatological data studies have indicated that the performance chart can be applied for other locations with quite satisfactory results.

Application of the Performance Chart to a System Design

The application of the performance chart on Figure 6 will be illustrated in this section by considering the design of a residential type structure in Indianapolis, Indiana. Suppose that the design heat load is found to be 61,000 Btu's/hr. at an ambient temperature of 4°F. This results in a 24,000 Btu/°day house. The monthly and annual heating loads may be determined by referring to the Climatic Atlas to obtain an estimate of the °days/month as well as the annual degree days for Indianapolis, Indiana. Suppose that the water heating load is

Figure 5
(from Ref. 1)

NOMENCLATURE

A	collector area [m^2]
f	fraction of the total heating load supplied by solar energy each month
F_R	collector efficiency factor
F'_R	a modified collector efficiency factor which accounts for the penalty in energy collection imposed by the use of a double-loop flow circuit
$F'_R = F_R \left[\frac{1}{1 + \frac{F_R U_L A (\overline{m}_p)_c}{(\overline{m}_p)_c [1 + \frac{L}{(\overline{m}_p)_{min} A \epsilon_c}]}} \right]$	
L	total space and water heating loads for each calendar month [kJ]
$(\overline{m}_p)_c$	collector fluid capacitance rate [$kJ hr^{-1} ^\circ C^{-1}$]
$(\overline{m}_p)_{min}$	minimum fluid capacitance rate through the collector tank heat exchanger [$kJ hr^{-1} ^\circ C^{-1}$]
S	total radiation per unit area incident upon the collector during each calendar month [$kJ m^{-2}$]
$\overline{T}_{ref}$	reference temperature [$100^\circ C$]
U_L	collector overall energy loss coefficient [$kJ hr^{-1} ^\circ C^{-1} m^{-2}$]
Δt	number of hours in each calendar month [hr]
ϵ_c	effectiveness of the collector-storage tank heat exchanger
$\overline{(\tau\alpha)}$	average product of the cover transmittance and the collector plate absorptance

estimated to be 80 gallons per day to be raised from 52°F to 140°F. Suppose, furthermore, that this does not change throughout the year.

Suppose that flat plate collectors are to be used and suppose, furthermore, that the design characteristics of these collectors are known to be

$$F_R U_L = 0.86 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$$F_R \overline{\tau\alpha} = 0.72$$

Also suppose that the other required system parameters are

$$(\dot{m} C_p)_c/A = 10.28 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$$(\dot{m} C_p)_s/A = 12.05 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$$

$$\epsilon_c = 0.70.$$

Then

$$\begin{aligned} F_R'/F_R &= \left\{ 1 + \frac{0.86}{10.28} \cdot \frac{1}{.7} - 1 \right\} \\ &= 0.965. \end{aligned}$$

Therefore,

$$F_R' U_L = 0.83$$

and

$$F_R' \overline{\tau\alpha} = 0.69.$$

The collectors are to be mounted facing due south at a slope equal to the latitude. The ratio of the storage tank to the collector area is to be 75 kg. water/sq. meter of collector (15.4 lb/ft²).

The service hot water load is

$$\begin{aligned} L_{SHW} &= \left(80 \frac{\text{gal}}{\text{day}} \right) \left(8.25 \frac{\text{lb}}{\text{gal}} \right) \left(\frac{1 \text{ Btu}}{\text{lb} \cdot ^\circ\text{F}} \right) (140-52)^\circ\text{F} (30 \text{ days}) \\ &= 1,742,400 \text{ Btu/month.} \end{aligned}$$

This value was added to the heating load to obtain the total load for each month.

The value for the total radiation on each square foot of the collector for each month, S , is obtained from the product of $\bar{H}_T$ and the number of days in each month.

The abscissa and ordinate (x and y) values for the f -chart, Figure 6, were calculated for collectors of 500, 750, and 1000 ft^2 using the previously determined values. The fraction of the load supplied by solar for each month was determined from Figure 6 using the calculated values for x and y . The figures shown on the bottom row of the f -column on Table 1 represent the fraction of the annual load supplied by solar for each size of collector array considered.

Automated Use of the Performance Charts

The calculations required for use of the performance chart are tedious; the efficiency of the calculation process can be improved significantly by automating the calculations. By means of standard curve-fitting programs the following relationships have been obtained for the f -charts for water and air systems, respectively (Ref. 4).

MONTH	$\bar{H}$ Btu/Ft ²	$\bar{K}_T$	$\bar{R}$	$\bar{H}_T$ Btu/Ft ²	DD	T_A °F	$(T_{REF} - T_A)$	L_H Btu · 10 ⁻⁶	L Btu · 10 ⁻⁶	Δ Btu/Ft ²	$F_R U_L (T_{REF} - T_A)$ Btu/L Ft ⁻² · 10 ⁻³	$F_R \bar{U}_L S/L$ Ft ⁻² · 10 ⁻⁴	X and Y Values						f-Fraction of Load Supplied by Solar		
													500Ft ²		750Ft ²		1000Ft ²		500	750	1000
													X	Y	X	Y	X	Y			
JAN	526	.360	1.58	154	11.3	29	18	26.71	28.45	25761	3.97	6.25	1.985	.7125	2.98	.47	3.97	.63	.18	.30	.35
FEB	797	.424	1.47	1172	949	31	181	22.78	24.52	32816	4.12	9.23	2.06	.46	3.09	.69	4.12	.92	.35	.47	.58
MAR	1184	.472	1.23	1456	809	39	173	19.42	21.16	45136	5.05	14.72	2.53	.74	3.79	1.10	5.05	1.47	.54	.67	.85
APR	1481	.470	1.04	1540	432	51	161	10.37	12.11	46200	7.94	26.32	3.97	1.32	5.96	1.97	7.94	2.63	.78	.95	1.00
MAY	1828	.511	0.93	1700	177	59	153	4.25	5.99	52700	15.77	60.71	7.89	3.04	11.83	4.55	15.77	6.07	1.00	1.00	1.00
JUN	2042	.543	0.88	1797	39	64	148	0.94	2.68	53910	33.00	138.80	16.50	6.94	24.75	10.41	33.00	13.88	1.00	1.00	1.00
JUL	2040	.554	0.90	1836	0	65	147	0	1.74	56916	52.17	225.70	26.08	11.29	39.12	16.92	52.17	22.57	1.00	1.00	1.00
AUG	1836	.552	0.99	1814	0	65	147	0	1.74	56234	52.17	223.00	26.08	11.15	39.12	16.72	22.98	22.30	1.00	1.00	1.00
SEP	1513	.549	1.16	1755	90	62	150	2.16	3.90	52650	22.99	93.15	11.49	4.66	17.24	6.99	10.40	9.32	1.00	1.00	1.00
OCT	1094	.520	1.42	1553	316	55	157	7.58	9.32	48143	10.40	35.64	5.20	1.78	7.80	2.67	5.35	3.56	.92	1.00	1.00
NOV	662	.413	1.54	1019	723	41	171	17.35	19.09	30570	5.35	11.05	2.68	.55	4.01	.83	4.15	1.11	.33	.50	.60
DEC	491	.391	1.85	908	1051	31	181	25.22	26.96	28148	4.15	7.20	2.08	.36	3.11	.54		.72	.20	.32	.39
YEARLY AVERAGE																			.45	.57	.64

TABLE 1
FRACTION OF LOAD SUPPLIED BY SOLAR

$$f_v = -0.0218 + 1.086y - 0.0642x - 0.2874y^2 + 0.00176x^2 + 0.030074y^3$$

$$f_a = -0.034021 + 1.1477y - 0.063263x - 0.25702y^2 + 0.0017435x^2 + 0.0154y^3.$$

These equations may be used in place of attempting to read values for f from the appropriate f -charts.

The complete procedure has been automated on an HP-65 hand-calculator. In addition, the procedure has also been programmed for a small digital computer. A sample output from the program is shown on Figure 7. This program also includes an economic analysis developed in Ref. 1.

REVIEW OF COMPUTER-AIDED DESIGN PROGRAMS

Several computer aided design programs have been developed for the purpose of analyzing and/or designing solar systems. Some of these programs will be discussed in this section.

Interactive Program

The first program to be discussed is an interactive version of the design chart procedure that was discussed in the previous section. The program contains climatological and solar data for 112 locations in the United States and Canada. The program determines the performance of a solar system in any of these locations. The percentage of the load that will be supplied by solar for each month is determined. The user supplies the collector parameters necessary for the program; these are $F_R'(\tau\alpha)$ and $F_R' U_L$. The collector is modeled according to the equations presented in the previous section. The user also specifies the slope and area of the collector array.

LATITUDE = 39.7

COLLECTOR TILT = 39.7

GROUND REFLECTIVITY = .20

COLLECTOR AREA = 154.0 SQ.FT.

FRRPRIME-UL PRODUCT = .830 BTU/HR-SQ.FT.-F

DOMESTIC USAGE PER DAY = 80.0 GAL/DAY

DOMESTIC TANK TEMP = 140.0 F

FUEL COST = 9.00 \$/MMBTU

COST OF INSTALLATION = 16.00 \$/SQ.FT. COLL.

STORAGE CAP. TO COLL. AREA RATIO = 15.4 LB WATER/SQ.FT. COLL.

ADDITIONAL EQUIPMENT COSTS = 1400.

FRRPRIME-TAU-ALPHA PRODUCT = .690

HOUSE DESIGN = 24000.0 BTU/DD

DOMESTIC SUPPLY TEMP = 52.0 F

ANNUAL CAPITAL INVEST. CHARGE = .090

MATERIAL TANK COST = .120 \$/LB STORAGE FLUID

MTM	SOLAR HORIZ PTU ----- SQ.FT.-DAY	MONTHLY AVERAGE K	SOLAR TILT BTU ----- SQ.FT.-MTM	DEGREE DAYS	MONTHLY AVERAGE TEMP	MONTHLY TOTAL LOAD	X	Y	PERCENT SOLAR
1	530.0	1.62	26572.45	1113.0	29.10	28512480.	2.971	.482	.263
2	785.0	1.43	31538.06	949.0	31.11	24402240.	3.101	.669	.403
3	1145.0	1.21	41780.36	809.0	38.90	21216480.	3.779	1.068	.629
4	1460.0	1.02	44519.50	432.0	50.60	12110400.	5.973	1.902	.890
5	1799.0	.90	50324.98	177.0	59.29	6048480.	11.693	4.306	1.000
6	2002.0	.85	51230.06	39.0	63.70	2678400.	24.816	9.898	1.000
7	1995.0	.87	54100.79	0.0	65.00	1800480.	37.813	*.550	1.000
8	1807.0	.97	54535.43	0.0	65.00	1800480.	37.813	*.675	1.000
9	1493.0	1.16	51808.68	90.0	62.00	3902400.	17.228	6.870	1.000
10	1080.0	1.42	47487.39	316.0	54.81	9384480.	7.758	2.619	.999
11	653.0	1.63	31916.56	723.0	40.90	19094400.	4.016	.865	.492
12	487.0	1.72	25916.01	1051.0	31.10	27024480.	3.100	.496	.268

YEARLY DOLLAR SAVINGS = \$ -577.08 WITH .530 OF THE REQUIRED LOAD CARRIED BY SOLAR

FIGURE 7: SAMPLE OUTPUT

The building heating load is determined according to a UA AT calculation or is specified, in monthly values, by the user. If the load is to be calculated the user must provide a UA value in $\text{kJ/hr-}^{\circ}\text{C}$ for the building. A service hot water load may also be included. The user must specify the amount of service hot water (Kg/day), the water set temperature ($^{\circ}\text{C}$), and the water main temperature ($^{\circ}\text{C}$). Internal heat generation from lights, people, etc. may also be specified in kJ/day . These factors are used in the program to determine the total load.

Finally, the user specifies whether the system being considered is an air or water system and whether the printout is to show monthly or yearly results. A sample output from this program is shown on Table 2.

Economic considerations are also included in the program. The user has the option of having the program determine the optimal collector size. The optimum is determined on the basis of minimizing life cycle costs.

TRNSYS and SIMSHAC

The design techniques that have been presented earlier were based upon standard type designs. If one were to use these techniques for a situation that was quite different from the standard configuration, then there would be no guarantee as to their validity. As a specific example, if one wanted to use the Owens-Illinois Evacuated Tube Collector in a design study, then some modification of the performance curves that were presented in the previous section would be required. As another example, suppose one wished to use a solar augmented heat pump in a design. There would be no way in which the previously

SAMPLE OUTPUT FROM INTERACTIVE DESIGN PROGRAM

CODE		VALUE	UNITS
1	FRPRIME --TAU--ALPHA PRODUCT	.695	
2	FRPRIME --UL PRODUCT	16.900	KJ/hr-C-M ²
3	BUILDING UA	1898.000	KJ/hr-C
4	HOT WATER LOAD	300.000	KG/day
5	WATER SET TEMPERATURE	60.000	C
6	WATER MAIN TEMPERATURE	11.000	C
7	COLLECTOR SLOPE	40.000	DEGREES
8	CITY ABBREVIATION	IND	
9	COLLECTOR AREA	69.750	M ² = 750 ft ²
10	CONSTANT DAILY BLDG HEAT GENERATION	0.000	KJ/day
11	AIR SYSTEM = 1, WATER SYSTEM = 2	2.000	
12	PRINT OUT BY MONTH = 1, YEARLY = 2	1.000	

TYPE YES IF YOU WISH TO CHANGE VALUE(S) IN LIST OF SYSTEM PARAMETERS

TYPE CHANGE IF YOU WISH TO CHANGE MONTHLY LOADS OR VALUES OF REFLECTIVITY

OTHERWISE TYPE READY OR STOP

READY

DO YOU WISH TO HAVE YOUR VALUES RELISTED YES=1, NO=2

2

INDIANAPOLIS IN 39.44

TIME	PERCENT SOLAR	INCIDENT SOLAR (MJ)	HEATING LOAD (MJ)	WATER LOAD (MJ)	DEGREE DAYS (C-day)	AMBIENT TEMP. (C)
JAN	27.6	21.54	28.17	1.91	618.	-2.
FEB	40.1	24.66	24.02	1.72	527.	-0.
MAR	62.1	33.91	20.47	1.91	449.	4.
APR	88.8	34.79	10.93	1.85	240.	10.
MAY	100.0	39.89	4.48	1.91	98.	15.
JUN	100.0	40.64	.99	1.85	22.	18.
JUL	100.0	42.64	0.00	1.91	0.	18.
AUG	100.0	41.49	0.00	1.91	0.	18.
SEP	100.0	39.09	2.28	1.85	50.	17.
OCT	99.6	37.03	8.00	1.91	176.	13.
NOV	46.1	23.67	18.30	1.85	402.	5.
DEC	25.3	19.58	26.60	1.91	584.	-1.
YEAR	52.4	398.93	144.22	22.48	3166.	

presented material would be valid for such a design study. In order to handle this type of situation, several computer-aided design programs have been developed. These programs model specific components that may be found in solar heating and cooling systems for buildings. The user of one of these programs can use these component models to build a model of a complete solar heating and/or cooling system, and then proceed to simulate the performance of this system when subjected to particular climatological conditions. In this way, one can readily investigate different control strategies as well as variations in an overall system performance due to changes in any of the components of the system. These programs provide a very valuable analysis and design tool.

There are two primary programs in this category at the present time. The first of these programs is TRNSYS, developed by faculty and students at the University of Wisconsin. TRNSYS has had widespread dissemination and is the most widely used of these programs. A User's Manual for TRNSYS is available along with documentation of the program. The program has been checked for internal consistencies (that is, verified), but has not yet been validated against actual performance data for a solar heated and/or cooled building. It is expected that this model validation process is going on at the present time.

The second of these computer aided design programs, and one that has been used in the design of several solar systems that have been constructed, is SIMSHAC. This program was developed by Gearold R. Johnson and C. Byron Winn, and some of

their associates. The program has not been released at the present time due to lack of documentation. This documentation is nearly completed, however, at this time, and the program will soon be made available. This program, as is the case with TRNSYS, has been verified so that the user may be assured that there are no programming errors. In addition, however, it has been validated against actual performance data that were obtained from the operation of CSU Solar House I.

AVAILABLE CLIMATOLOGICAL AND PERFORMANCE DATA

If a simulation program is to be used for the design of solar systems, it must be validated against actual climatological and performance data for selected systems. There are very few solar systems at the present time for which climatological and performance data are available. Systems for which data are available include CSU Solar I, the Bridgers and Paxton Office Building, the Townes Elementary School, and, to a limited extent, CSU Solar II. Of these four, CSU Solar I has provided the most complete data set. Eighty-eight pieces of data have been recorded at two minute intervals on magnetic tape since August of 1974. The data collection system is automatic except for the tape driver, which goes off and remains off whenever there is a power interruption and consequently requires a manual re-start. Consequently there have been interruptions in the data recorded on the magnetic tapes. There have also been periods during which some of the instrumentation has been either out of calibration or out of operation. Therefore an extensive effort has been conducted by SEEC personnel to fill in

the gaps and develop a climatological and performance data tape for a complete year of operation. The two minute data have been compiled into hourly average values. SEEC has performed the following tasks:

1. Data collected from Solar I include the following data types:

1. Incident Solar Radiation on Horizontal Surface (SIHOR):
Kilojoules/square meter;
2. Incident Solar Radiation on 45° inclined surface (SI45):
Kilojoules/square meter;
3. Air Temperature (TDRY): Degrees, Celsius;
4. Dew Point Temperature (TDEW): Degrees, Celsius;
5. Wind Velocity (VWIND): Meters/Second.

The data were registered on 20-minute tapes, and later on, were processed and put into hourly data points for further use.

Since the raw data were noisy and had some missing data points, the following procedure has been taken by SEEC to "validate" the data set collected from Solar I:

2. Clustering Analysis for preliminary data evaluation:

By using the BMD X74D computer program to compute the Mahalanobis distance of each data point from the mean of the cluster formed by other data points of the same "group" (i.e., same hour and same month), all "outliers" can then be identified and plotted for verification and correction.

After this step, all data points of the same "group" can be considered as belonging to the same population; statistical analysis techniques can then be applied for further analysis.

3. Statistical Analysis for Data Characteristics evaluation:

The following steps have been taken to analyze data characteristics which are necessary for filling in missing data points:

- (1) Mean and Standard Deviation calculation for data of the same month and of the same hour.
- (2) Calculate the relative frequency distribution (PDF) and the Cumulative Distribution Function (CDF) for data of each "group."
- (3) Stepwise Regression Analysis (BMD02R) to identify relationships between variables (i.e., SIHOR $\leftrightarrow$ SI45 $\leftrightarrow$ TDRY). The plots of residuals vs. input variables can also be used in the data screening process.
- (4) Polynomial Regression (BMD05R) and Stepwise Regression Analysis with transgeneration cards (BMD02R) can then be used for higher order (i.e., 3rd order) regression investigations. The results obtained from this step will then be used to fill-in missing data points, if required.

4. Fill-in missing data points: two approaches have been used by SEEC for the following two cases:

- (1) For short missing data records: generate missing values of adjacent points of the same "group" through simple interpolation process.

- (2) For long missing data records: generate mean hourly values of one data type from the mean hourly values of the other data types (i.e., generate mean hourly values of SI45 from the mean hourly values of TDRY and TDEW) then add a random number generated by the distribution functions computed in the previous steps.
5. Post-processing: after step 4, the data set needs to be re-evaluated before releasing to users. Therefore, steps (2), (3), and (4) can be used again to ensure good quality of the data tapes produced.
6. User's Tapes: User's tapes contain hourly values for data points in coded form for easy use or retrieval on punched cards. The first data tape contains hourly data from August 27/1974 through September 3/ 1975.

Table 3 shows the daily summaries for the period between August 27, 1974 and August 26, 1975. The column labeled "order" represents the ordering of the insolation values, that is, number 105 beside August 27 means that that day had the one hundred and fifth highest daily insolation value of the year. The column labeled "insolation" represents the daily total insolation measured on the horizontal surface. The data have been converted so that the units are Btu/square foot/day. The average insolation represents the average for the month. The total insolation represents the total insolation on the horizontal surface for that month. The column labeled "radiation" represent the amount measured on the 45° tilted collector surface.

Table 4 presents temperature data for the year. The column labeled "average temperature" represents the average temperature in degrees Fahrenheit for the given day. The column labeled

MONTH	DATE	ORDER	INSOLATION	AVERAGE INSOLATION	TOTAL INSOLATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
9	1	143	498.0	1344.0	43213.0	1629.1	50501.0	449.0
9	2	325	632.0	1344.0	43213.0	1629.1	50501.0	585.0
9	3	93	1933.0	1344.0	43213.0	1629.1	50501.0	2165.0
9	4	63	2086.0	1344.0	43213.0	1629.1	50501.0	2344.0
9	5	298	1105.0	1344.0	43213.0	1629.1	50501.0	1253.0
9	6	78	1941.0	1344.0	43213.0	1629.1	50501.0	2786.0
9	7	64	2002.0	1344.0	43213.0	1629.1	50501.0	2407.0
9	8	243	1171.0	1344.0	43213.0	1629.1	50501.0	1249.0
9	9	101	1379.0	1344.0	43213.0	1629.1	50501.0	1495.0
9	10	157	1545.0	1344.0	43213.0	1629.1	50501.0	1745.0
9	11	346	429.0	1344.0	43213.0	1629.1	50501.0	399.0
9	12	330	503.0	1344.0	43213.0	1629.1	50501.0	539.0
9	13	143	1617.0	1344.0	43213.0	1629.1	50501.0	1931.0
9	14	205	1298.0	1344.0	43213.0	1629.1	50501.0	1426.0
9	15	270	1002.0	1344.0	43213.0	1629.1	50501.0	1125.0
9	16	104	1827.0	1344.0	43213.0	1629.1	50501.0	2265.0
9	17	112	1784.0	1344.0	43213.0	1629.1	50501.0	2249.0
9	18	189	1354.0	1344.0	43213.0	1629.1	50501.0	1748.0
9	19	204	1303.0	1344.0	43213.0	1629.1	50501.0	1695.0
9	20	277	1010.0	1344.0	43213.0	1629.1	50501.0	1307.0
9	21	90	1873.0	1344.0	43213.0	1629.1	50501.0	2196.0
9	22	101	1835.0	1344.0	43213.0	1629.1	50501.0	2202.0
9	23	87	1902.0	1344.0	43213.0	1629.1	50501.0	2209.0
9	24	98	1848.0	1344.0	43213.0	1629.1	50501.0	2117.0
9	25	91	1871.0	1344.0	43213.0	1629.1	50501.0	2243.0
9	26	124	1643.0	1344.0	43213.0	1629.1	50501.0	2079.0
9	27	352	212.0	1344.0	43213.0	1629.1	50501.0	255.0
9	28	94	1859.0	1344.0	43213.0	1629.1	50501.0	2230.0
9	29	106	1817.0	1344.0	43213.0	1629.1	50501.0	2279.0
9	30	155	1558.0	1344.0	43213.0	1629.1	50501.0	1911.0
10	1	137	1648.0	1232.2	39432.0	1520.0	48641.0	2135.0
10	2	108	1794.0	1232.2	39432.0	1520.0	48641.0	2174.0
10	3	218	1284.0	1232.2	39432.0	1520.0	48641.0	1521.0
10	4	214	1264.0	1232.2	39432.0	1520.0	48641.0	1598.0
10	5	250	1121.0	1232.2	39432.0	1520.0	48641.0	1446.0
10	6	177	1410.0	1232.2	39432.0	1520.0	48641.0	1734.0
10	7	167	1482.0	1232.2	39432.0	1520.0	48641.0	1824.0
10	8	146	1627.0	1232.2	39432.0	1520.0	48641.0	2000.0
10	9	125	1673.0	1232.2	39432.0	1520.0	48641.0	2129.0
10	10	245	1151.0	1232.2	39432.0	1520.0	48641.0	1505.0
10	11	348	378.0	1232.2	39432.0	1520.0	48641.0	407.0
10	12	363	177.0	1232.2	39432.0	1520.0	48641.0	160.0
10	13	92	1867.0	1232.2	39432.0	1520.0	48641.0	2182.0
10	14	198	1330.0	1232.2	39432.0	1520.0	48641.0	1614.0
10	15	193	1343.0	1232.2	39432.0	1520.0	48641.0	1677.0

TABLE 3: SOLAR DATA

NO.	DATE	ORDER	INSULATION	AVERAGE INSULATION	TOTAL INSULATION	AVERAGE RADIATION	TOTAL RADIATION	AVERAGE RADIATION
10	16	208	1243.0	1252.2	39432.0	1520.0	48641.0	1598.0
10	17	113	1755.0	1252.2	39432.0	1520.0	48641.0	2135.0
10	18	118	1407.0	1252.2	39432.0	1520.0	48641.0	1721.0
10	19	200	1525.0	1252.2	39432.0	1520.0	48641.0	1701.0
10	20	197	1329.0	1252.2	39432.0	1520.0	48641.0	1695.0
10	21	275	1034.0	1252.2	39432.0	1520.0	48641.0	1344.0
10	22	241	1175.0	1252.2	39432.0	1520.0	48641.0	1478.0
10	23	235	1143.0	1252.2	39432.0	1520.0	48641.0	1478.0
10	24	246	891.0	1252.2	39432.0	1520.0	48641.0	1180.0
10	25	245	894.0	1252.2	39432.0	1520.0	48641.0	1149.0
10	26	170	1404.0	1252.2	39432.0	1520.0	48641.0	1817.0
10	27	162	1507.0	1252.2	39432.0	1520.0	48641.0	1875.0
10	28	154	1536.0	1252.2	39432.0	1520.0	48641.0	1764.0
10	29	168	1473.0	1252.2	39432.0	1520.0	48641.0	1724.0
10	30	234	1104.0	1252.2	39432.0	1520.0	48641.0	1428.0
10	31	347	386.0	1252.2	39432.0	1520.0	48641.0	348.0
11	1	315	753.0	922.7	28604.0	1297.3	40215.0	869.0
11	2	159	217.0	922.7	28604.0	1297.3	40215.0	177.0
11	3	314	554.0	922.7	28604.0	1297.3	40215.0	460.0
11	4	209	1242.0	922.7	28604.0	1297.3	40215.0	1977.0
11	5	206	1290.0	922.7	28604.0	1297.3	40215.0	2011.0
11	6	286	970.0	922.7	28604.0	1297.3	40215.0	1419.0
11	7	274	1038.0	922.7	28604.0	1297.3	40215.0	1128.0
11	8	284	943.0	922.7	28604.0	1297.3	40215.0	1655.0
11	9	351	369.0	922.7	28604.0	1297.3	40215.0	345.0
11	10	297	858.0	922.7	28604.0	1297.3	40215.0	1330.0
11	11	240	1184.0	922.7	28604.0	1297.3	40215.0	1999.0
11	12	224	1225.0	922.7	28604.0	1297.3	40215.0	1666.0
11	13	229	1209.0	922.7	28604.0	1297.3	40215.0	1664.0
11	14	292	1000.0	922.7	28604.0	1297.3	40215.0	1476.0
11	15	294	944.0	922.7	28604.0	1297.3	40215.0	1370.0
11	16	232	1201.0	922.7	28604.0	1297.3	40215.0	1673.0
11	17	252	1113.0	922.7	28604.0	1297.3	40215.0	1609.0
11	18	285	943.0	922.7	28604.0	1297.3	40215.0	1448.0
11	19	281	1001.0	922.7	28604.0	1297.3	40215.0	1471.0
11	20	261	1093.0	922.7	28604.0	1297.3	40215.0	1524.0
11	21	250	968.0	922.7	28604.0	1297.3	40215.0	1350.0
11	22	332	578.0	922.7	28604.0	1297.3	40215.0	844.0
11	23	244	1165.0	922.7	28604.0	1297.3	40215.0	1699.0
11	24	257	1136.0	922.7	28604.0	1297.3	40215.0	1615.0
11	25	302	804.0	922.7	28604.0	1297.3	40215.0	1194.0
11	26	213	1279.0	922.7	28604.0	1297.3	40215.0	1755.0
11	27	317	467.0	922.7	28604.0	1297.3	40215.0	900.0
11	28	355	318.0	922.7	28604.0	1297.3	40215.0	460.0
11	29	268	1067.0	922.7	28604.0	1297.3	40215.0	1359.0
11	30	198	1329.0	922.7	28604.0	1297.3	40215.0	1768.0

TABLE 3: SOLAR DATA (con't.)

MONTH	DATE	ORDER	INSULATION	AVERAGE INSULATION	TOTAL INSULATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
12	1	202	1308.0	938.1	30019.0	1282.9	41052.0	1778.0
12	2	211	1285.0	938.1	30019.0	1282.9	41052.0	1738.0
12	3	259	1366.0	938.1	30019.0	1282.9	41052.0	1499.0
12	4	186	1366.0	938.1	30019.0	1282.9	41052.0	1844.0
12	5	329	573.0	938.1	30019.0	1282.9	41052.0	850.0
12	6	179	1320.0	938.1	30019.0	1282.9	41052.0	1724.0
12	7	361	223.0	938.1	30019.0	1282.9	41052.0	304.0
12	8	145	1366.0	938.1	30019.0	1282.9	41052.0	1779.0
12	9	212	1204.0	938.1	30019.0	1282.9	41052.0	1755.0
12	10	210	1262.0	938.1	30019.0	1282.9	41052.0	1576.0
12	11	142	1372.0	938.1	30019.0	1282.9	41052.0	1586.0
12	12	223	1236.0	938.1	30019.0	1282.9	41052.0	1576.0
12	13	237	1107.0	938.1	30019.0	1282.9	41052.0	1572.0
12	14	256	1109.0	938.1	30019.0	1282.9	41052.0	1442.0
12	15	274	1009.0	938.1	30019.0	1282.9	41052.0	1408.0
12	16	293	925.0	938.1	30019.0	1282.9	41052.0	1328.0
12	17	300	837.0	938.1	30019.0	1282.9	41052.0	1205.0
12	18	319	661.0	938.1	30019.0	1282.9	41052.0	994.0
12	19	342	502.0	938.1	30019.0	1282.9	41052.0	804.0
12	20	354	363.0	938.1	30019.0	1282.9	41052.0	498.0
12	21	349	372.0	938.1	30019.0	1282.9	41052.0	564.0
12	22	221	1200.0	938.1	30019.0	1282.9	41052.0	1794.0
12	23	365	144.0	938.1	30019.0	1282.9	41052.0	197.0
12	24	260	1099.0	938.1	30019.0	1282.9	41052.0	1509.0
12	25	267	1297.0	938.1	30019.0	1282.9	41052.0	1829.0
12	26	341	505.0	938.1	30019.0	1282.9	41052.0	664.0
12	27	251	1169.0	938.1	30019.0	1282.9	41052.0	1531.0
12	28	273	1047.0	938.1	30019.0	1282.9	41052.0	1447.0
12	29	299	842.0	938.1	30019.0	1282.9	41052.0	1173.0
12	30	242	1173.0	938.1	30019.0	1282.9	41052.0	1609.0
12	31	280	1002.0	938.1	30019.0	1282.9	41052.0	1370.0
1	1	217	1250.0	809.2	25896.0	1267.6	40564.0	1785.0
1	2	204	231.0	809.2	25896.0	1267.6	40564.0	342.0
1	3	231	1204.0	809.2	25896.0	1267.6	40564.0	1598.0
1	4	270	1027.0	809.2	25896.0	1267.6	40564.0	1545.0
1	5	240	1131.0	809.2	25896.0	1267.6	40564.0	1652.0
1	6	227	1213.0	809.2	25896.0	1267.6	40564.0	1728.0
1	7	323	642.0	809.2	25896.0	1267.6	40564.0	1012.0
1	8	328	600.0	809.2	25896.0	1267.6	40564.0	788.0
1	9	310	746.0	809.2	25896.0	1267.6	40564.0	1165.0
1	10	337	542.0	809.2	25896.0	1267.6	40564.0	924.0
1	11	357	301.0	809.2	25896.0	1267.6	40564.0	263.0
1	12	341	819.0	809.2	25896.0	1267.6	40564.0	1305.0
1	13	324	634.0	809.2	25896.0	1267.6	40564.0	870.0
1	14	306	799.0	809.2	25896.0	1267.6	40564.0	1463.0
1	15	339	520.0	809.2	25896.0	1267.6	40564.0	908.0

TABLE 3: SOLAR DATA (con't.)

Month	DATE	ORDER	INSOLATION	AVERAGE INSOLATION	TOTAL INSOLATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
1	16	335	550.0	809.2	25896.0	1267.6	40544.0	804.0
1	17	374	804.0	809.2	25896.0	1267.6	40544.0	1760.0
1	18	375	801.0	809.2	25896.0	1267.6	40544.0	1514.0
1	19	291	947.0	809.2	25896.0	1267.6	40544.0	1799.0
1	21	290	944.0	809.2	25896.0	1267.6	40544.0	1768.0
1	21	398	777.0	809.2	25896.0	1267.6	40544.0	1776.0
1	22	243	944.0	809.2	25896.0	1267.6	40544.0	1821.0
1	23	320	659.0	809.2	25896.0	1267.6	40544.0	1042.0
1	24	219	1740.0	809.2	25896.0	1267.6	40544.0	2028.0
1	25	316	644.0	809.2	25896.0	1267.6	40544.0	1022.0
1	26	228	1211.0	809.2	25896.0	1267.6	40544.0	1522.0
1	27	298	854.0	809.2	25896.0	1267.6	40544.0	1005.0
1	28	314	708.0	809.2	25896.0	1267.6	40544.0	1048.0
1	29	265	1070.0	809.2	25896.0	1267.6	40544.0	1868.0
1	30	242	946.0	809.2	25896.0	1267.6	40544.0	1520.0
1	31	272	1048.0	809.2	25896.0	1267.6	40544.0	1869.0
2	1	254	1108.0	1067.7	30962.0	1560.1	45243.0	1980.0
2	2	257	1137.0	1067.7	30962.0	1560.1	45243.0	1998.0
2	3	203	1308.0	1067.7	30962.0	1560.1	45243.0	2055.0
2	4	304	101.0	1067.7	30962.0	1560.1	45243.0	151.0
2	5	321	652.0	1067.7	30962.0	1560.1	45243.0	489.0
2	6	215	1204.0	1067.7	30962.0	1560.1	45243.0	2070.0
2	7	242	1041.0	1067.7	30962.0	1560.1	45243.0	1820.0
2	8	344	517.0	1067.7	30962.0	1560.1	45243.0	449.0
2	9	309	757.0	1067.7	30962.0	1560.1	45243.0	887.0
2	10	311	742.0	1067.7	30962.0	1560.1	45243.0	950.0
2	11	144	1343.0	1067.7	30962.0	1560.1	45243.0	2133.0
2	12	255	1108.0	1067.7	30962.0	1560.1	45243.0	1677.0
2	14	377	748.0	1067.7	30962.0	1560.1	45243.0	936.0
2	14	353	343.0	1067.7	30962.0	1560.1	45243.0	349.0
2	15	322	652.0	1067.7	30962.0	1560.1	45243.0	1364.0
2	16	222	1237.0	1067.7	30962.0	1560.1	45243.0	2125.0
2	17	263	1075.0	1067.7	30962.0	1560.1	45243.0	1553.0
2	18	180	1348.0	1067.7	30962.0	1560.1	45243.0	2290.0
2	19	190	1374.0	1067.7	30962.0	1560.1	45243.0	2104.0
2	20	236	1149.0	1067.7	30962.0	1560.1	45243.0	1676.0
2	21	172	1447.0	1067.7	30962.0	1560.1	45243.0	1987.0
2	22	173	1433.0	1067.7	30962.0	1560.1	45243.0	2193.0
2	23	267	1068.0	1067.7	30962.0	1560.1	45243.0	1338.0
2	24	158	1530.0	1067.7	30962.0	1560.1	45243.0	2173.0
2	25	121	1703.0	1067.7	30962.0	1560.1	45243.0	2184.0
2	26	111	1774.0	1067.7	30962.0	1560.1	45243.0	2185.0
2	27	169	1470.0	1067.7	30962.0	1560.1	45243.0	2121.0
2	28	201	1315.0	1067.7	30962.0	1560.1	45243.0	1824.0
3	1	240	1145.0	1254.7	40149.0	1510.6	48338.0	1506.0
3	2	179	1404.0	1254.7	40149.0	1510.6	48338.0	1954.0

TABLE3: SOLAR DATA (con't.)

MONTH	DATE	ORDER	INSULATION	AVERAGE INSULATION	TOTAL INSULATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
3	3	249	1131.0	1254.7	40149.0	1510.6	48338.0	1426.0
3	4	155	1436.0	1254.7	40149.0	1510.6	48338.0	2048.0
3	5	135	1657.0	1254.7	40149.0	1510.6	48338.0	2330.0
3	6	345	471.0	1254.7	40149.0	1510.6	48338.0	447.0
3	7	327	611.0	1254.7	40149.0	1510.6	48338.0	550.0
3	8	220	1244.0	1254.7	40149.0	1510.6	48338.0	1555.0
3	9	333	504.0	1254.7	40149.0	1510.6	48338.0	571.0
3	10	338	505.0	1254.7	40149.0	1510.6	48338.0	501.0
3	11	356	311.0	1254.7	40149.0	1510.6	48338.0	283.0
3	12	130	1675.0	1254.7	40149.0	1510.6	48338.0	2215.0
3	13	151	1603.0	1254.7	40149.0	1510.6	48338.0	2089.0
3	14	176	1470.0	1254.7	40149.0	1510.6	48338.0	2141.0
3	15	287	977.0	1254.7	40149.0	1510.6	48338.0	1102.0
3	16	116	1728.0	1254.7	40149.0	1510.6	48338.0	2179.0
3	17	176	1413.0	1254.7	40149.0	1510.6	48338.0	1756.0
3	18	140	1609.0	1254.7	40149.0	1510.6	48338.0	2053.0
3	19	122	1702.0	1254.7	40149.0	1510.6	48338.0	2099.0
3	20	145	1619.0	1254.7	40149.0	1510.6	48338.0	2251.0
3	21	226	1216.0	1254.7	40149.0	1510.6	48338.0	1410.0
3	22	150	1550.0	1254.7	40149.0	1510.6	48338.0	1781.0
3	23	147	1359.0	1254.7	40149.0	1510.6	48338.0	1797.0
3	24	76	1908.0	1254.7	40149.0	1510.6	48338.0	2406.0
3	25	225	1273.0	1254.7	40149.0	1510.6	48338.0	1312.0
3	26	314	652.0	1254.7	40149.0	1510.6	48338.0	629.0
3	27	119	1705.0	1254.7	40149.0	1510.6	48338.0	1796.0
3	28	69	1943.0	1254.7	40149.0	1510.6	48338.0	2411.0
3	29	141	1623.0	1254.7	40149.0	1510.6	48338.0	1917.0
3	30	145	1440.0	1254.7	40149.0	1510.6	48338.0	1707.0
3	31	331	579.0	1254.7	40149.0	1510.6	48338.0	514.0
4	1	271	1000.0	1723.3	53421.0	1827.3	56646.0	1135.0
4	2	36	2319.0	1723.3	53421.0	1827.3	56646.0	2771.0
4	3	58	2113.0	1723.3	53421.0	1827.3	56646.0	2604.0
4	4	52	2150.0	1723.3	53421.0	1827.3	56646.0	2586.0
4	5	56	2115.0	1723.3	53421.0	1827.3	56646.0	2394.0
4	6	66	2069.0	1723.3	53421.0	1827.3	56646.0	2343.0
4	7	191	1750.0	1723.3	53421.0	1827.3	56646.0	1374.0
4	8	184	1764.0	1723.3	53421.0	1827.3	56646.0	1387.0
4	9	127	1649.0	1723.3	53421.0	1827.3	56646.0	1787.0
4	10	344	641.0	1723.3	53421.0	1827.3	56646.0	409.0
4	11	313	714.0	1723.3	53421.0	1827.3	56646.0	635.0
4	12	62	2090.0	1723.3	53421.0	1827.3	56646.0	2326.0
4	13	54	2120.0	1723.3	53421.0	1827.3	56646.0	2299.0
4	14	47	1849.0	1723.3	53421.0	1827.3	56646.0	1909.0
4	15	103	1831.0	1723.3	53421.0	1827.3	56646.0	1885.0
4	16	65	2081.0	1723.3	53421.0	1827.3	56646.0	2235.0
4	17	294	912.0	1723.3	53421.0	1827.3	56646.0	908.0

TABLE 3: SOLAR DATA (con't.)

HUI	DATE	ORDER	INSOLATION	AVERAGE INSOLATION	TOTAL INSOLATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
4	18	55	2119.0	1723.3	53421.0	1827.3	56646.0	2186.0
4	19	40	2306.0	1723.3	53421.0	1827.3	56646.0	2414.0
4	20	34	1940.0	1723.3	53421.0	1827.3	56646.0	1949.0
4	21	86	1908.0	1723.3	53421.0	1827.3	56646.0	1959.0
4	22	31	2344.0	1723.3	53421.0	1827.3	56646.0	2420.0
4	23	131	1676.0	1723.3	53421.0	1827.3	56646.0	1459.0
4	24	43	2236.0	1723.3	53421.0	1827.3	56646.0	2499.0
4	25	30	2346.0	1723.3	53421.0	1827.3	56646.0	2528.0
4	26	41	2243.0	1723.3	53421.0	1827.3	56646.0	2357.0
4	27	303	805.0	1723.3	53421.0	1827.3	56646.0	786.0
4	28	37	2315.0	1723.3	53421.0	1827.3	56646.0	2370.0
4	29	107	1307.0	1723.3	53421.0	1827.3	56646.0	1288.0
4	30	192	1300.0	1723.3	53421.0	1827.3	56646.0	1244.0
5	1	109	1747.0	1802.5	51281.0	1465.3	46891.0	1741.0
5	2	76	1955.0	1802.5	51281.0	1465.3	46891.0	1875.0
5	3	42	2293.0	1802.5	51281.0	1465.3	46891.0	2245.0
5	4	44	2757.0	1802.5	51281.0	1465.3	46891.0	2224.0
5	5	152	1576.0	1802.5	51281.0	1465.3	46891.0	1526.0
5	6	80	1876.0	1802.5	51281.0	1465.3	46891.0	1777.0
5	7	264	1071.0	1802.5	51281.0	1465.3	46891.0	957.0
5	8	164	1494.0	1802.5	51281.0	1465.3	46891.0	1300.0
5	9	90	1931.0	1802.5	51281.0	1465.3	46891.0	1836.0
5	10	175	1413.0	1802.5	51281.0	1465.3	46891.0	1305.0
5	11	59	2117.0	1802.5	51281.0	1465.3	46891.0	2015.0
5	12	233	1201.0	1802.5	51281.0	1465.3	46891.0	1098.0
5	13	32	2347.0	1802.5	51281.0	1465.3	46891.0	2229.0
5	14	14	2547.0	1802.5	51281.0	1465.3	46891.0	2335.0
5	15	93	1956.0	1802.5	51281.0	1465.3	46891.0	1634.0
5	16	81	1342.0	1802.5	51281.0	1465.3	46891.0	1695.0
5	17	117	1719.0	1802.5	51281.0	1465.3	46891.0	1543.0
5	18	133	1008.0	1802.5	51281.0	1465.3	46891.0	1503.0
5	19	73	1972.0	1802.5	51281.0	1465.3	46891.0	1816.0
5	20	336	547.0	1802.5	51281.0	1465.3	46891.0	455.0
5	21	352	308.0	1802.5	51281.0	1465.3	46891.0	297.0
5	22	326	514.0	1802.5	51281.0	1465.3	46891.0	523.0
5	23	129	1605.0	1802.5	51281.0	1465.3	46891.0	1399.0
5	24	9	2636.0	1802.5	51281.0	1465.3	46891.0	2318.0
5	25	253	1111.0	1802.5	51281.0	1465.3	46891.0	947.0
5	26	7	2649.0	1802.5	51281.0	1465.3	46891.0	2345.0
5	27	132	1649.0	1802.5	51281.0	1465.3	46891.0	1461.0
5	28	358	754.0	1802.5	51281.0	1465.3	46891.0	761.0
5	29	316	717.0	1802.5	51281.0	1465.3	46891.0	627.0
5	30	43	2256.0	1802.5	51281.0	1465.3	46891.0	1992.0
5	31	145	1612.0	1802.5	51281.0	1465.3	46891.0	1460.0
6	1	10	2424.0	2000.1	64048.0	1804.8	55950.0	2304.0
6	2	24	2404.0	2000.1	64048.0	1804.8	55950.0	2220.0

TABLE 3: SOLAR DATA (con't.)

MONT.	DATE	ORDER	INSULATION	AVERAGE INSULATION	TOTAL INSULATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
6	3	74	1972.0	2066.1	64048.0	1804.8	55950.0	1729.0
6	4	34	2339.0	2066.1	64048.0	1804.8	55950.0	2081.0
6	5	6	2707.0	2066.1	64048.0	1804.8	55950.0	2365.0
6	6	48	2247.0	2066.1	64048.0	1804.8	55950.0	1935.0
6	7	114	1744.0	2066.1	64048.0	1804.8	55950.0	1692.0
6	8	214	1250.0	2066.1	64048.0	1804.8	55950.0	982.0
6	9	148	1355.0	2066.1	64048.0	1804.8	55950.0	1063.0
6	10	253	1106.0	2066.1	64048.0	1804.8	55950.0	856.0
6	11	23	2475.0	2066.1	64048.0	1804.8	55950.0	2184.0
6	12	85	1920.0	2066.1	64048.0	1804.8	55950.0	1711.0
6	13	46	2252.0	2066.1	64048.0	1804.8	55950.0	2009.0
6	14	123	1697.0	2066.1	64048.0	1804.8	55950.0	1504.0
6	15	13	2574.0	2066.1	64048.0	1804.8	55950.0	2252.0
6	16	279	1003.0	2066.1	64048.0	1804.8	55950.0	876.0
6	17	153	1505.0	2066.1	64048.0	1804.8	55950.0	1352.0
6	18	259	1100.0	2066.1	64048.0	1804.8	55950.0	983.0
6	19	38	2315.0	2066.1	64048.0	1804.8	55950.0	1988.0
6	20	35	2310.0	2066.1	64048.0	1804.8	55950.0	2012.0
6	21	144	1615.0	2066.1	64048.0	1804.8	55950.0	1403.0
6	22	77	1956.0	2066.1	64048.0	1804.8	55950.0	1712.0
6	23	19	2515.0	2066.1	64048.0	1804.8	55950.0	2245.0
6	24	51	2171.0	2066.1	64048.0	1804.8	55950.0	1969.0
6	25	47	2250.0	2066.1	64048.0	1804.8	55950.0	1863.0
6	26	4	2750.0	2066.1	64048.0	1804.8	55950.0	2244.0
6	27	1	3781.0	2066.1	64048.0	1804.8	55950.0	2994.0
6	28	11	2018.0	2066.1	64048.0	1804.8	55950.0	2362.0
6	29	2	3038.0	2066.1	64048.0	1804.8	55950.0	2771.0
6	30	5	2711.0	2066.1	64048.0	1804.8	55950.0	2449.0
7	1	8	2637.0	2045.1	65443.0	1796.6	57491.0	2335.0
7	2	15	2545.0	2045.1	65443.0	1796.6	57491.0	2350.0
7	3	49	2197.0	2045.1	65443.0	1796.6	57491.0	2098.0
7	4	22	2404.0	2045.1	65443.0	1796.6	57491.0	2237.0
7	5	134	1402.0	2045.1	65443.0	1796.6	57491.0	1485.0
7	6	28	2428.0	2045.1	65443.0	1796.6	57491.0	2135.0
7	7	142	1422.0	2045.1	65443.0	1796.6	57491.0	1455.0
7	8	26	2436.0	2045.1	65443.0	1796.6	57491.0	2175.0
7	9	154	1505.0	2045.1	65443.0	1796.6	57491.0	1357.0
7	10	3	2957.0	2045.1	65443.0	1796.6	57491.0	2006.0
7	11	27	2405.0	2045.1	65443.0	1796.6	57491.0	2125.0
7	12	12	2619.0	2045.1	65443.0	1796.6	57491.0	2256.0
7	13	21	2490.0	2045.1	65443.0	1796.6	57491.0	2188.0
7	14	174	1425.0	2045.1	65443.0	1796.6	57491.0	1255.0
7	15	89	1841.0	2045.1	65443.0	1796.6	57491.0	1644.0
7	16	107	1802.0	2045.1	65443.0	1796.6	57491.0	1610.0
7	17	96	1853.0	2045.1	65443.0	1796.6	57491.0	1562.0
7	18	95	1854.0	2045.1	65443.0	1796.6	57491.0	1638.0

TABLE 3: SOLAR DATA (con't.)

MONTH	DATE	ORDER	INSOLATION	AVERAGE INSOLATION	TOTAL INSOLATION	AVERAGE RADIATION	TOTAL RADIATION	RADIATION
7	19	60	2100.0	2045.1	65443.0	1796.6	57491.0	1811.0
7	20	160	1573.0	2045.1	65443.0	1796.6	57491.0	1316.0
7	21	120	1775.0	2045.1	65443.0	1796.6	57491.0	1513.0
7	22	53	2197.0	2045.1	65443.0	1796.6	57491.0	1924.0
7	23	102	1437.0	2045.1	65443.0	1796.6	57491.0	1558.0
7	24	25	2440.0	2045.1	65443.0	1796.6	57491.0	2125.0
7	25	17	2537.0	2045.1	65443.0	1796.6	57491.0	2251.0
7	26	18	2520.0	2045.1	65443.0	1796.6	57491.0	2252.0
7	27	16	2544.0	2045.1	65443.0	1796.6	57491.0	2290.0
7	28	100	1843.0	2045.1	65443.0	1796.6	57491.0	1806.0
7	29	61	2047.0	2045.1	65443.0	1796.6	57491.0	1945.0
7	30	130	1607.0	2045.1	65443.0	1796.6	57491.0	1494.0
7	31	150	1608.0	2045.1	65443.0	1796.6	57491.0	1495.0
8	1	57	2114.0	1693.2	52488.0	1763.0	54554.0	2017.0
8	2	39	2313.0	1693.2	52488.0	1763.0	54554.0	2224.0
8	3	20	2514.0	1693.2	52488.0	1763.0	54554.0	2383.0
8	4	29	2428.0	1693.2	52488.0	1763.0	54554.0	2324.0
8	5	67	2010.0	1693.2	52488.0	1763.0	54554.0	1962.0
8	6	183	1309.0	1693.2	52488.0	1763.0	54554.0	1787.0
8	7	147	1610.0	1693.2	52488.0	1763.0	54554.0	1499.0
8	8	33	2379.0	1693.2	52488.0	1763.0	54554.0	2121.0
8	9	50	2143.0	1693.2	52488.0	1763.0	54554.0	2181.0
8	10	114	1712.0	1693.2	52488.0	1763.0	54554.0	2185.0
8	11	171	1403.0	1693.2	52488.0	1763.0	54554.0	1430.0
8	12	254	1110.0	1693.2	52488.0	1763.0	54554.0	1033.0
8	13	350	371.0	1693.2	52488.0	1763.0	54554.0	359.0
8	14	234	1140.0	1693.2	52488.0	1763.0	54554.0	1197.0
8	15	120	1644.0	1693.2	52488.0	1763.0	54554.0	1714.0
8	16	139	1445.0	1693.2	52488.0	1763.0	54554.0	1738.0
8	17	110	1714.0	1693.2	52488.0	1763.0	54554.0	1790.0
8	18	73	1971.0	1693.2	52488.0	1763.0	54554.0	2062.0
8	19	153	1571.0	1693.2	52488.0	1763.0	54554.0	1579.0
8	20	230	1208.0	1693.2	52488.0	1763.0	54554.0	1209.0
8	21	149	1604.0	1693.2	52488.0	1763.0	54554.0	1720.0
8	22	146	1611.0	1693.2	52488.0	1763.0	54554.0	1769.0
8	23	136	1654.0	1693.2	52488.0	1763.0	54554.0	1795.0
8	24	99	1844.0	1693.2	52488.0	1763.0	54554.0	2048.0
8	25	42	1939.0	1693.2	52488.0	1763.0	54554.0	2262.0
8	26	72	1987.0	1693.2	52488.0	1763.0	54554.0	2296.0
8	27	161	1513.0	1693.2	52488.0	1763.0	54554.0	1659.0
8	28	115	1730.0	1693.2	52488.0	1763.0	54554.0	1952.0
8	29	79	1952.0	1693.2	52488.0	1763.0	54554.0	2305.0
8	30	68	1943.0	1693.2	52488.0	1763.0	54554.0	2354.0
8	31	71	1941.0	1693.2	52488.0	1763.0	54554.0	2369.0

TABLE 3: SOLAR DATA (conclusion)

MONTH	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE DEGREE DAY	HIGH-LOW DEGREE DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
9	1	158	51.9	13.1	17.4	61.0	44.2	62.3	49.0
9	2	199	55.5	19.5	17.2	59.4	40.1	62.3	49.0
9	3	156	52.2	12.8	12.1	60.0	37.8	62.3	49.0
9	4	106	62.4	2.6	2.4	79.3	45.9	62.3	49.0
9	5	61	66.9	7.9	-2.3	83.3	51.4	62.3	49.0
9	6	42	64.4	.6	.5	77.7	51.1	62.3	49.0
9	7	53	71.9	-6.9	-5.4	68.9	52.0	62.3	49.0
9	8	70	69.9	-4.9	-4.8	62.9	56.7	62.3	49.0
9	9	24	75.1	-10.1	-12.0	89.1	64.9	62.3	49.0
9	10	8	77.9	-12.9	-11.4	91.9	61.0	62.3	49.0
9	11	179	57.4	7.6	8.3	63.5	50.0	62.3	49.0
9	12	110	59.7	5.3	2.7	66.5	50.1	62.3	49.0
9	13	94	64.2	.8	-1.9	77.4	58.5	62.3	49.0
9	14	54	61.9	-6.9	-5.9	66.0	55.2	62.3	49.0
9	15	17	76.3	-11.3	-12.7	87.8	67.5	62.3	49.0
9	16	9	77.3	-12.3	-14.4	94.3	64.6	62.3	49.0
9	17	3	79.0	-14.0	-15.5	92.7	68.4	62.3	49.0
9	18	58	70.1	-5.1	-4.9	82.0	57.9	62.3	49.0
9	19	119	59.2	5.8	6.1	65.8	52.0	62.3	49.0
9	20	176	48.6	16.2	14.0	60.1	41.9	62.3	49.0
9	21	162	51.0	14.0	12.7	65.5	39.0	62.3	49.0
9	22	150	54.2	10.8	10.5	67.3	41.7	62.3	49.0
9	23	86	65.8	-2.8	-2.0	81.5	62.5	62.3	49.0
9	24	99	63.6	1.4	1.1	75.7	52.2	62.3	49.0
9	25	104	62.6	2.4	.9	81.1	47.1	62.3	49.0
9	26	73	69.3	-4.3	-4.4	83.5	52.4	62.3	49.0
9	27	195	46.3	18.7	15.9	61.2	36.9	62.3	49.0
9	28	100	51.5	14.5	13.8	69.1	33.3	62.3	49.0
9	29	123	58.7	4.3	-4.8	75.9	44.6	62.3	49.0
9	30	140	55.2	9.8	7.9	74.8	39.4	62.3	49.0
10	1	153	53.1	11.9	10.4	68.7	40.5	50.0	49.0
10	2	122	56.9	6.1	5.3	80.8	30.7	50.0	49.0
10	3	65	66.5	-1.5	-1.3	83.1	49.5	50.0	49.0
10	4	103	62.6	2.4	2.1	75.2	50.7	50.0	49.0
10	5	164	50.0	15.0	15.9	61.7	30.5	50.0	49.0
10	6	230	40.8	24.2	22.8	49.6	24.7	50.0	49.0
10	7	114	60.3	4.7	9.0	76.6	35.4	50.0	49.0
10	8	116	60.2	4.6	2.9	74.5	47.7	50.0	49.0
10	9	111	61.2	3.6	2.6	78.4	46.4	50.0	49.0
10	10	125	58.4	6.6	3.2	71.8	51.8	50.0	49.0
10	11	166	50.5	14.5	14.1	57.9	43.9	50.0	49.0
10	12	206	44.1	20.9	22.1	46.8	39.0	50.0	49.0
10	13	172	50.0	15.0	15.6	64.2	32.7	50.0	49.0
10	14	221	42.1	22.9	22.8	50.2	34.2	50.0	49.0
10	15	191	46.6	18.4	18.1	64.0	29.8	50.0	49.0

TABLE 4: TEMPERATURE DATA

MONTH	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE DEGREE-DAY	HIGH-LOW DEGREE-DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
10	10	135	56.6	8.4	7.0	73.8	42.1	50.0	49.0
10	11	110	61.4	3.6	1.2	76.6	51.1	50.0	49.0
10	12	127	57.7	7.3	6.4	60.1	48.0	50.0	49.0
10	14	126	58.1	6.9	6.0	73.9	44.1	50.0	49.0
10	20	141	55.1	9.9	8.5	70.0	43.0	50.0	49.0
10	21	132	57.3	7.7	6.3	74.5	43.0	50.0	49.0
10	22	193	45.4	16.6	16.8	52.2	44.1	50.0	49.0
10	23	174	49.2	15.4	13.7	50.7	43.0	50.0	49.0
10	24	167	47.4	17.6	16.9	54.1	42.1	50.0	49.0
10	25	169	47.3	17.7	17.1	56.3	39.6	50.0	49.0
10	26	186	47.4	17.6	17.2	59.5	40.1	50.0	49.0
10	27	163	50.9	14.1	11.3	65.5	41.9	50.0	49.0
10	28	165	50.7	14.3	11.2	63.7	43.9	50.0	49.0
10	29	192	46.5	10.5	17.2	53.2	42.4	50.0	49.0
10	30	239	39.9	23.1	25.8	46.0	32.4	50.0	49.0
10	31	267	35.9	29.1	29.8	45.3	27.0	50.0	49.0
11	1	286	40.2	24.8	24.2	49.3	32.2	36.5	49.0
11	2	270	35.7	29.3	30.4	38.1	31.1	36.5	49.0
11	3	300	30.9	34.1	33.1	34.1	27.7	36.5	49.0
11	4	280	32.7	32.3	31.0	42.8	25.2	36.5	49.0
11	5	253	33.4	26.6	24.9	48.9	31.3	36.5	49.0
11	6	254	38.3	26.7	25.2	48.2	31.5	36.5	49.0
11	7	256	38.2	26.8	25.1	47.0	32.0	36.5	49.0
11	8	264	44.5	20.5	18.2	59.2	34.3	36.5	49.0
11	9	252	38.5	26.5	26.1	43.5	34.3	36.5	49.0
11	10	251	38.9	26.1	24.5	49.6	31.3	36.5	49.0
11	11	233	40.4	24.6	23.4	50.0	33.1	36.5	49.0
11	12	168	50.4	14.6	15.7	64.0	32.5	36.5	49.0
11	13	138	56.1	8.9	11.7	62.1	44.6	36.5	49.0
11	14	215	42.9	22.1	17.9	54.5	35.6	36.5	49.0
11	15	242	39.9	25.2	24.2	48.4	33.1	36.5	49.0
11	16	245	39.3	25.7	23.6	62.0	30.9	36.5	49.0
11	17	219	42.4	22.6	21.5	57.0	30.0	36.5	49.0
11	18	207	44.0	21.0	19.0	57.9	34.0	36.5	49.0
11	19	257	38.2	26.8	26.1	46.9	30.9	36.5	49.0
11	20	247	39.2	25.8	23.4	59.0	24.1	36.5	49.0
11	21	183	47.8	17.2	14.0	66.9	35.1	36.5	49.0
11	22	165	47.5	17.5	16.9	57.0	41.0	36.5	49.0
11	23	243	39.5	25.5	25.2	48.5	30.9	36.5	49.0
11	24	268	35.8	29.2	28.2	48.7	25.0	36.5	49.0
11	25	217	42.7	22.3	19.4	61.7	24.5	36.5	49.0
11	26	265	36.1	28.9	30.5	45.7	23.2	36.5	49.0
11	27	307	29.9	35.1	35.5	39.9	19.0	36.5	49.0
11	28	331	25.2	39.8	40.8	30.9	17.4	36.5	49.0
11	29	356	16.3	48.7	45.9	31.5	6.6	36.5	49.0
11	30	358	15.0	50.0	48.2	30.0	3.7	36.5	49.0

TABLE 4: TEMPERATURE DATA (con't.)

MONTH	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE WINDSPEED	HIGH-LOW DEGREE DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEAR AVERAGE TEMPERATURE
12	1	329	28.0	34.0	37.0	42.8	13.1	28.5	49.0
12	2	318	29.7	35.3	37.1	43.0	20.8	28.5	49.0
12	3	244	34.2	30.8	29.4	50.2	21.0	28.5	49.0
12	4	235	40.2	24.8	22.7	55.6	28.9	28.5	49.0
12	5	214	43.8	22.1	29.6	53.8	35.2	28.5	49.0
12	6	178	34.4	30.6	29.4	44.1	27.0	28.5	49.0
12	7	317	28.2	36.5	36.4	32.7	24.4	28.5	49.0
12	8	225	26.9	38.1	34.1	40.8	17.2	28.5	49.0
12	9	273	35.2	29.8	23.2	52.5	21.0	28.5	49.0
12	10	207	31.4	33.6	31.2	46.0	21.7	28.5	49.0
12	11	308	30.3	34.9	35.1	37.9	21.9	28.5	49.0
12	12	277	34.4	30.6	32.7	39.9	26.1	28.5	49.0
12	13	319	28.4	36.8	36.5	37.4	14.0	28.5	49.0
12	14	312	29.4	35.8	36.1	37.9	14.9	28.5	49.0
12	15	313	29.5	35.2	37.0	37.9	16.0	28.5	49.0
12	16	242	31.3	33.7	32.0	44.1	21.9	28.5	49.0
12	17	271	35.5	24.5	27.9	49.0	26.1	28.5	49.0
12	18	285	32.6	32.4	32.4	41.0	24.1	28.5	49.0
12	19	285	33.4	31.6	33.9	37.9	24.3	28.5	49.0
12	20	246	41.5	33.5	32.3	44.8	20.5	28.5	49.0
12	21	220	42.4	22.6	23.6	54.5	26.4	28.5	49.0
12	22	315	28.9	35.1	31.0	45.7	22.3	28.5	49.0
12	23	355	16.9	48.1	49.2	24.1	7.5	28.5	49.0
12	24	384	8.3	56.7	54.5	20.1	.9	28.5	49.0
12	25	354	16.9	48.1	46.5	33.8	3.2	29.5	49.0
12	26	333	24.8	48.2	39.5	33.4	17.6	28.5	49.0
12	27	321	27.8	37.2	35.0	43.9	16.0	28.5	49.0
12	28	290	32.5	32.5	31.7	45.3	21.4	28.5	49.0
12	29	341	22.5	42.5	40.5	32.5	16.5	28.5	49.0
12	30	338	23.7	41.3	38.4	38.7	14.5	28.5	49.0
12	31	336	24.2	40.8	40.2	34.2	15.3	28.5	49.0
1	1	340	22.5	44.5	41.8	36.0	10.4	29.0	49.0
1	2	337	23.8	41.2	41.4	31.6	15.6	29.0	49.0
1	3	324	25.2	38.8	37.3	42.6	16.7	29.0	49.0
1	4	318	29.6	35.4	36.0	41.4	16.5	29.0	49.0
1	5	303	30.3	34.7	33.4	39.6	23.5	29.0	49.0
1	6	241	39.8	25.2	27.7	52.0	22.5	29.0	49.0
1	7	241	32.3	32.7	33.0	41.2	22.8	29.0	49.0
1	8	323	27.4	37.6	37.7	39.7	14.9	29.0	49.0
1	9	309	29.6	35.4	37.2	33.6	21.9	29.0	49.0
1	10	353	17.0	48.0	46.7	24.1	10.4	29.0	49.0
1	11	365	8.1	56.9	56.6	18.9	-2.2	29.0	49.0
1	12	361	12.8	52.2	53.7	25.3	-2.7	29.0	49.0
1	13	240	39.9	25.1	28.1	46.8	27.0	29.0	49.0
1	14	164	47.5	17.5	17.4	58.6	36.5	29.0	49.0
1	15	228	41.2	23.9	24.7	52.7	28.0	29.0	49.0

TABLE 4: TEMPERATURE DATA (con't.)

MONTH	DATE	CHIEF	AVERAGE TEMPERATURE	AVERAGE DEGREE-DAY	HIGH-LOW DEGREE-DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
1	16	314	29.3	35.7	35.1	36.1	23.0	29.0	49.0
1	17	255	38.7	26.8	27.3	52.2	21.2	29.0	49.0
1	18	229	41.6	24.0	21.2	59.2	28.4	29.0	49.0
1	19	294	31.8	33.2	32.7	44.6	20.1	29.0	49.0
1	20	208	43.9	21.1	23.0	54.7	29.3	29.0	49.0
1	21	339	23.2	41.8	41.4	29.7	13.5	29.0	49.0
1	22	334	24.6	40.4	39.5	39.2	11.8	29.0	49.0
1	23	126	29.9	25.1	26.3	50.9	20.4	29.0	49.0
1	24	277	41.2	23.8	29.5	46.0	25.0	29.0	49.0
1	25	301	40.5	34.5	33.9	36.0	26.1	29.0	49.0
1	26	274	34.4	30.1	30.1	50.0	19.9	29.0	49.0
1	27	345	20.4	44.6	40.4	33.1	10.0	29.0	49.0
1	28	335	24.4	40.6	37.9	40.5	13.8	29.0	49.0
1	29	376	26.9	38.1	36.9	36.5	19.6	29.0	49.0
1	30	344	21.2	43.8	41.7	29.8	10.9	29.0	49.0
1	31	347	19.3	45.7	43.8	31.8	10.6	29.0	49.0
2	1	302	30.4	34.6	32.8	48.4	10.0	30.3	49.0
2	2	287	42.9	32.1	30.2	48.6	21.0	30.3	49.0
2	3	328	26.4	38.6	35.3	43.3	14.2	30.3	49.0
2	4	352	17.1	47.9	43.6	21.0	11.8	30.3	49.0
2	5	363	9.0	56.0	57.2	18.7	-3.1	30.3	49.0
2	6	362	11.6	53.3	52.1	32.0	-0.2	30.3	49.0
2	7	278	34.4	30.6	31.1	50.0	10.0	30.3	49.0
2	8	240	49.0	26.0	24.1	59.7	14.2	30.3	49.0
2	9	202	44.7	20.3	24.6	41.2	19.6	30.3	49.0
2	10	238	40.7	24.3	23.5	50.5	12.4	30.3	49.0
2	11	244	39.3	25.7	23.3	54.3	29.1	30.3	49.0
2	12	234	40.3	24.7	23.9	57.4	26.6	30.3	49.0
2	13	186	48.1	16.9	15.9	58.5	34.6	30.3	49.0
2	14	264	36.4	20.6	31.6	45.0	21.9	30.3	49.0
2	15	349	17.7	47.3	45.9	24.2	8.1	30.3	49.0
2	16	357	16.1	48.9	48.6	29.7	1.0	30.3	49.0
2	17	332	24.9	40.1	39.4	36.1	10.0	30.3	49.0
2	18	343	21.7	43.3	41.5	35.8	13.1	30.3	49.0
2	19	336	25.2	39.6	38.9	40.5	11.7	30.3	49.0
2	20	313	29.3	35.7	32.7	41.5	23.2	30.3	49.0
2	21	342	22.2	42.8	41.4	31.1	10.0	30.3	49.0
2	22	148	19.1	45.9	43.2	32.4	10.6	30.3	49.0
2	23	275	34.6	30.4	36.3	46.0	11.5	30.3	49.0
2	24	146	46.0	19.0	17.2	61.3	24.3	30.3	49.0
2	25	263	33.6	31.4	29.3	46.8	24.8	30.3	49.0
2	26	304	30.3	34.7	33.0	41.9	22.1	30.3	49.0
2	27	269	43.9	21.1	24.2	53.1	28.4	30.3	49.0
2	28	263	44.6	20.4	20.4	58.5	20.7	30.3	49.0
3	1	178	50.0	13.0	13.8	62.8	34.6	33.4	49.0
3	2	248	39.0	20.0	22.5	56.7	28.2	33.4	49.0

TABLE 4: TEMPERATURE DATA (con't.)

MONTH	DATE	ORIG	AVERAGE TEMPERATURE	AVERAGE PRECIP. INCH	HIGH-LOW DEGREE DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
1	3	213	36.4	20.6	27.2	50.7	24.8	33.4	49.0
3	4	217	42.5	22.4	21.7	61.4	26.1	33.4	49.0
3	5	167	51.5	14.5	14.4	62.8	38.3	33.4	49.0
3	6	174	34.2	30.8	31.4	47.7	23.5	33.4	49.0
3	7	314	24.5	36.5	36.4	37.8	22.5	33.4	49.0
3	8	246	31.5	33.5	31.2	44.1	23.5	33.4	49.0
3	9	243	31.9	32.1	20.9	41.5	26.6	33.4	49.0
3	10	316	28.6	30.4	36.5	33.4	23.5	33.4	49.0
3	11	322	27.8	31.2	38.3	32.4	21.0	33.4	49.0
3	12	324	27.0	38.0	36.2	40.1	17.6	33.4	49.0
3	13	282	43.6	31.4	30.7	49.3	19.4	33.4	49.0
3	14	246	34.2	25.8	23.1	57.0	26.8	33.4	49.0
3	15	250	34.4	20.1	24.2	52.2	24.5	33.4	49.0
3	16	254	34.3	20.0	25.5	57.4	21.0	33.4	49.0
3	17	224	41.7	23.3	21.9	53.1	23.1	33.4	49.0
3	18	200	45.1	19.9	17.3	60.3	31.1	33.4	49.0
3	19	142	34.9	10.4	9.2	70.9	40.2	33.4	49.0
3	20	145	34.6	10.4	9.8	70.7	39.7	33.4	49.0
3	21	225	41.3	23.7	22.9	50.9	23.4	33.4	49.0
3	22	211	43.2	21.8	13.9	59.4	22.7	33.4	49.0
3	23	281	33.8	31.2	32.1	46.1	25.7	33.4	49.0
3	24	216	34.9	29.1	29.3	46.0	26.1	33.4	49.0
3	25	212	35.5	29.5	29.2	51.8	21.9	33.4	49.0
3	26	327	26.7	30.3	38.4	38.1	15.1	33.4	49.0
3	27	360	17.6	32.2	53.9	15.8	6.4	33.4	49.0
3	28	384	14.3	30.7	49.5	24.4	2.8	33.4	49.0
3	29	346	19.9	45.1	46.8	34.0	3.9	33.4	49.0
3	30	286	33.0	32.0	31.6	55.4	18.9	33.4	49.0
3	31	249	31.1	34.9	34.5	41.5	19.4	33.4	49.0
4	1	351	17.3	47.7	43.9	27.5	4.6	42.7	49.0
4	2	356	17.3	47.7	47.7	36.0	-1.3	42.7	49.0
4	3	304	30.2	44.8	35.7	43.0	13.6	42.7	49.0
4	4	222	47.4	23.0	23.4	55.0	26.2	42.7	49.0
4	5	174	46.3	16.7	14.7	63.5	27.2	42.7	49.0
4	6	176	48.4	16.6	15.8	64.8	33.6	42.7	49.0
4	7	212	43.2	21.8	16.9	58.6	27.8	42.7	49.0
4	8	260	37.5	27.5	27.5	47.3	21.7	42.7	49.0
4	9	261	36.8	28.2	27.4	51.1	24.1	42.7	49.0
4	10	284	33.6	31.4	31.1	38.7	24.1	42.7	49.0
4	11	292	32.1	32.9	31.2	38.8	26.8	42.7	49.0
4	12	264	35.7	24.3	27.5	41.2	24.8	42.7	49.0
4	13	259	37.9	27.1	26.3	50.4	27.0	42.7	49.0
4	14	205	44.3	20.7	19.7	63.0	27.5	42.7	49.0
4	15	157	52.0	13.0	13.1	64.2	37.6	42.7	49.0
4	16	139	55.8	9.2	7.4	71.1	44.1	42.7	49.0
4	17	273	41.8	23.2	23.0	54.9	29.1	42.7	49.0

TABLE 4: TEMPERATURE DATA (con't.)

NUMBER	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE DEGREE-DAY	HIGH-LOW DEGREE-DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
4	15	262	36.8	26.2	29.3	45.3	26.1	42.7	49.0
4	15	198	45.0	19.4	19.0	58.6	33.4	42.7	49.0
4	20	161	51.4	13.6	11.7	65.7	41.0	42.7	49.0
4	21	190	46.8	18.2	17.6	61.7	33.1	42.7	49.0
4	22	143	54.9	10.1	9.6	74.1	36.7	42.7	49.0
4	23	131	57.4	7.6	8.3	70.0	43.3	42.7	49.0
4	24	152	53.6	11.4	10.6	69.4	23.4	42.7	49.0
4	25	112	61.6	4.0	2.9	82.9	41.2	42.7	49.0
4	26	93	64.4	.6	1.6	84.6	46.2	42.7	49.0
4	27	210	43.7	21.3	22.7	52.7	32.0	42.7	49.0
4	28	213	43.1	21.9	21.7	52.7	43.8	42.7	49.0
4	29	237	40.1	24.9	24.0	49.4	33.6	42.7	49.0
4	30	231	43.7	24.3	24.2	51.1	30.6	42.7	49.0
5	1	177	48.5	16.5	16.4	64.6	32.4	52.9	49.0
5	2	154	52.4	12.2	13.2	63.9	39.6	52.9	49.0
5	3	137	56.1	8.9	11.0	71.8	36.1	52.9	49.0
5	4	109	61.9	3.5	4.8	77.9	42.6	52.9	49.0
5	5	159	51.0	13.2	8.4	71.4	41.7	52.9	49.0
5	6	197	45.4	19.2	19.4	55.9	35.2	52.9	49.0
5	7	182	48.0	17.0	15.2	61.2	30.5	52.9	49.0
5	8	173	44.5	15.5	14.2	64.6	41.0	52.9	49.0
5	9	149	54.2	10.8	9.5	73.6	37.4	52.9	49.0
5	10	130	57.4	7.6	9.9	73.2	43.0	52.9	49.0
5	11	124	57.7	7.1	6.7	70.2	46.4	52.9	49.0
5	12	175	44.9	16.1	15.3	57.7	41.7	52.9	49.0
5	13	151	53.7	11.3	10.6	66.0	41.2	52.9	49.0
5	14	105	52.9	2.5	3.9	77.0	45.1	52.9	49.0
5	15	44	65.3	-.3	-1.9	85.5	48.4	52.9	49.0
5	16	70	65.0	-3.0	-4.9	84.7	47.1	52.9	49.0
5	17	41	65.1	-.1	-3.1	80.6	45.6	52.9	49.0
5	18	161	63.2	1.8	-.5	80.6	50.4	52.9	49.0
5	19	63	65.8	1.8	-1.5	81.7	51.3	52.9	49.0
5	20	194	46.4	18.6	16.1	58.3	39.6	52.9	49.0
5	21	201	45.0	20.0	15.4	61.0	37.8	52.9	49.0
5	22	141	48.0	17.0	16.5	57.9	39.0	52.9	49.0
5	23	154	50.7	14.3	13.7	60.4	42.3	52.9	49.0
5	24	117	59.8	5.2	7.0	74.1	41.9	52.9	49.0
5	25	145	54.3	10.7	10.6	63.5	44.3	52.9	49.0
5	26	140	54.4	10.6	11.8	68.4	37.9	52.9	49.0
5	27	120	59.2	5.8	6.8	73.8	42.6	52.9	49.0
5	28	220	41.2	23.8	23.2	47.3	36.3	52.9	49.0
5	29	210	42.0	22.2	22.2	50.9	34.7	52.9	49.0
5	30	144	54.7	10.3	10.1	66.7	43.2	52.9	49.0
5	31	155	52.2	12.8	11.3	61.9	45.5	52.9	49.0
6	1	147	54.4	10.6	11.2	65.1	42.6	63.2	49.0
6	2	192	43.1	1.9	3.1	77.7	40.2	63.2	49.0

TABLE 4: TEMPERATURE DATA (con't.)

MONTH	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE SOURCE-DAY	HIGH-LOW DEGREE DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	YEARLY AVERAGE TEMPERATURE
5	3	74	67.7	-2.7	-4.3	84.0	54.7	63.2	49.0
5	4	75	64.2	-1.0	-1.3	79.7	51.6	63.2	49.0
5	5	77	62.3	-3.3	-1.3	81.3	51.3	63.2	49.0
5	6	40	73.0	-8.0	-7.6	88.0	57.2	63.2	49.0
5	7	67	60.0	-1.0	-6.7	67.4	55.9	63.2	49.0
5	8	121	59.0	6.0	6.2	68.0	49.6	63.2	49.0
5	9	171	50.0	15.0	14.2	58.1	43.5	63.2	49.0
5	10	140	47.0	17.6	15.7	57.2	41.5	63.2	49.0
5	11	124	58.5	6.5	9.3	71.4	39.9	63.2	49.0
5	12	47	75.5	-1.5	-1.2	80.2	52.2	63.2	49.0
5	13	46	72.6	-2.6	-3.6	83.8	53.4	63.2	49.0
5	14	84	60.6	-1.6	-2.0	75.7	50.3	63.2	49.0
5	15	51	72.1	-7.1	-3.8	86.7	50.9	63.2	49.0
5	16	115	60.7	-4.6	-7.0	70.0	46.0	63.2	49.0
5	17	130	70.3	8.7	7.1	69.8	46.0	63.2	49.0
5	18	134	57.0	8.0	5.0	70.2	49.8	63.2	49.0
5	19	106	61.8	-2.2	-1.8	74.5	52.0	63.2	49.0
5	20	97	64.0	1.0	.5	81.3	47.7	63.2	49.0
5	21	107	61.8	3.2	1.8	75.6	49.4	63.2	49.0
5	22	48	63.8	-1.2	.8	77.9	50.4	63.2	49.0
5	23	80	67.1	-2.1	-2.8	83.7	52.0	63.2	49.0
5	24	55	70.4	-5.4	-5.8	89.4	52.2	63.2	49.0
5	25	66	70.3	-5.3	-7.8	80.9	46.7	63.2	49.0
5	26	93	65.1	-1.3	1.1	80.6	47.3	63.2	49.0
5	27	69	70.0	-5.0	-3.3	67.1	49.6	63.2	49.0
5	28	71	69.8	-4.8	-4.4	84.9	54.0	63.2	49.0
5	29	52	71.9	-6.9	-6.9	88.0	45.9	63.2	49.0
5	30	15	76.7	-11.7	-10.4	95.0	55.9	63.2	49.0
7	1	6	78.1	-13.1	-14.2	97.2	61.3	71.4	49.0
7	2	26	74.0	-11.0	-12.0	95.0	54.0	71.4	49.0
7	3	27	74.9	-4.9	-11.4	97.8	60.1	71.4	49.0
7	4	14	76.0	-11.0	-11.4	92.3	50.6	71.4	49.0
7	5	50	72.7	-7.7	-11.5	90.0	63.0	71.4	49.0
7	6	36	73.4	-8.4	-8.9	84.9	59.0	71.4	49.0
7	7	38	73.1	-8.1	-9.7	87.3	62.1	71.4	49.0
7	8	42	72.9	-7.9	-8.5	87.3	59.7	71.4	49.0
7	9	75	66.9	-3.9	-7.1	85.6	60.6	71.4	49.0
7	10	62	70.5	-5.5	-5.8	83.8	57.7	71.4	49.0
7	11	59	70.9	-5.9	-6.7	84.0	57.4	71.4	49.0
7	12	76	68.6	-3.6	-2.8	87.0	53.0	71.4	49.0
7	13	35	73.6	-8.6	-7.0	88.5	55.6	71.4	49.0
7	14	34	73.5	-8.5	-11.5	92.1	61.0	71.4	49.0
7	15	25	75.0	-10.0	-10.4	90.5	60.4	71.4	49.0
7	16	37	73.1	-8.1	-11.3	92.4	59.9	71.4	49.0
7	17	45	72.6	-7.6	-6.6	86.7	56.5	71.4	49.0
7	18	11	77.2	-12.2	-12.0	92.5	61.5	71.4	49.0

TABLE 4: TEMPERATURE DATA (con't.)

NO.	DATE	ORDER	AVERAGE TEMPERATURE	AVERAGE DEGREE-DAY	HIGH-LOW DEGREE-DAY	DAILY HIGH TEMPERATURE	DAILY LOW TEMPERATURE	MONTHLY AVERAGE TEMPERATURE	MONTHLY AVERAGE TEMPERATURE
7	14	7	78.1	-13.1	-13.0	91.8	65.7	71.4	49.0
7	20	61	78.3	-5.5	-6.3	81.9	60.6	71.4	49.0
7	21	20	74.9	-9.9	-10.2	93.4	57.0	71.4	49.0
7	22	30	74.4	-9.4	-11.8	90.7	63.0	71.4	49.0
7	23	64	78.4	-5.4	-9.0	82.0	57.2	71.4	49.0
7	24	50	78.7	-5.7	-6.9	89.1	54.7	71.4	49.0
7	25	14	76.1	-11.1	-10.2	91.9	58.5	71.4	49.0
7	26	10	77.7	-12.2	-11.6	92.0	40.4	71.4	49.0
7	27	12	77.1	-12.1	-11.2	92.3	60.1	71.4	49.0
7	28	28	74.8	-9.8	-8.3	89.2	57.4	71.4	49.0
7	29	2	74.4	-14.4	-14.5	94.8	64.2	71.4	49.0
7	30	27	75.8	-10.8	-10.7	87.3	63.1	71.4	49.0
7	31	48	72.4	-7.4	-8.2	87.8	58.5	71.4	49.0
8	1	72	64.4	-4.5	-6.9	84.0	47.9	69.6	49.0
8	2	54	71.3	-6.3	-7.9	86.7	54.2	69.6	49.0
8	3	16	70.3	-11.3	-7.9	91.0	54.9	69.6	49.0
8	4	4	78.1	-13.1	-11.5	94.8	58.3	69.6	49.0
8	5	29	74.5	-9.5	-9.3	89.6	59.0	69.6	49.0
8	6	4	78.3	-13.3	-13.2	94.5	61.9	69.6	49.0
8	7	1	79.0	-14.0	-14.0	94.6	63.5	69.6	49.0
8	8	34	73.0	-8.0	-8.3	84.7	41.9	69.6	49.0
8	9	16	76.7	-11.7	-11.8	95.2	58.5	69.6	49.0
8	10	23	75.7	-10.7	-10.5	91.0	40.1	69.6	49.0
8	11	13	77.0	-12.0	-12.2	91.4	63.0	69.6	49.0
8	12	57	71.5	-6.5	-7.3	82.0	62.6	69.6	49.0
8	13	133	57.7	-7.0	-7.8	68.4	54.1	69.6	49.0
8	14	113	60.3	4.7	3.1	69.3	54.5	69.6	49.0
8	15	46	64.7	4.8	7	74.1	52.5	69.6	49.0
8	16	68	65.4	4	-1.3	77.2	55.4	69.6	49.0
8	17	74	69.0	-4.0	-4.3	85.3	53.4	69.6	49.0
8	18	49	72.2	-7.2	-7.4	87.8	57.0	69.6	49.0
8	19	32	74.0	-4.0	-8.0	88.3	47.7	69.6	49.0
8	20	31	74.3	-4.3	-13.7	91.8	65.5	69.6	49.0
8	21	55	71.9	-6.9	-10.4	89.1	61.7	69.6	49.0
8	22	63	70.4	-5.4	-5.9	84.2	57.7	69.6	49.0
8	23	44	72.7	-7.7	-8.4	86.3	58.5	69.6	49.0
8	24	33	73.4	-8.9	-7.8	86.7	54.0	69.6	49.0
8	25	100	63.3	-1.7	-1.9	78.3	47.8	69.6	49.0
8	26	67	70.2	-5.2	-3.6	84.9	52.3	69.6	49.0
8	27	47	72.6	-7.6	-9.1	88.2	60.1	69.6	49.0
8	28	41	72.9	-7.9	-8.3	86.5	40.1	69.6	49.0
8	29	43	72.0	-7.8	-8.8	86.9	50.6	69.6	49.0
8	30	56	71.7	-6.7	-7.0	88.2	55.8	69.6	49.0
8	31	21	75.8	-10.8	-12.1	92.5	61.7	69.6	49.0

TABLE 4: TEMPERATURE DATA (conclusion)

"average degree day" gives the degree days based upon the average temperature. That is, the difference between 65°F and the average temperature gives the degree days. The column labeled "H-L degree day" represents the degree days based upon the mean between the high and low temperature for the day. "Day high" and "day low" represent the high and low temperature for the particular month. "Year average" clearly gives the average ambient temperature for the year.

Table 5 represents a summary of the number of hours during the year for which the ambient temperature was between specified values as shown by the table.

Data for Solar House II are not yet available on magnetic tape; however, strip chart recordings have been developed for an extended period and these are in the process of being reduced and transposed to magnetic tape to provide the same information as is available for CSU Solar I. The same situation applies with respect to data from the Townes Elementary School. The Bridgers and Paxton data should be available on magnetic tape, but we have not yet been able to acquire these.

The above-mentioned four data sets would provide data for validation of residential type structures using both air and water systems, validation of an institutional type building utilizing a different set of components, and validation of a commercial type building utilizing still a different set of components. We believe that this range of buildings will provide for satisfactory validation of the computer aided design program. The validation, in each case, would necessarily be based upon performance and not involve the economic considerations.

BELOW ZERO =		17.00	HOURS
0 TO 5=		47.00	HOURS
5 TO 10=		69.00	HOURS
10 TO 15=		157.00	HOURS
15 TO 20=		306.00	HOURS
20 TO 25=		382.00	HOURS
25 TO 30=		542.00	HOURS
30 TO 35=		741.00	HOURS
35 TO 40=		845.00	HOURS
40 TO 45=		761.00	HOURS
45 TO 50=		763.00	HOURS
50 TO 55=		663.00	HOURS
55 TO 60=		725.00	HOURS
60 TO 65=		703.00	HOURS
65 TO 70=		531.00	HOURS
70 TO 75=		472.00	HOURS
75 TO 80=		367.00	HOURS
80 TO 85=		330.00	HOURS
85 TO 90=		186.00	HOURS
90 TO 95=		97.00	HOURS
95 TO 100=		6.00	HOURS
ABOVE 100 DEGREES =		0.00	HOURS

TABLE 5: SUMMARY OF TEMPERATURE DATA

SUMMARY OF RESEARCH ACTIVITIES

AND

DEVELOPMENT PLAN FOR THE VALIDATION OF MITAS

1. Because the time frame for producing the final product for this project is relatively short (4-1/2 months), two separate research activities have been conducted simultaneously at SEEC since April 1, 1976, namely, (1) the Data Processing and Analysis activities, and (2) the Model Validation activities. The coordination of these two functions within SEEC can be illustrated by the flowchart of Figure 8.
2. The Data Processing and Analysis activities cover two main areas in this research project, namely, (1) the processing and analysis of climatic data and Solar Systems performance data which are to be used in the validation of MITAS, and (2) the investigation of optimal approaches to Data Filtering and Discrimination techniques for choosing among competing digital simulation models.
3. The Data Analysis Procedure is illustrated by the flowchart on Figure 9, which shows five major steps in this approach:
 - (a) Data Preprocessing: data correction according to operating conditions;
 - (b) Data Filtering: which includes thresholding operation to eliminate shot noise and data transformation by a first-order statistical filter. In the next reporting period, this task will also include the use of pattern recognition techniques, i.e., discriminant analysis for outliers identification and clustering analysis for group association investigation, and of higher order statistical filters to remove the effect of persistence in the data and the power at unwanted frequencies. The proposed approach to Data Filtering is given by the flowchart on Figure 10.
 - (c) Clustering Analysis: this task aims at identifying bad data points (outliers) and investigating group characteristics, and is therefore very useful for preliminary data analysis.
 - (d) Statistical Analysis: This task aims at the identification of characteristic features of the given data set. It consists of basic statistical moments computation, range and mid-range values, cumulative and relative frequency distribution computation and plots. Samples of these results are given in Figures 11 to 18.
 - (e) Data evaluation: This task constitutes the final step in the proposed data analysis approach. From the analysis of results obtained by the above steps, one can decide whether the data set is acceptable for model validation or still needs further processing.

FIGURE 8: FLOWCHART OF RESEARCH ACTIVITIES FOR THE EVALUATION OF MITAS

FIGURE 9: FLOWCHART OF THE DATA ANALYSIS PROCEDURE

FIGURE 10: FLOWCHART OF THE PROPOSED APPROACH TO DATA FILTERING

TABLE OF THE COMPUTED RELATIVE FREQUENCIES (RPF) AND THE CUMULATIVE FREQUENCIES (COF)
 REFERENCE INSTANT 0000Z 10 JANUARY 1975

NO.	RANGE	WIDTH	NO. OF OBS.	COF	RPF
1	0.0-1.0	1.0	30.0000	.09477	.09477
2	1.0-2.0	1.0	11.0000	.13226	.23548
3	2.0-3.0	1.0	8.0000	.15946	.25581
4	3.0-4.0	1.0	10.0000	.19072	.33226
5	4.0-5.0	1.0	9.0000	.21935	.32403
6	5.0-6.0	1.0	8.0000	.24516	.32581
7	6.0-7.0	1.0	12.0000	.29397	.33671
8	7.0-8.0	1.0	6.0000	.30323	.31935
9	8.0-9.0	1.0	4.0000	.31613	.31790
10	9.0-10.0	1.0	11.0000	.35151	.33671
11	10.0-11.0	1.0	2.0000	.35806	.33446
12	11.0-12.0	1.0	1.0000	.36134	.33523
13	12.0-13.0	1.0	9.0000	.37032	.32903
14	13.0-14.0	1.0	7.0000	.41290	.32258
15	14.0-15.0	1.0	15.0000	.46129	.34639
16	15.0-16.0	1.0	8.0000	.46714	.32581
17	16.0-17.0	1.0	16.0000	.51935	.33726
18	17.0-18.0	1.0	8.0000	.54516	.32581
19	18.0-19.0	1.0	4.0000	.54906	.31290
20	19.0-20.0	1.0	4.0000	.57097	.31290
21	20.0-21.0	1.0	7.0000	.59355	.32258
22	21.0-22.0	1.0	7.0000	.61613	.32258
23	22.0-23.0	1.0	2.0000	.62258	.30645
24	23.0-24.0	1.0	6.0000	.64104	.31935
25	24.0-25.0	1.0	10.0000	.67414	.33226
26	25.0-26.0	1.0	8.0000	.70393	.32903
27	26.0-27.0	1.0	2.0000	.70946	.30645
28	27.0-28.0	1.0	12.0000	.74494	.33726
29	28.0-29.0	1.0	4.0000	.76129	.31290
30	29.0-30.0	1.0	10.0000	.79355	.33226
31	30.0-31.0	1.0	6.0000	.80645	.31290
32	31.0-32.0	1.0	9.0000	.83548	.32903
33	32.0-33.0	1.0	8.0000	.86174	.32581
34	33.0-34.0	1.0	6.0000	.88710	.32581
35	34.0-35.0	1.0	5.0000	.90323	.31613
36	35.0-36.0	1.0	3.0000	.91290	.30966
37	36.0-37.0	1.0	3.0000	.92258	.30966
38	37.0-38.0	1.0	3.0000	.93226	.30966
39	38.0-39.0	1.0	0.0000	.93226	0.00000
40	39.0-40.0	1.0	2.0000	.93871	.30645
41	40.0-41.0	1.0	6.0000	.95806	.31935
42	41.0-42.0	1.0	4.0000	.97697	.31290
43	42.0-43.0	1.0	3.0000	.98065	.30966
44	43.0-44.0	1.0	1.0000	.98397	.30323
45	44.0-45.0	1.0	0.0000	.98397	0.00000
46	45.0-46.0	1.0	1.0000	.98710	.30323
47	46.0-47.0	1.0	2.0000	.99355	.30645
48	47.0-48.0	1.0	1.0000	.99477	.30323
49	48.0-49.0	1.0	0.0000	.99477	0.00000
50	49.0-50.0	1.0	1.0000	1.00000	.30323

FIGURE 11

COMPUTED RELATIVE FREQUENCY CURVE
AVERAGE INTENSITY OF SOLAR RADIATION ON HORIZONTAL SURFACE JANUARY 1975

N		MID-R FREQ		RHS. FREQ.		CDF		RHS	
1	1	3.42294	3.42294	0.00000	34.00000	.09677	---	.09677	---
2	1	3.42294	4.35181	0.00000	12.00000	.13544	---	.03867	---
3	1	9.42294	1.41324	12.00000	7.00000	.16400	---	.02258	---
4	1	15.42294	2.11229	18.00000	8.00000	.18327	---	.02581	---
5	1	21.42294	27.11229	24.00000	12.00000	.22244	---	.03871	---
6	1	27.42294	33.21229	30.00000	4.00000	.23871	---	.01813	---
7	1	33.42294	39.21229	36.00000	9.00000	.26779	---	.02403	---
8	1	39.42294	45.21229	42.00000	5.00000	.28371	---	.01813	---
9	1	45.42294	51.21229	48.00000	9.00000	.31279	---	.02403	---
10	1	51.42294	57.21229	54.00000	3.00000	.32244	---	.00968	---
11	1	57.42294	63.21229	60.00000	10.00000	.35244	---	.03226	---
12	1	63.42294	69.21229	66.00000	4.00000	.36779	---	.01290	---
13	1	69.42294	75.21229	72.00000	2.00000	.37479	---	.00645	---
14	1	75.42294	81.21229	78.00000	2.00000	.38444	---	.00645	---
15	1	81.42294	87.21229	84.00000	3.00000	.39779	---	.00968	---
16	1	87.42294	93.21229	90.00000	4.00000	.40379	---	.01290	---
17	1	93.42294	99.21229	96.00000	2.00000	.40444	---	.00645	---
18	1	99.42294	105.21229	102.00000	4.00000	.42244	---	.01290	---
19	1	105.42294	111.21229	108.00000	6.00000	.44179	---	.01625	---
20	1	111.42294	117.21229	114.00000	5.00000	.45244	---	.01813	---
21	1	117.42294	123.21229	120.00000	9.00000	.48179	---	.02581	---
22	1	123.42294	129.21229	126.00000	6.00000	.51244	---	.02403	---
23	1	129.42294	135.21229	132.00000	11.00000	.54244	---	.03548	---
24	1	135.42294	141.21229	138.00000	7.00000	.57179	---	.02258	---
25	1	141.42294	147.21229	144.00000	9.00000	.59244	---	.02403	---
26	1	147.42294	153.21229	150.00000	3.00000	.60444	---	.00968	---
27	1	153.42294	159.21229	156.00000	4.00000	.62244	---	.01290	---
28	1	159.42294	165.21229	162.00000	4.00000	.63544	---	.01290	---
29	1	165.42294	171.21229	168.00000	1.00000	.63871	---	.00323	---
30	1	171.42294	177.21229	174.00000	3.00000	.64244	---	.00968	---
31	1	177.42294	183.21229	180.00000	2.00000	.65444	---	.00645	---
32	1	183.42294	189.21229	186.00000	4.00000	.67779	---	.01290	---
33	1	189.42294	195.21229	192.00000	5.00000	.68779	---	.01613	---
34	1	195.42294	201.21229	198.00000	6.00000	.70379	---	.01925	---
35	1	201.42294	207.21229	204.00000	8.00000	.72444	---	.02581	---
36	1	207.42294	213.21229	210.00000	9.00000	.75444	---	.02403	---
37	1	213.42294	219.21229	216.00000	3.00000	.76779	---	.00968	---
38	1	219.42294	225.21229	222.00000	5.00000	.78179	---	.01613	---
39	1	225.42294	231.21229	228.00000	5.00000	.80000	---	.01613	---
40	1	231.42294	237.21229	234.00000	4.00000	.81244	---	.01290	---

COULUMINE RELATIVE FREQUENCY CONVE
AVERAGE ILLUMINANCE SOLAR RADIATION ON A 45 DEG. TILTED SURFACE *** JANUARY 1966

CUMULATIVE RELATIVE FREQUENCY CURVE

AVG RAINFALL OF 57.44 RADIATION OF 45 DEG. TILTED SURFACE JANUARY 1975

Y-INCREMENT = .0100 X-INCREMENT = 2.00

FIGURE 14

TABLE 2. ALL (U. S. POPULATION) AND THE CUMULATIVE FREQUENCIES (COF) AND THE CUMULATIVE PERCENTAGES (COP) FOR THE YEAR 1970

AGE	SEX	POP.	COF	COP
1	M	3,315	2,710	2.0000
2	M	3,315	2,710	2.0000
3	M	3,315	2,710	2.0000
4	M	3,315	2,710	2.0000
5	M	3,315	2,710	2.0000
6	M	3,315	2,710	2.0000
7	M	3,315	2,710	2.0000
8	M	3,315	2,710	2.0000
9	M	3,315	2,710	2.0000
10	M	3,315	2,710	2.0000
11	M	3,315	2,710	2.0000
12	M	3,315	2,710	2.0000
13	M	3,315	2,710	2.0000
14	M	3,315	2,710	2.0000
15	M	3,315	2,710	2.0000
16	M	3,315	2,710	2.0000
17	M	3,315	2,710	2.0000
18	M	3,315	2,710	2.0000
19	M	3,315	2,710	2.0000
20	M	3,315	2,710	2.0000
21	M	3,315	2,710	2.0000
22	M	3,315	2,710	2.0000
23	M	3,315	2,710	2.0000
24	M	3,315	2,710	2.0000
25	M	3,315	2,710	2.0000
26	M	3,315	2,710	2.0000
27	M	3,315	2,710	2.0000
28	M	3,315	2,710	2.0000
29	M	3,315	2,710	2.0000
30	M	3,315	2,710	2.0000
31	M	3,315	2,710	2.0000
32	M	3,315	2,710	2.0000
33	M	3,315	2,710	2.0000
34	M	3,315	2,710	2.0000
35	M	3,315	2,710	2.0000
36	M	3,315	2,710	2.0000
37	M	3,315	2,710	2.0000
38	M	3,315	2,710	2.0000
39	M	3,315	2,710	2.0000
40	M	3,315	2,710	2.0000
41	M	3,315	2,710	2.0000
42	M	3,315	2,710	2.0000
43	M	3,315	2,710	2.0000
44	M	3,315	2,710	2.0000
45	M	3,315	2,710	2.0000
46	M	3,315	2,710	2.0000
47	M	3,315	2,710	2.0000
48	M	3,315	2,710	2.0000
49	M	3,315	2,710	2.0000
50	M	3,315	2,710	2.0000
51	M	3,315	2,710	2.0000
52	M	3,315	2,710	2.0000
53	M	3,315	2,710	2.0000
54	M	3,315	2,710	2.0000
55	M	3,315	2,710	2.0000
56	M	3,315	2,710	2.0000
57	M	3,315	2,710	2.0000
58	M	3,315	2,710	2.0000
59	M	3,315	2,710	2.0000
60	M	3,315	2,710	2.0000
61	M	3,315	2,710	2.0000
62	M	3,315	2,710	2.0000
63	M	3,315	2,710	2.0000
64	M	3,315	2,710	2.0000
65	M	3,315	2,710	2.0000
66	M	3,315	2,710	2.0000
67	M	3,315	2,710	2.0000
68	M	3,315	2,710	2.0000
69	M	3,315	2,710	2.0000
70	M	3,315	2,710	2.0000
71	M	3,315	2,710	2.0000
72	M	3,315	2,710	2.0000
73	M	3,315	2,710	2.0000
74	M	3,315	2,710	2.0000
75	M	3,315	2,710	2.0000
76	M	3,315	2,710	2.0000
77	M	3,315	2,710	2.0000
78	M	3,315	2,710	2.0000
79	M	3,315	2,710	2.0000
80	M	3,315	2,710	2.0000
81	M	3,315	2,710	2.0000
82	M	3,315	2,710	2.0000
83	M	3,315	2,710	2.0000
84	M	3,315	2,710	2.0000
85	M	3,315	2,710	2.0000
86	M	3,315	2,710	2.0000
87	M	3,315	2,710	2.0000
88	M	3,315	2,710	2.0000
89	M	3,315	2,710	2.0000
90	M	3,315	2,710	2.0000
91	M	3,315	2,710	2.0000
92	M	3,315	2,710	2.0000
93	M	3,315	2,710	2.0000
94	M	3,315	2,710	2.0000
95	M	3,315	2,710	2.0000
96	M	3,315	2,710	2.0000
97	M	3,315	2,710	2.0000
98	M	3,315	2,710	2.0000
99	M	3,315	2,710	2.0000
100	M	3,315	2,710	2.0000

FIGURE 15

CUMULATIVE RELATIVE FREQUENCY CURVE
AVERAGE DAILY AIR TEMPERATURE JANUARY 1975

Y-INCREMENT = .2046-01 X-INCREMENT = .619

FIGURE 16

SOLAR *** AVERAGE INCIDENT SOLAR RADIATION ON HORIZONTAL SURFACE FROM 9AM TO 6PM

DAY	SEP 1974	OCT 1974	NOV 1974	DEC 1974	JAN 1975	FEB 1975	MAR 1975	APR 1975	MAY 1975	JUN 1975	JUL 1975	AUG 1975
1	60.	155.	66.	127.	127.	169.	110.	101.	157.	230.	234.	185.
2	60.	157.	18.	125.	23.	110.	137.	211.	173.	212.	225.	207.
3	120.	119.	47.	100.	119.	128.	108.	140.	205.	165.	195.	225.
4	120.	122.	117.	123.	101.	15.	141.	199.	202.	210.	217.	216.
5	111.	113.	117.	54.	111.	65.	154.	194.	137.	233.	138.	160.
6	174.	134.	40.	129.	129.	123.	43.	144.	174.	166.	205.	114.
7	147.	130.	90.	21.	02.	100.	59.	124.	91.	147.	140.	136.
8	102.	151.	90.	139.	59.	99.	127.	122.	135.	97.	211.	215.
9	130.	104.	35.	125.	74.	75.	54.	150.	170.	102.	120.	195.
10	144.	125.	04.	123.	53.	73.	32.	37.	132.	42.	205.	154.
11	39.	31.	115.	133.	30.	131.	20.	66.	190.	218.	214.	127.
12	57.	17.	121.	123.	08.	169.	164.	199.	100.	164.	231.	102.
13	58.	170.	114.	117.	07.	79.	152.	194.	221.	190.	222.	33.
14	130.	125.	04.	103.	79.	37.	100.	164.	224.	147.	116.	104.
15	126.	170.	87.	97.	51.	63.	44.	164.	157.	225.	161.	148.
16	174.	111.	114.	92.	50.	171.	170.	207.	164.	89.	154.	143.
17	211.	140.	109.	32.	41.	105.	136.	70.	144.	137.	155.	150.
18	120.	125.	90.	64.	74.	137.	157.	200.	139.	194.	157.	176.
19	127.	104.	94.	44.	73.	133.	161.	210.	178.	196.	179.	136.
20	04.	110.	105.	30.	75.	112.	172.	187.	42.	201.	127.	112.
21	174.	09.	72.	37.	70.	136.	119.	174.	31.	134.	145.	143.
22	171.	114.	47.	127.	77.	159.	151.	210.	60.	174.	189.	143.
23	170.	94.	115.	14.	09.	104.	131.	144.	137.	223.	157.	147.
24	175.	09.	100.	104.	123.	145.	148.	207.	232.	154.	216.	144.
25	174.	111.	70.	127.	67.	152.	115.	217.	84.	140.	225.	176.
26	140.	130.	120.	50.	120.	100.	63.	205.	233.	239.	224.	102.
27	11.	147.	64.	119.	72.	149.	165.	63.	141.	287.	227.	140.
28	174.	147.	32.	102.	04.	127.	187.	221.	25.	234.	100.	156.
29	170.	141.	106.	04.	105.	0.	156.	115.	66.	241.	104.	177.
30	140.	43.	129.	118.	72.	0.	132.	114.	190.	242.	151.	102.
31	6.	37.	0.	139.	104.	0.	93.	0.	135.	0.	141.	101.
MONTH	134.	116.	90.	94.	62.	107.	124.	162.	144.	184.	184.	157.

NOTE *** UNIT OF MEASURE FOR INCIDENT SOLAR RADIATION IS BTU/HOUR/SQUARE-FOOT.

FIGURE 17

- CUMULATIVE TIME FROM CY CURVE
 - AVERAGE TIME T CLIP ENDIATION OF HORIZONTAL SURFACE - FROM SEP 74 TO AUG 75

Y-INCREMENT = 100.00 X-INCREMENT = 2.76

FIGURE 18

4. The Model validation activities consist of four main steps, namely,

- (1) the Model performance evaluation,
- (2) the Model sensitivity analysis,
- (3) the Model correction and re-evaluation,
and
- (4) the performance discussion and computation efficiency evaluation.

Validation of the program for specific systems will be as follows.

- a. Use CSU Solar I data to validate the Martin Marietta Solar House design program for residential systems using water as a transport medium.
- b. Use CSU Solar II data to validate the Martin Marietta program for the design of systems using air as a transport medium.
- c. Use the Bridgers and Paxton data to validate the Martin Marietta program for the design of solar systems for a commercial building utilizing heat pumps.
- d. Use the Townes Elementary School data to validate the Martin Marietta design program for an institutional building.

5. Utilizability

This aspect of the work will focus on the utilizability of the design program. That is, the ease with which the program may be used by an architectural and engineering firm and the degree to which the results obtained from the program are useful in selecting the components for a particular solar system will be investigated. The approach used to investigate techniques for choosing among competing digital simulation models will be in the following two areas: pattern recognition and statistical discrimination. Both deal with error analysis and decision making processes. The results of this investigation will be reported at the end of the project.

6. Implementation

SEEC is in an excellent position to serve as the central site for implementation of the Martin Marietta design program. Therefore, if desired by ERDA, this phase of the effort will be devoted to setting up the mechanism for handling requests which come in from solar systems designers, processing the requests, and sending the results obtained from the design program to the interested parties.

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