AN EVALUATION OF SESP AND F-CHART METHODS OF SOLAR PERFORMANCE STIMULATION

by

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ABSTRACT

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METHODS OF SOLAR PERFORMANCE SIMULATION

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Two methods for simulation of load fractions supplied by a liquid-type solar heating system for residential and/or industrial application are evaluated, SESP and F-CHART. Test procedures designed to emphasize the versatility, accuracy, and short comings of each method are employed. The first test compares the methods at a chosen standard location: Columbus, Ohio. The remaining three tests vary the collector area, the slope of the collector efficiency curve, and the location of the simulation to test the performance of the methods under extreme conditions.

The results show SESP to be more versatile and that it will perform under extreme conditions when F-CHART breaks down. SESP is also found to offer increased accuracy due to its method of modeling flux distribution.

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A special thanks to Dr. Charles K. Alexander whose patience and guidance were greatly appreciated.

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LIST OF SYMBOLS

SYMBOLS USED IN SESP SIMULATION (Chronological order)

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
C_1	Number of system runs to be made	none	max.value = 10.
C_2	Simulation starting month	none	Jan = 1. Dec. =12.
C_3	Simulation end month	none	Jan = 1. Dec = 12.
C_4	Customer data print enable	none	1. = print o. = do not
C_5	Plot option print enable	none	1. = print o. = do not
DD_1 - DD_{12}	Vector of monthly average degree days	^oF - days	12 elements
$HBAR_1$ - $HBAR_{12}$	Vector of monthly average daily solar energy on a horizontal surface	BTU/ Ft^2	12 elements
$TAMB_1$ - $TAMB_{12}$	Vector of monthly average ambient temperatures	^oF	12 elements
GAL_1 - GAL_{24}	24 hour water usage model	gallons	24 elements, midnight to 1 a.m. = 1st hour
STO	Storage thermal capacity	BTU/ ^oF	multiple run values
A	Collector active area	Ft^2	multiple run values
CH	Collector loop fluid flow rate	gal/ hr.	multiple run values
CC	Storage loop fluid flow rate	gal/ hr.	multiple run values
TILT	Zenith to normal angle of collector	degrees	multiple run values
VOL	Storage volume	gallons	multiple run values

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
UA (S)	Heat exchanger figure of merit	BTU/ HR-°F	
XM	Slope of collector efficiency curve	BTU/ Hr-Ft^2-°F	Same as F_RU_L
B	Intercept of collector efficiency curve	none	Same as $F_R\ (\tau\alpha)_n$
AZ	Azimuth of collector array	degrees	deviation from south
DENH	Density of solar loop fluid	lbm/ gal	
DENC	Density of storage loop fluid	lbm/ gal	
SPHTH	Specific heat of solar loop fluid	BTU/ lbm°F	
SPHTC	Specific heat of storage loop fluid	BTU/ lbm°F	
T HOT	Required hot water temperature	°F	
T COLD	Cold water supply temperature	°F	
RLOSS	Installation insulation R-Factor	BTU/ °F-day	UA in F-CHART
$ S	Cost per delivered million BTU's for space heat	$/million BTU	
$ W	Cost per delivered million BTU's for water heat	$/million BTU	
RLAT	Latitude of installation	degrees	
TI	Initial storage temperature	°F	
TLIM	Lower limit on storage temperature for space heat removal	°F	
$FAN	Cost of operating solar pump	$/hr.	

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
UATOP	Storage unit top heat loss factor	BTU/ hr.-^{o}F	
UABOT	Storage unit bottom heat loss factor	BTU/ hr.-^{o}F	
UASEG	Storage unit side segment heat loss factor	BTU/ Hr.^{o}F	There are 10 side segments
ETA	Water to air heat exchanger effectiveness	none	
GPH	Volume flow rate of water in water to air heat exchanger	gal/hr.	
ETA 2	Water to water effectiveness for domestic water heat exchanger	none	
GPH 2	Volume flow rate of storage-side water in domestic exchanger	gal/hr.	Not used at this point in time

SYMBOLS USED IN F-CHART SIMULATION (Chronological order)

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
ϕ	Latitude	degrees	Table A.1
S	Angle between the plane of the collector and the horizontal	degrees	Table A.1
ρ	Ground reflectance	none	Table A.1
H and $\overline{H}$	Daily and monthly average daily total radiation on a horizontal surface per unit area	J/month-m^2	Table A.1
$\overline{K}_T$	Ratio of monthly average actual to extraterrestrial solar radiation	none	Table A.1
H_d and $\overline{H}_d$	Daily and monthly average daily diffuse radiation on a horizontal surface per unit area	J/month-m^2	Table A.1
$\overline{R}_b$	Ratio of monthly average daily beam radiation on a tilted surface to that on a horizontal surface	none	Table A.1
W_s	The sunset hour angle on a horizontal surface	degrees	Table A.1
W_s'	The sunset hour angle on a tilted surface	degrees	Table A.1
δ	The solar declination	degrees	Table A.1
n	The day of the year	none	Table A.1
$\overline{R}$	Ratio of monthly average daily total radiation on a tilted surface to that on a horizontal surface	none	Table A.1
$\overline{H}_T$	Monthly average daily total radiation on a tilted surface per unit area	J/month-m^2	Table A.1

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
$\bar{\theta}_b$	Average incidence angle for beam radiation	degrees	Table A.2
τ	Transmittance of the collector cover system	none	Table A.2
τ_n	Normal incidence transmittance	none	Table A.2
α	Absorptance of the collector plate surface	none	Table A.2
α_n	Normal incidence absorptance	none	Table A.2
$(\overline{\tau\alpha})$	Monthly average transmittance-absorptance product	none	Table A.2
$(\tau\alpha)_n$	Transmittance-absorptance product for radiation at normal incidence	none	Table A.2
UA(F)	Building overall energy loss coefficient area product	$W/^oC$	Table A.3
DD	Monthly degree - days	^oC-Day	Table A.3
F_R	Collector heat removal efficiency factor	none	Table A.4
U_L	Collector energy loss coefficient	$W/^oC$	Table A.4
F_R'	Collector heat exchanger efficiency factor	none	Table A.4
$\bar{T}_a$	Monthly average ambient temperature	^oC	Table A.4
X	Value used in calculating F	none	Equation (19)
Y	Value used in calculating F	none	Equation (19)
ε_L	Effectiveness of the load heat exchanger	none	Equation (18)
C_{min}	Minimum capacitance rate in a heat exchanger	$W/^oC$	Equation (18)
F	Fraction of monthly load supplied by solar energy	none	Equation (19)

LIST OF SYMBOLS (GENERAL)

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
$\overline{H}_D$	Monthly average daily direct radiation received on a horizontal surface	BTU/ day-Ft^2	
H_o	Extraterrestrial daily insolation received on a horizontal surface	BTU/ day-Ft^2	Equation (3)
I_{Dh}	Intensity of direct radiation incident upon a horizontal surface	BTU/ hr-Ft^2	
I_{Dn}	Intensity of direct radiation at normal incidence	BTU/ hr-Ft^2	
I_{dh}	Intensity of diffuse radiation on a horizontal surface	BTU/ hr-Ft^2	
I_{oh}	Intensity of solar radiation incident upon a horizontal surface outside the atmosphere of the earth	BTU/ hr-Ft^2	
I_{on}	Intensity of solar radiation at normal incidence outside the atmosphere of the earth	BTU/ hr-Ft^2	
I_{Th}	Intensity of total (direct plus diffuse) radiation incident upon a horizontal surface	BTU/ hr-Ft^2	
K_d and $\underline{K_d}$	The ratio H_d/H_o and $\overline{H}_d/H_o$	none	Equation (3)
K_D	$(H - H_d)/H_o$	none	Equation (6)
K_T and $\underline{K_T}$	H/H_o and $\overline{H}/H_o$	none	Equation (4)
Z	The Zenith angle	degrees	
τ_D	$I_{Dn}/I_{on} = I_{Dh}/I_{oh}$ = transmission coefficient for direct solar radiation	none	Equation (1)

SYMBOL	DEFINITION	UNITS	COMMENTS OR REFERENCE
τ_d	I_{dn}/I_{oh} = transmission coefficient for diffuse radiation on a horizontal surface	none	Equation (1)
τ_T	I_{Th}/I_{oh} = transmission coefficient for total radiation on a horizontal surface	none	Equation (2)

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CHAPTER I

INTRODUCTION

Solar energy systems must be accurately evaluated by modeling well before actual construction takes place. This is absolutely necessary to the consumer since it is not wise to invest in such systems if they are not "financially feasible". A main step in this feasibility study is the simulation of a solar energy system's performance.

A solar energy system's projected performance is determined by evaluating detailed simulations over a period of time (usually one year). In the area of solar energy simulation, a number of methods exist, whereby, given the location of a structure along with collector area and other necessary input variables, an approximate projected performance of said system can be given with relative accuracy. The two methods considered in this paper are SESP[1] and F-CHART[2]. F-CHART is available in computer program form[3], and since 1977, it has been available in workbook form. The workbook form of F-CHART employs a step-by-step procedure which is followed in order to perform a simulation. The work is done on worksheets which were developed in order to more clearly organize the various aspects of the simulation. F-CHART is perhaps the most widely used simulation method.

SESP, on the other hand, has been developed just this year. SESP boasts exclusive computer simulations to provide output which is fast, economical, and reliable.

The second chapter gives the reader an insight into Liu and Jordan's work on diffuse and direct flux distribution which plays a crucial part in each simulation method. The third and fourth chapters contain a brief introduction on how each method performs a sumulation, along with their similarities and differences. This is followed by Chapter V which explains the tests and results designed to evaluate both methods. There are four separate tests conducted. In the first test, a comparison run is made for a standard location in which the collector area is varied. This serves as the initial comparison between the two systems under conditions for which F-CHART is designed. After the initial verification of SESP with F-CHART, three other tests are conducted to test behavior of the systems under extreme conditions. In the first of these, the same location is kept and the performance of the systems with very small collector areas is observed. Again comparison runs are made for the same location. This time the collector area remains constant ($50_m{}^2$), and the slope of the collector efficiency curve is then varied making the collector less and less efficient. Finally comparison runs are made for different locations. There are two locations chosen, one for its extremely warm climate (El Paso, Texas), and one for its extremely cold climate (Caribou, Maine).

Runs are made at $50m^2$ for both locations and again at $25m^2$ for El Paso (due to its extremely high fraction at $50m^2$). All of these comparison runs serve to point out similarities and differences in each method when input parameters are varied. All runs are made for a liquid-type collecting system as opposed to an air-type collecting system.

CHAPTER II

SIMULATING DIRECT AND DIFFUSE RADIATION USING LIU AND JORDAN'S TECHNIQUE

For several decades, meteorological data have been recorded at locations all over the United States and the world. For those people working in the field of solar energy these data have proven to be invaluable. The fact that the data have been gathered over a considerable number of years allows an average value to be calculated. These values are figured on a per month basis, assuming that the values would be relatively constant over a month's span. Of the several data types used in a solar energy analysis (Discussed in Chapter III) one of the most necessary is $\overline{H}$. $\overline{H}$ is defined as the monthly average daily total radiation incident on a horizontal surface. Unfortunately, in many areas of solar energy engineering,particularly those of simulation and design, it becomes necessary to know the diffuse and direct components of $\overline{H}$. Since $\overline{H}$ is nothing more than the sum of the direct and diffuse radiation, only one of these values need to be known in order for the other to be found. This problem was resolved in a very satisfactory way by Liu and Jordan [4] in 1960. Their paper; "The Interrelationship and Characteristic Distribution of Direct, Diffuse, and Total Solar Radiation", in part consisted of a relatively simple method to determine the diffuse component of $\bar{H}$.

In approaching the problem, they decided to forego any attempt to theoretically compute the diffuse radiation and instead to use the limited data at their disposal to find a relationship between diffuse and total radiation for use in areas where only the total radiation is known. As a first step, the relationship between the intensities of direct and diffuse radiation on clear days was studied. The transmission coefficients τ_D and τ_d are functions of solar altitude, atmospheric water vapor content, dust content, ozone content, and any other radiation deflecting factors. Of these factors the most influential is water vapor content. Thus, as the water vapor content varies, a relationship between τ_D and τ_d is generated. Through experimental results at three North American locations, a straight line approximation of the experimental data was calculated.

$$\tau_d = 0.2710 - 0.2939\,\tau_D \qquad (1)$$

Equation (1) provides a means for estimating the intensity of diffuse radiation on a horizontal surface under a cloudless atmosphere when the intensity of direct radiation at normal incidence is known. Since the intensity of total radiation on a horizontal surface is the sum of the intensities of direct and diffuse radiation on a horizontal surface, the following equation between τ_d and τ_T was derived from Equation (1)

$$\tau_d = 0.3840 - 0.4160\,\tau_T \qquad (2)$$

These equations were found to hold true in general as long as the dust content of the sky and the reflectivity of the ground were relatively close to those of the test locations.

These relationships were then expanded to include daily diffuse and daily total radiation on cloudy days. The variation in cloud cover then became the primary factor and water vapor, dust, and ozone became secondary factors. Due to the extreme variation in cloud cover over a day, average values were used to arrive at a relationship between the daily total and daily diffuse radiation of each month. It was found that the ratio of diffuse to extraterrestrial and total to extraterrestrial was relatively constant for a location and could be expressed as

$$K_d = H_d / H_o \tag{3}$$

and

$$K_T = H / H_o \tag{4}$$

It was further found that there existed a relationship between K_d and K_T that varied only slightly as the month varied. From this relationship another expression relating $\frac{H_d}{H}$ to K_T was found. An empirical curve fit to the experimental results yielded the following equation

$$\frac{H_d}{H} = 1.0045 + 2.6313\ K_T^3 - 3.5227\ K_T^2 + 0.04349\ K_T \tag{5}$$

This equation is valid for values of K_T between 0.4 and 0.75. Any values out of this range try to curve fit experimental data that is so widely scattered that the values have little meaning.

In further relating the ratios to one another it was found that K_D, which is expressed as

$$K_D = \frac{(H - H_d)}{H_o} = K_T - K_d, \quad (6)$$

is related to K_d in the following way

$$K_d = 0.2710 - 0.2939\ K_D \quad (7)$$

This linear relationship is only good for clear days. The corresponding relationship for cloudy days was found to give a greater value of K_d for the same values of K_D when K_D was greater than 0.1. When K_D became smaller ($K_D < 0.1$) the value of K_d rapidly tended toward zero.

They then decided to conduct several tests for a possible correlation between the various statistical distribution curves of different localities. Statistical distribution curves of daily total radiation for widely separated localities were constructed and compared. These curves used data from monthly daily radiation figures. This meant that monthly average values were now being used such as $\bar{K}_T$ and $\bar{K}_d$. A relationship was indeed found and was expressed in several different forms. The most significant of these was the relationship between $\frac{\bar{H}_d}{\bar{H}}$ and $\bar{K}_T$. This is shown in Figure 1. The corresponding curve fit equation is

$$\frac{\bar{H}_d}{\bar{H}} = 1.39 - 4.03\ \bar{K}_T + 5.53\ \bar{K}_T^2 - 3.11\ \bar{K}_T^3 \quad (8)$$

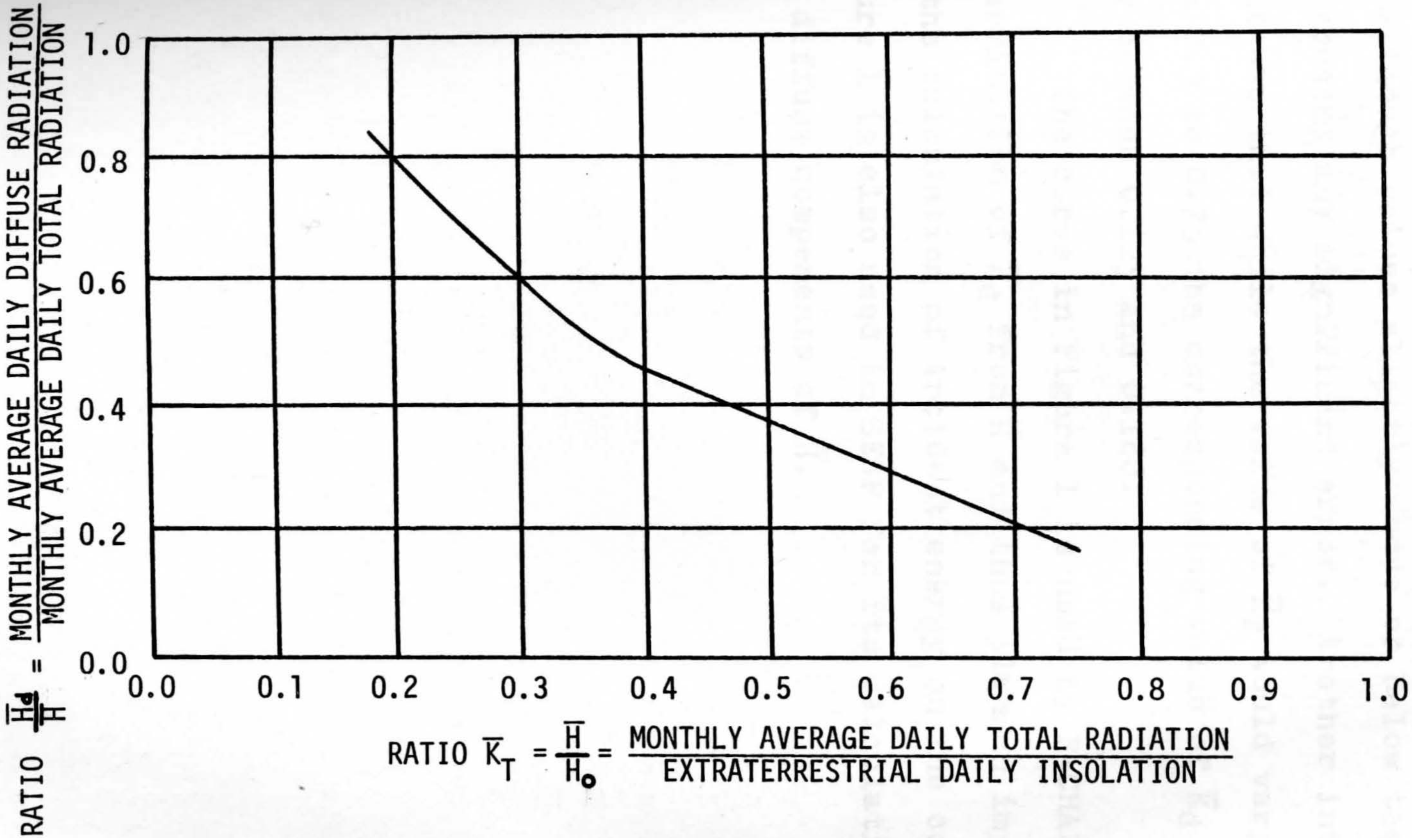

Fig. 1 $\overline{K}_T$ as a Function of $\frac{\overline{H}_d}{\overline{H}}$

This relationship is good for values of $\overline{K}_T$ between 0.3 and 0.7 although values slightly above or below these limits do not present any significant error. Another interesting point was that while the value of $\overline{K}_T$ would vary anywhere from 0.3 to 0.75 the corresponding value of $\overline{K}_d$ would only vary between 0.125 and 0.188.

The curve in Figure 1 is used by F-CHART in its determination of $\overline{H}_d$ from $\overline{H}$ and thus plays an important part in the calculation of incident energy on the collector face. Figure 1 is also used in SESP for its calculation of direct and diffuse compenents of $\overline{H}$.

CHAPTER III

THE F-CHART METHOD

In the F-CHART method of solar heating design, the approach is to take separable groups of the overall system and evaluate each one over monthly intervals. These separate evaluations can be broken down into several steps:

1) The effect of collector orientation as applied to the average daily radiation on tilted surfaces.
2) The effect of collector orientation on the monthly average transmittance-absorptance product.
3) The heating loads of the structure.
4) The fraction of heating loads supplied by the system.

The meteorological data needed to perform a simulation for a particular location are:

$\bar{H}$ - The monthly average daily total radiation on a horizontal surface.

$\bar{K}_T$ - The ratio of actual daily radiation to the daily extraterrestrial radiation.

$\bar{T}_a$ - The monthly average ambient temperature.

DD - The number of degree-days in a month (The sum of the daily temperature differences between the ambient temperature and a building maintained at 22°C - values less than zero are not included).

These data are available for 171 locations in the United States and Canada.

The purpose of the first step in the simulation is to convert the values of $\bar{H}$ to corresponding values of $\bar{H}_T$. This is done in order to correct for the tilted surface of the collectors and normally results in higher values. The input variables are latitude, tilt, and ground reflection. These variables are combined with $\bar{H}$ and $\bar{K}_T$ for that location in order to calculate $\bar{H}_T$. It is at this point that $\bar{K}_T$ is used to find the diffuse component of $\bar{H}$ through the relationship developed by Liu and Jordan (Figure 1).

The second step takes into account the fact that the actual amount of energy absorbed by a collector depends upon how much is transmitted through the cover and absorbed by the collector absorber plate. This transmittance and absorptance varies as the angle between the collector normal and the incident energy changes. Although this angle is constantly changing, it is possible to arrive at a monthly average value that can be utilized in the simulation. The resulting monthly value is $(\tau\alpha)/(\tau\alpha)_n$ which is the ratio of the monthly average transmittance-absorptance product to the transmittance-absorptance product at normal incidence. The value of $(\tau\alpha)/(\tau\alpha)_n$ is dependant on the latitude and tilt of the collector as well as the transmittance and absorptance properties of the collectors as a function of incident angle. The monthly results of step two are then multiplied by $\overline{H}_T$ (step one) and the result is a true value of monthly average radiation that can be utilized by the collector.

In the third step the heating loads of the structure are calculated. The variables are: The heat loss co-efficient for the structure, the domestic hot water heating requirements, and the value of degree-days (DD). The heat loss co-efficient is based primarily on the construction of the structure and is very difficult to accurately predict. With these variables a monthly total as well as yearly total heating load is calculated for the given location and structure.

The fourth step involves the calculation of the fraction of each month's heating load supplied by the solar heating system. It begins with the calculation of two unitless variables X and Y which are related to the fraction of heating load supplied for each month. X can be associated with the ratio of a reference collector energy loss to the heating load and is expressed in per unit area terms by

$$\frac{X}{A} = \frac{F_R U_L \times (F_R'/F_R) \times (100 - \overline{T}_a) \times \#\text{seconds per month}}{\text{monthly total heating load}} \quad (9)$$

Y can be associated with the ratio of absorbed solar energy to the heating load and is expressed in per unit area terms by

$$Y = \frac{F_R(\tau\alpha)_n \times (F_R'/F_R) \times (\tau\alpha)/(\tau\alpha)_n \times \#\text{ days per month}}{\text{monthly total heating load}} \quad (10)$$

X/A values are calculated for each month using the slope of the collector efficiency curve, F_RU_L, along with $\bar{T}_a$ and the results of step three. Y/A values are calculated for each month using the results of steps one, two, and three and the maximum performance of the collector efficiency curve, $F_R(\tau\alpha)_n$. Collector array sizes are then chosen and the corresponding values of X and Y are used in an empirically curve-fitted equation to arrive at the value of F for each month. It should be noted that all simulations with the F-CHART method are done with monthly average data.

CHAPTER IV

THE SESP METHOD AND SOLAR FLUX MODEL

As with F-CHART, SESP also requires meteorological data for a given location. These variables are the same for each method with the exception of $\overline{K}_T$ which is internally generated in the SESP program. Since the use of dynamic difference equations is involved in SESP's system modeling, meteorological data along with data on water usage, heating load, storage temperatures and collector performance must be expressed as hourly valves.

In breaking up $\overline{H}$ into values of direct and diffuse energy, an extension of Liu and Jordan's results is used [5]. In order to arrive at hourly valves of direct and diffuse flux, Meinels developments of Lau's observations [6] are also used. This method first involves the calculation of $\overline{H}_d$ from $\overline{H}$ using Figure 1. Once $\overline{H}_d$ is known it is only necessary to subtract this value from $\overline{H}$ in order to obtain the value of direct flux or $\overline{H}_D$.

As can be seen from Lau's curves (Figure 2) the intensity of the incident flux varies as a function of the zenith angle, Z. There are curves representing several conditions under which incident flux strikes the earth. Each curve is representative of the diffuse, direct, or total energy striking the earth in urban, desert, or stan-

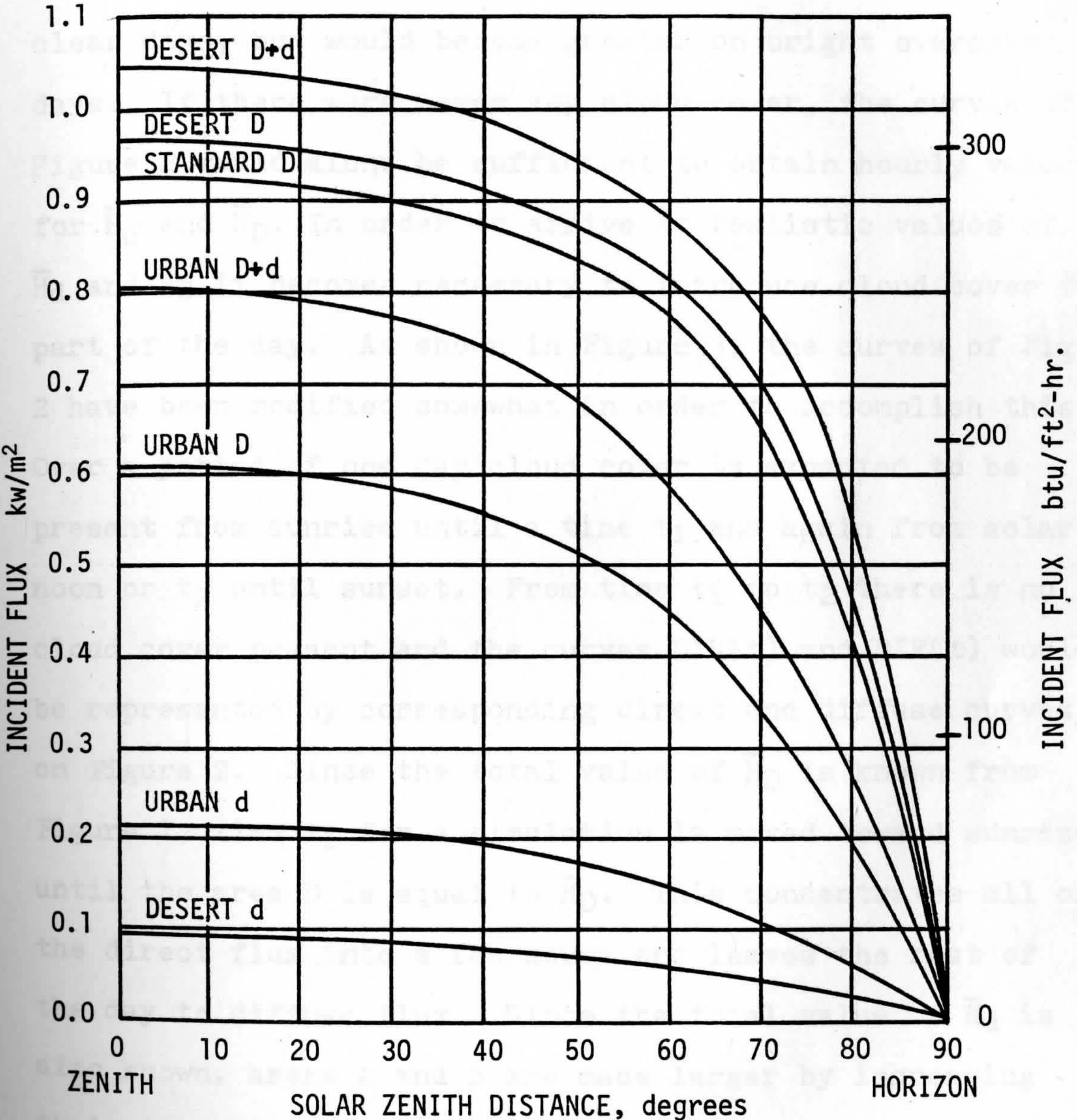

Fig. 2. Incident Flux as a Function of Zenith Angle for Direct and Diffuse Distribution.

dard locations. The standard direct curve is a result of Haurwitz's 1948 study [7] for standard application.

The direct flux curves give accurate data only when there is no cloud cover. The scattered curve is correct for clear days, but would become greater on bright overcast days. If there were never any cloud cover, the curves of Figure 2 would alone be sufficient to obtain hourly values for $\overline{H}_d$ and $\overline{H}_D$. In order to arrive at realistic values of $\overline{H}_d$ and $\overline{H}_D$ it becomes necessary to introduce cloud cover for part of the day. As shown in Figure 3, the curves of Figure 2 have been modified somewhat in order to accomplish this. Over a period of one day cloud cover is expected to be present from sunrise until a time t_1 and again from solar noon or t_2 until sunset. From time t_1 to t_2 there is no cloud cover present and the curves DIR(t) and DIF(t) would be represented by corresponding direct and diffuse curves on Figure 2. Since the total value of $\overline{H}_D$ is known from Figure 1, time t_1 for a simulation is moved toward sunrise until the area D is equal to $\overline{H}_D$. This concentrates all of the direct flux into a few hours and leaves the rest of the day to diffuse flux. Since the total value of $\overline{H}_d$ is also known, areas A and B are made larger by increasing their intensity until the sum of areas A, B, and C equal $\overline{H}_d$. Thus presented, the model of Figure 3 can give accurate hourly values of $\overline{H}_d$ and $\overline{H}_D$ for use in the simulation.

The other hourly data is generated in the program with the exception of GAL 1 - GAL 24 which are the domestic

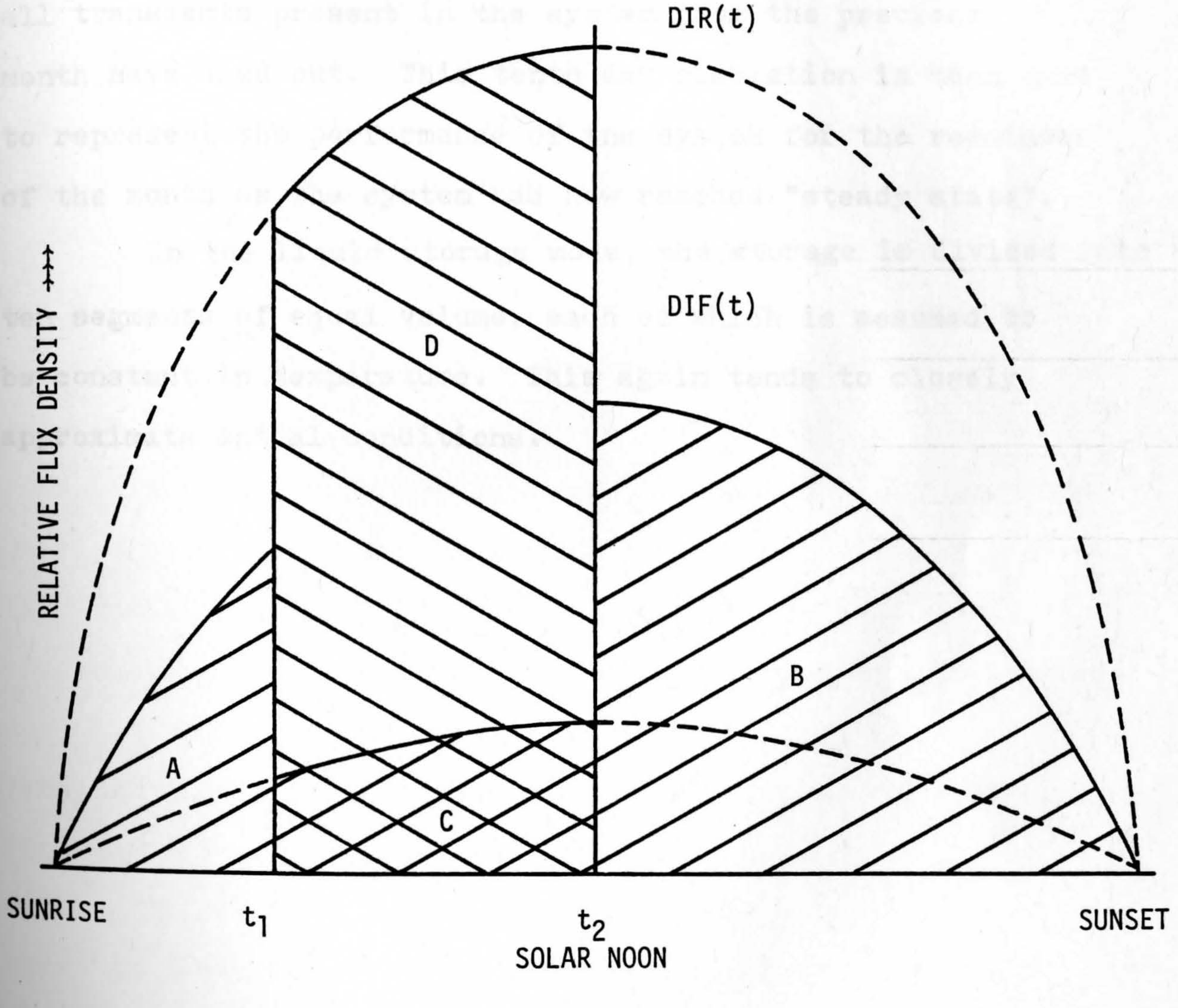

Figure 3. Realistic Representation of Direct and Diffuse Flux Distribution as a Function of Time of Day.

hot water requirements and are given as part of the input information. This hourly information and all of the hourly information generated in SESP is used to develop a 24 hour per day simulation of the energy supplied and used in the system. The calculations are started at the beginning of each month and carried out until the tenth day after which all transients present in the system from the previous month have died out. This tenth day simulation is then used to represent the performance of the system for the remainder of the month as the system has now reached "steady state".

In the liquid storage mode, the storage is divided into ten segments of equal volume, each of which is assumed to be constant in temperature. This again tends to closely approximate actual conditions.

CHAPTER V

COMPARISON, EVALUATION, AND TEST RESULTS

Introduction

This chapter is divided into the four different types of tests that are performed. The first portion covers the initial test runs in which a standard of comparison is achieved for use in the other tests. The second portion presents the results of a test based on small collector areas. As an extension of the first test, this test compares the behavior of the simulators when the area is reduced to extremely small values. Continuing in this vein of testing, the performance of the simulators is compared under extreme collector performance characteristics for the third test. And finally in order to test the simulator's adaptability to different climates, the fourth test conducted is that of climate extremes. It is felt that extreme variation tests of this type will best display any improper tendencies of each simulation method.

Before the initial comparison runs are made, extreme care is taken to make sure the input variables for each method are identical. In equalizing these input parameters; units, flow rates, storage capacities, efficiencies, and loss factors have to be made identical. Some variables in the SESP input are either assumed to be constants or are dependent on collector area in F-CHART. In evaluating the heat exchanger performance, several variables in SESP have to be matched to only one particular variable in F-CHART.

A difference in each method's approach is the inclusion of the effect of ground reflectance and collector reflectance variations for angles of incidence of solar radiation different than 90 degrees. The F-CHART method includes both of these effects while the SESP method does not. It should be noted that the incidence of diffuse energy on the collector varies as a function of incidence angle and is taken into account in F-CHART while it remains constant in SESP. However, if the value of reflectance used in F-CHART is 0.3 (an average value), the resulting diffuse plus reflected component, as a function of incidence angle, remains constant. This effectively is what happens in SESP by keeping the diffuse component constant and not including reflectance. Reflectance on the collector surface also varies as a function of the angle of incidence. F-CHART accounts for this by varying the transmittance - absorptance product ($\tau\alpha$).

In order to test the effect on performance of varying reflectance and the transmittance - absorptance product $\tau\alpha$, some preliminary simulations are run with F-CHART only. As can be seen in Figure 4, with varying collector areas, the smallest fractions come from the simulation in which the effect of varying $\tau\alpha$ is included and the reflectance is kept at 0.0. The second curve in which the effect of

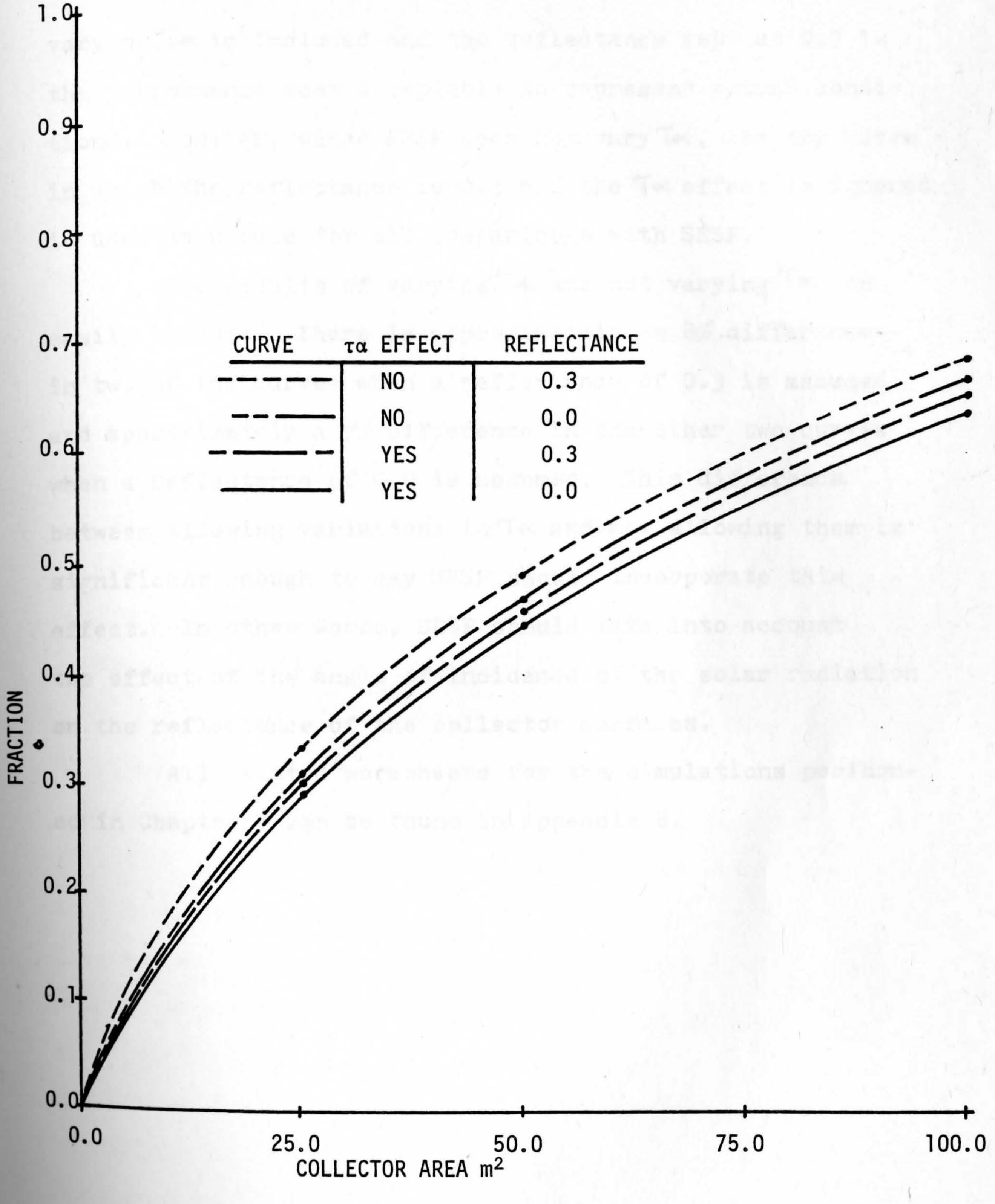

Fig. 4. Annual Solar Fraction as a Function of Collector Area as Predicted by F-CHART, Showing the Effects of Varying the Transmittance - Absorptance Product and Reflectance on the Fraction.

varying $\tau\alpha$ is included and the reflectance kept at 0.3 is the performance most acceptable to represent actual conditions. However, since SESP does not vary $\tau\alpha$, the top curve in which the reflectance is 0.3 and the $\tau\alpha$ effect is ignored is used as a base for all comparisons with SESP.

The results of varying $\tau\alpha$ and not varying $\tau\alpha$ can easily be seen. There is approximately an 8% difference in two of the curves when a reflectance of 0.3 is assumed and approximately a 7% difference in the other two curves when a reflectance of 0.0 is assumed. This difference between allowing variations in $\tau\alpha$ and not allowing them is significant enough to say SESP should incorporate this effect. In other words, SESP should take into account the effect of the angle of incidence of the solar radiation on the reflectance of the collector surfaces.

All related worksheets for the simulations performed in Chapter V can be found in Appendix B.

Initial Test Runs

In this test the location chosen is Columbus, Ohio. This is done in order to have a location that is not too different in climate from the location chosen for many of F-CHART's first simulations;Madison, Wisconsin. The collector area is varied from 25 m^2 to 50m^2 to 100m^2. The slope of the collector efficiency curve is chosen to be -3.75 $W/m^2 - {}^oC$ (see Figure 14, curve 1) and its maximum efficiency is chosen to be .68. All other inputs are kept identical and are given values suggested by the F-CHART book <u>Solar Heating Design</u>. The results of the simulation can be seen in Table 1 and Figures 5 and 6.

In Table 1 the annual fractions predicted by F-CHART and SESP are given. In the course of development of this thesis, a major change was made in the SESP program. This involved changing the method of heat removal from storage in the 24 hour simulation subroutine of the main program. The program before the change was renamed SESP (old) and the program after the change was named SESP (new) thereafter referred to only as SESP. As can be seen in the table, the annual fractions between the methods differ, but not significantly. The difference in the annual fractions predicted by SESP and F-CHART become progressively greater as the area is increased. Figure 5 shows this more easily. At 25m^2 the results are essentially the same while at

TABLE 1

ANNUAL FRACTIONS PREDICTED BY F-CHART, SESP (NEW), AND SESP (OLD) FOR THE INITIAL TEST RUNS

		ANNUAL FRACTION		
LOCATION	COLL. AREA M^2	F-CHART	SESP (NEW)	SESP (OLD)
COLUMBUS, OHIO	25.0	0.33	0.3307	0.3347
COLUMBUS, OHIO	50.0	0.488	0.5012	0.5046
COLUMBUS, OHIO	100.0	0.685	0.7181	0.7259

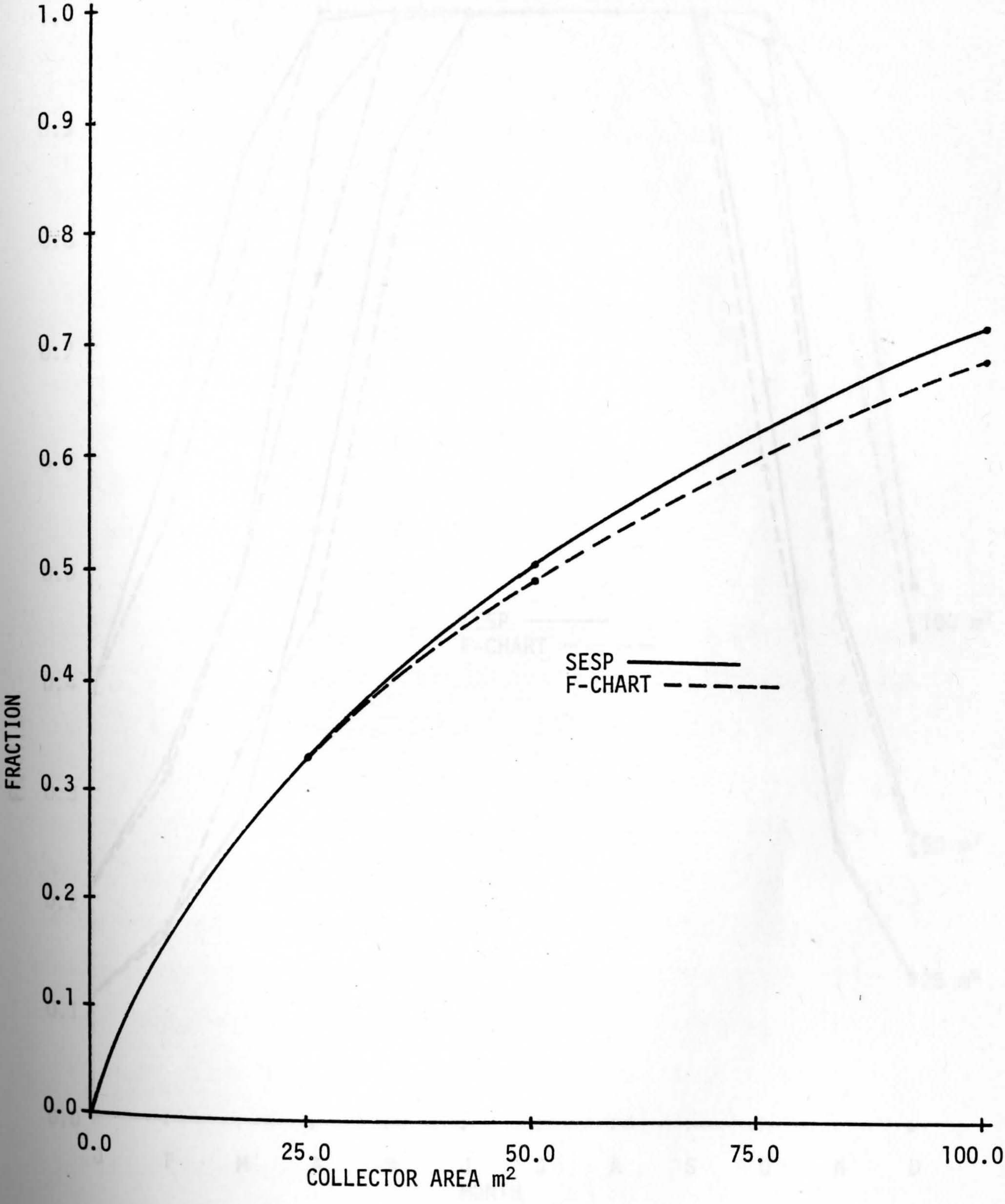

Fig. 5. Annual Fraction as a Function of Collector Area for F-CHART and SESP (Initial Test Runs).

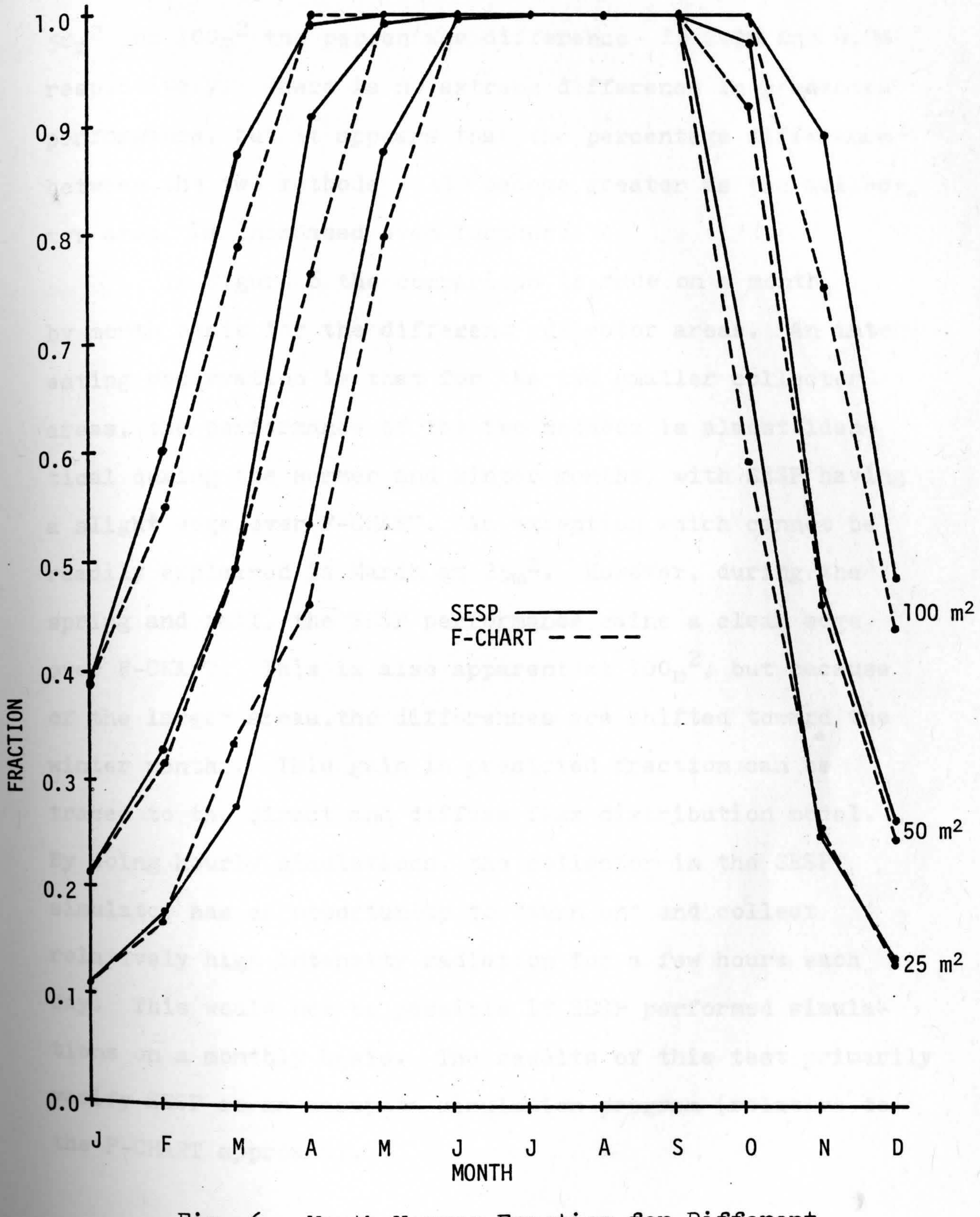

Fig. 6. Month Versus Fraction for Different Collector Areas for both SESP and F-CHART.

$50m^2$ and $100m^2$ the percentage difference is 2.7% and 4.8% respectively. There is no extreme difference in predicted performance, but it appears that the percentage difference between the two methods will become greater as the collector area is increased even further.

In Figure 6 the comparison is made on a month by month basis for the different collector areas. An interesting observation is that for the two smaller collector areas, the performance of the two methods is almost identical during the summer and winter months, with SESP having a slight edge over F-CHART. An exception which cannot be readily explained is March at $25m^2$. However, during the spring and fall, the SESP performance gains a clear edge over F-CHART. This is also apparent at $100m^2$, but because of the larger areas, the differences are shifted toward the winter months. This gain in predicted fraction can be traced to the direct and diffuse flux distribution model. By doing hourly simulations, the collector in the SESP simulator has an opportunity to "turn on" and collect relatively high intensity radiation for a few hours each day. This would not be possible if SESP performed simulations on a monthly basis. The results of this test primarily verify SESP as an accurate simulation program (relative to the F-CHART approach).

Small Collector Areas

In this test, the same location and collector slope are kept. This time the collector areas are varied between $1.0m^2$ and $10.0m^2$. This is done in order to test the behavior of the methods given unnatural conditions, but conditions under which the simulations should be valid. The primary results are given in Table 2 and Figure 7. The results again are very close and could be considered an extension of the results of the first test with the exception of the very small areas $1.0m^2$ and $2.0m^2$. As the areas become smaller, the two curves are predicting smaller and smaller fractions with the SESP Fraction consistently larger. When the area becomes $4.0m^2$, the fractions become identical. For the areas $1.0m^2$ and $2.0m^2$ the SESP fraction is less than the F-CHART fraction. This is due to the fact that F-CHART assumes a linear relationship between the variables X and Y and the collector area being used. Thus some fraction, no matter how small will always be shown by F-CHART under these conditions. SESP on the other hand, will show zero and even negative values of fraction if the collector area is too small. This comes about because the SESP simulation is performed exclusively with computer programs. When the collector area drops, the flow rates and storage capacities of the working fluids also drop. These low flow rates and storage capacities result in inaccurate

TABLE 2

ANNUAL FRACTIONS PREDICTED BY F-CHART AND SESP FOR VERY SMALL COLLECTOR AREAS

		ANNUAL FRACTION	
LOCATION	COLL. AREA M^2	F-CHART	SESP
COLUMBUS, OHIO	1.0	0.0195	0.0027
COLUMBUS, OHIO	2.0	0.0384	0.0262
COLUMBUS, OHIO	4.0	0.0742	0.0757
COLUMBUS, OHIO	6.0	0.1075	0.1190
COLUMBUS, OHIO	8.0	0.1386	0.1501
COLUMBUS, OHIO	10.0	0.1674	0.1793

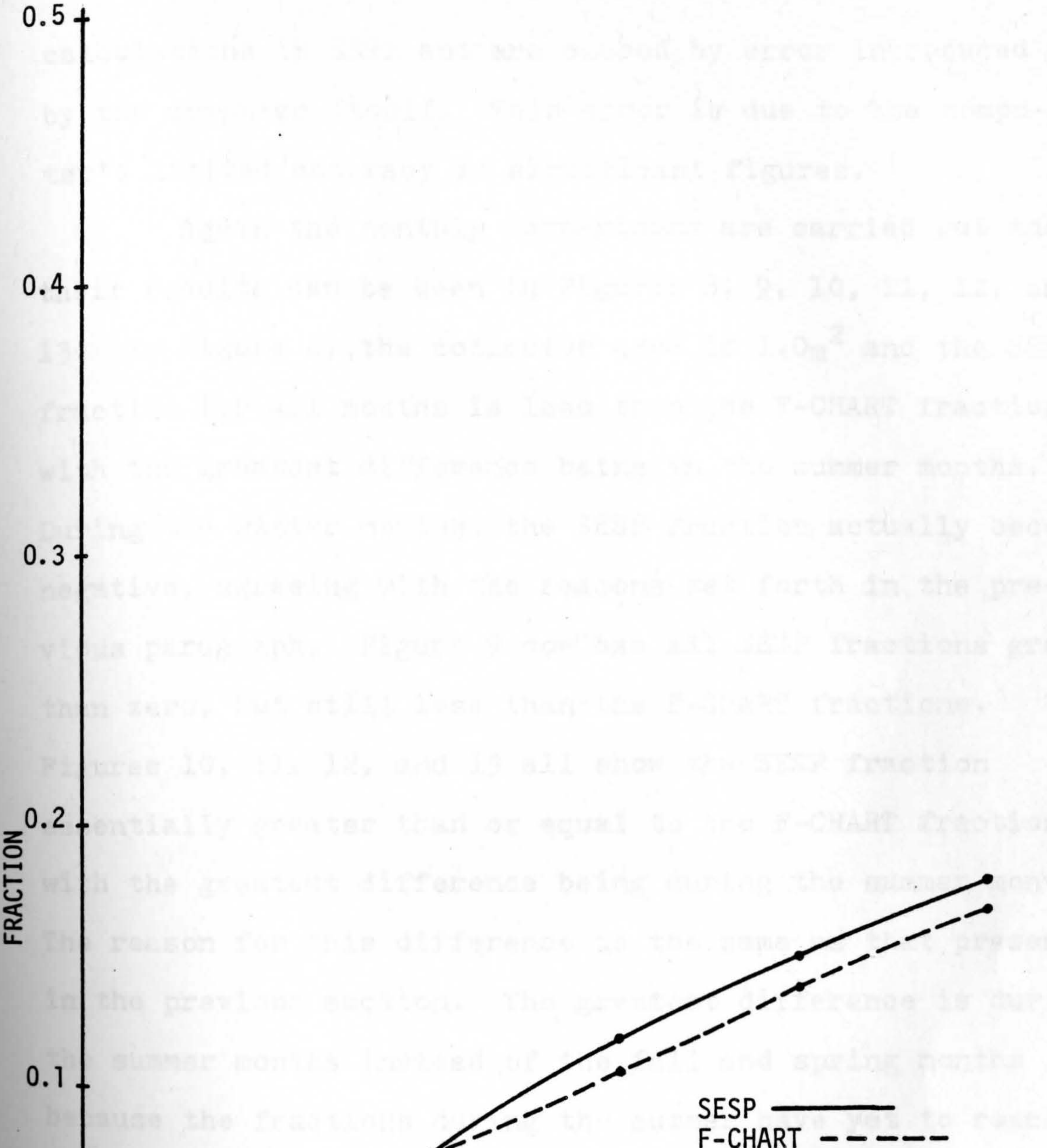

Fig. 7. Annual Fraction as a Function of Collector Area for F-CHART and SESP. (Small Collector Areas).

calculations in SESP and are caused by error introduced by the computer itself. This error is due to the computer's limited accuracy in significant figures.

Again the monthly comparisons are carried out and their results can be seen in Figures 8, 9, 10, 11, 12, and 13. In Figure 8, the collector area is 1.0m^2 and the SESP fraction for all months is less than the F-CHART fraction with the greatest difference being in the summer months. During the winter months, the SESP fraction actually becomes negative, agreeing with the reasons set forth in the previous paragraph. Figure 9 now has all SESP fractions greater than zero, but still less than the F-CHART fractions. Figures 10, 11, 12, and 13 all show the SESP fraction essentially greater than or equal to the F-CHART fraction with the greatest difference being during the summer months. The reason for this difference is the same as that presented in the previous section. The greatest difference is during the summer months instead of the fall and spring months because the fractions during the summer have yet to reach 1.0 and no energy is being wasted during those months. Therefore, the difference in energy gathered between the two methods is the same as the difference in the energy used in the two methods and thus will be greatest during those months in which the energy gathered is greatest, but still less than 100%.

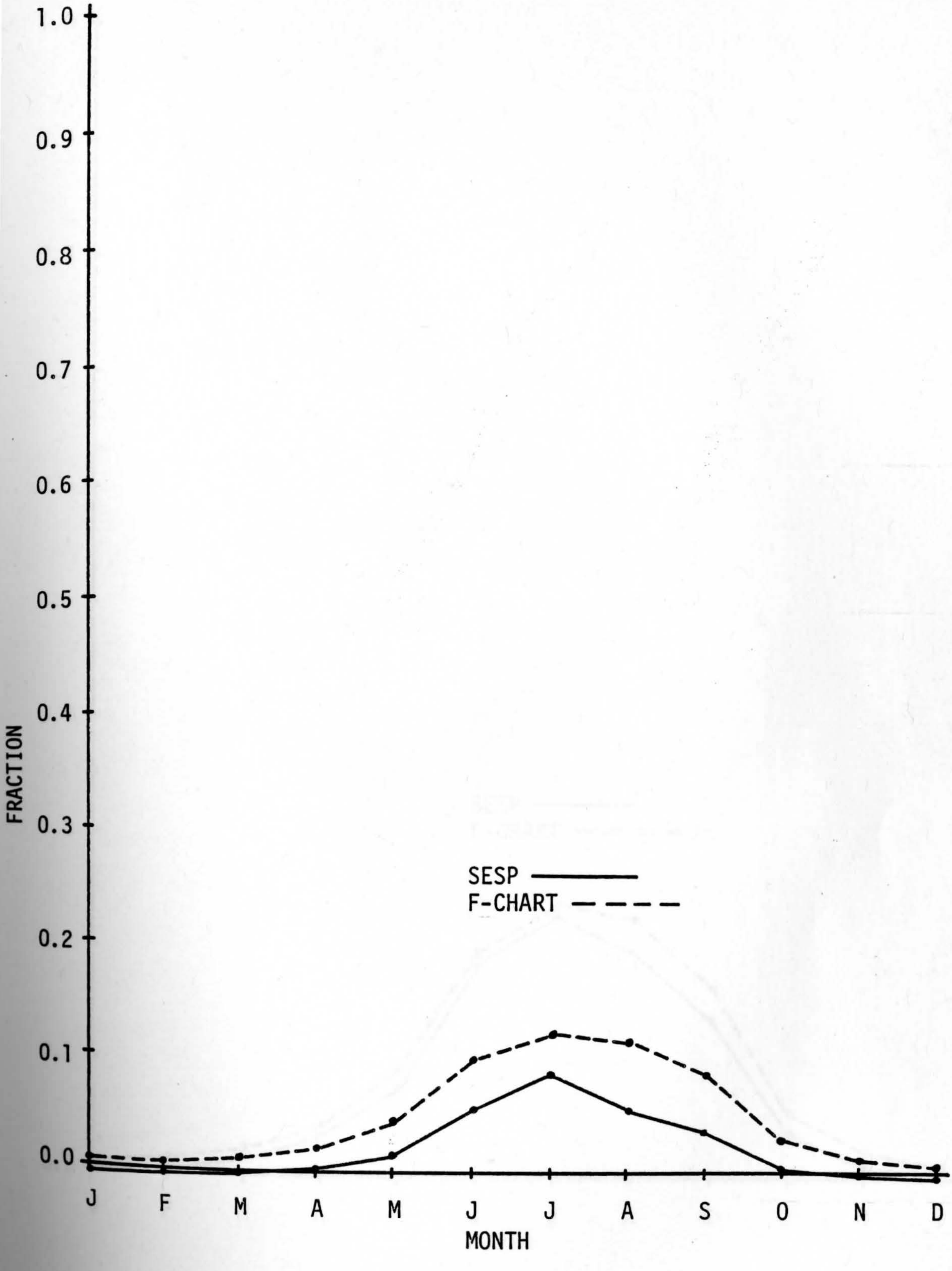

Fig. 8. Month Versus Fraction for SESP and F-CHART. Area - 1_m^2

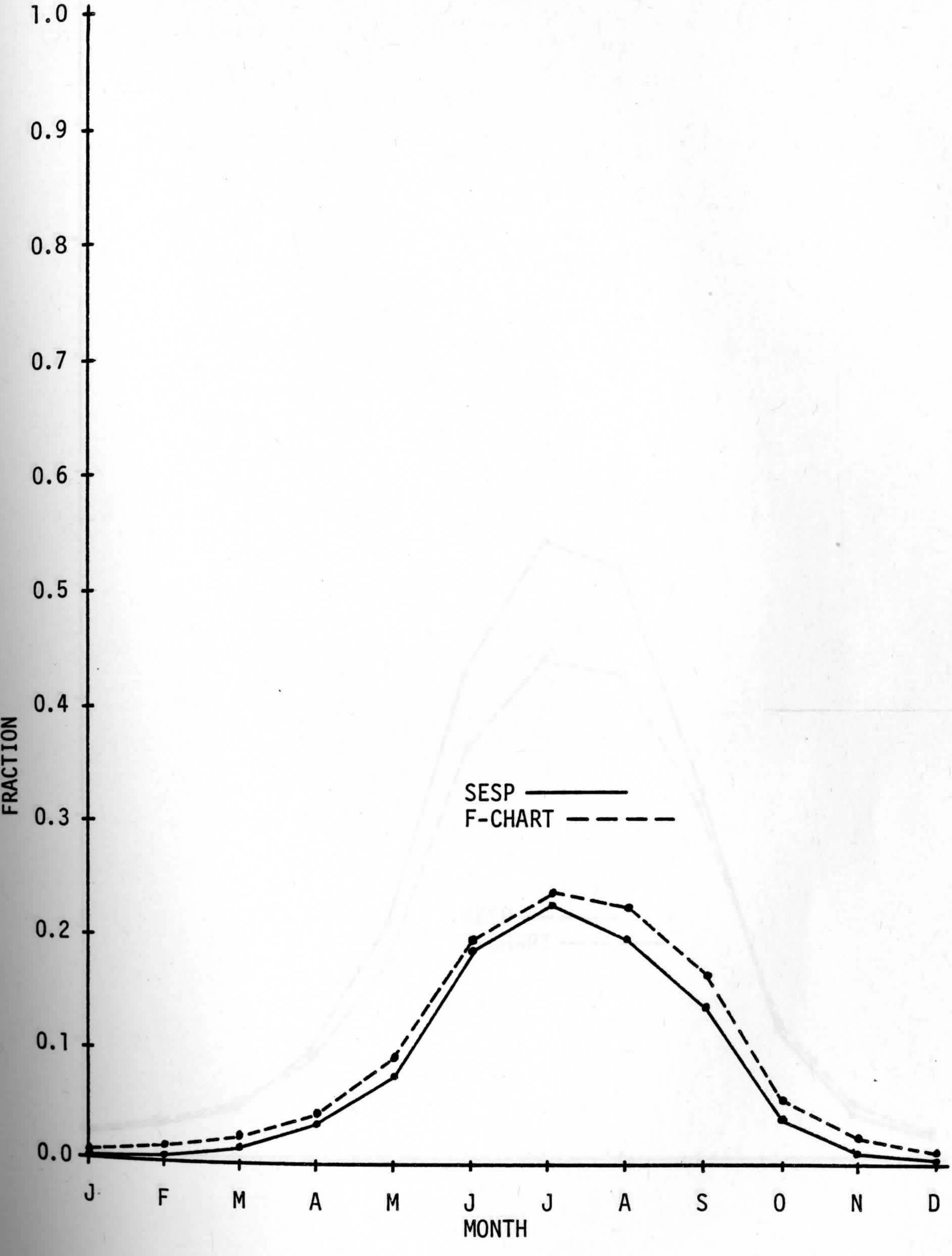

Fig. 9. Month Versus Fraction for SESP and F-CHART. Area = $2m^2$

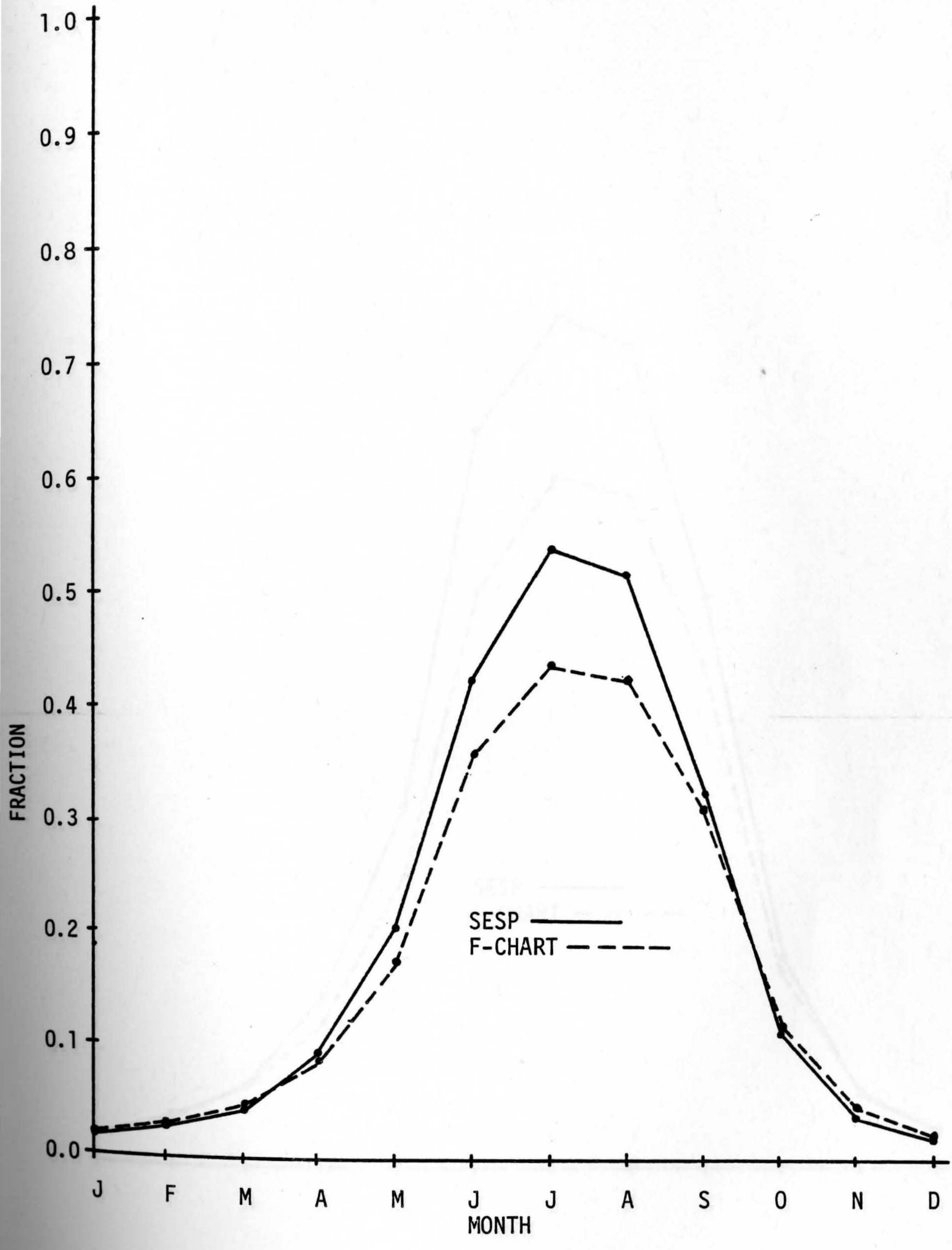

Fig. 10. Month Versus Fraction for SESP and F-CHART.
Area = $4 m^2$

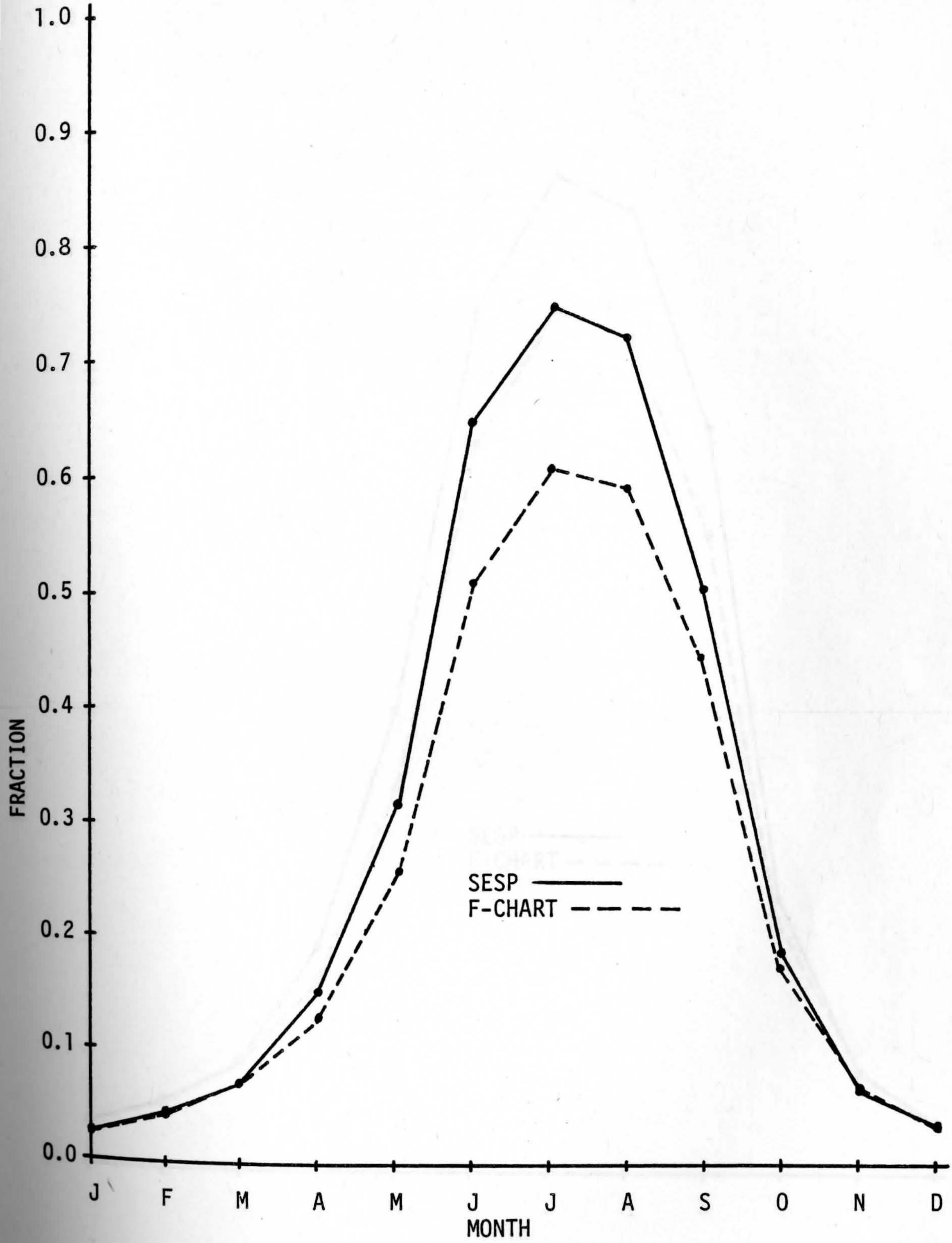

Fig. 11. Month Versus Fraction for SESP and F-CHART. Area - $6m^2$

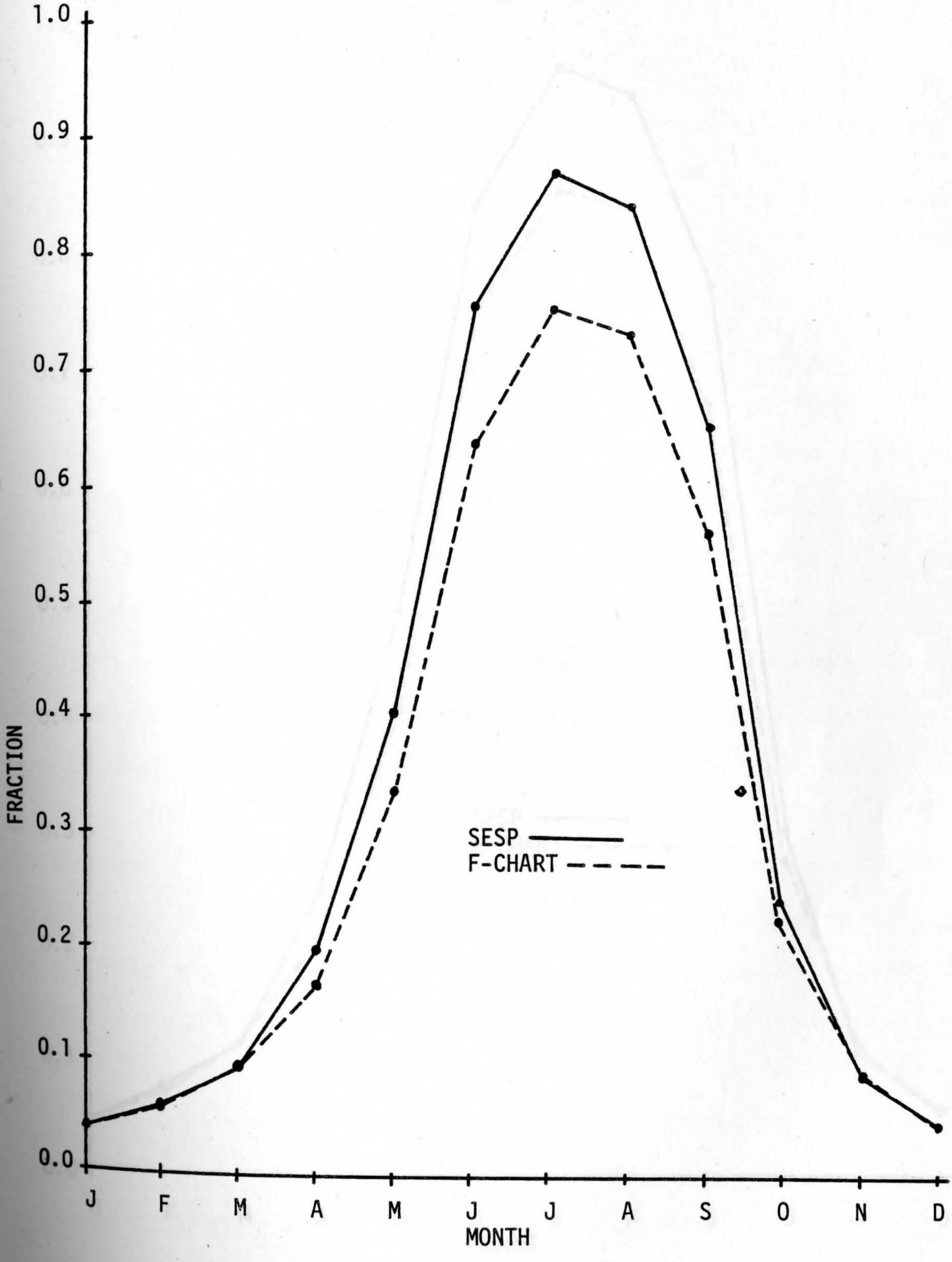

Fig. 12. Month Versus Fraction for SESP and F-CHART. Area = 8_m^2

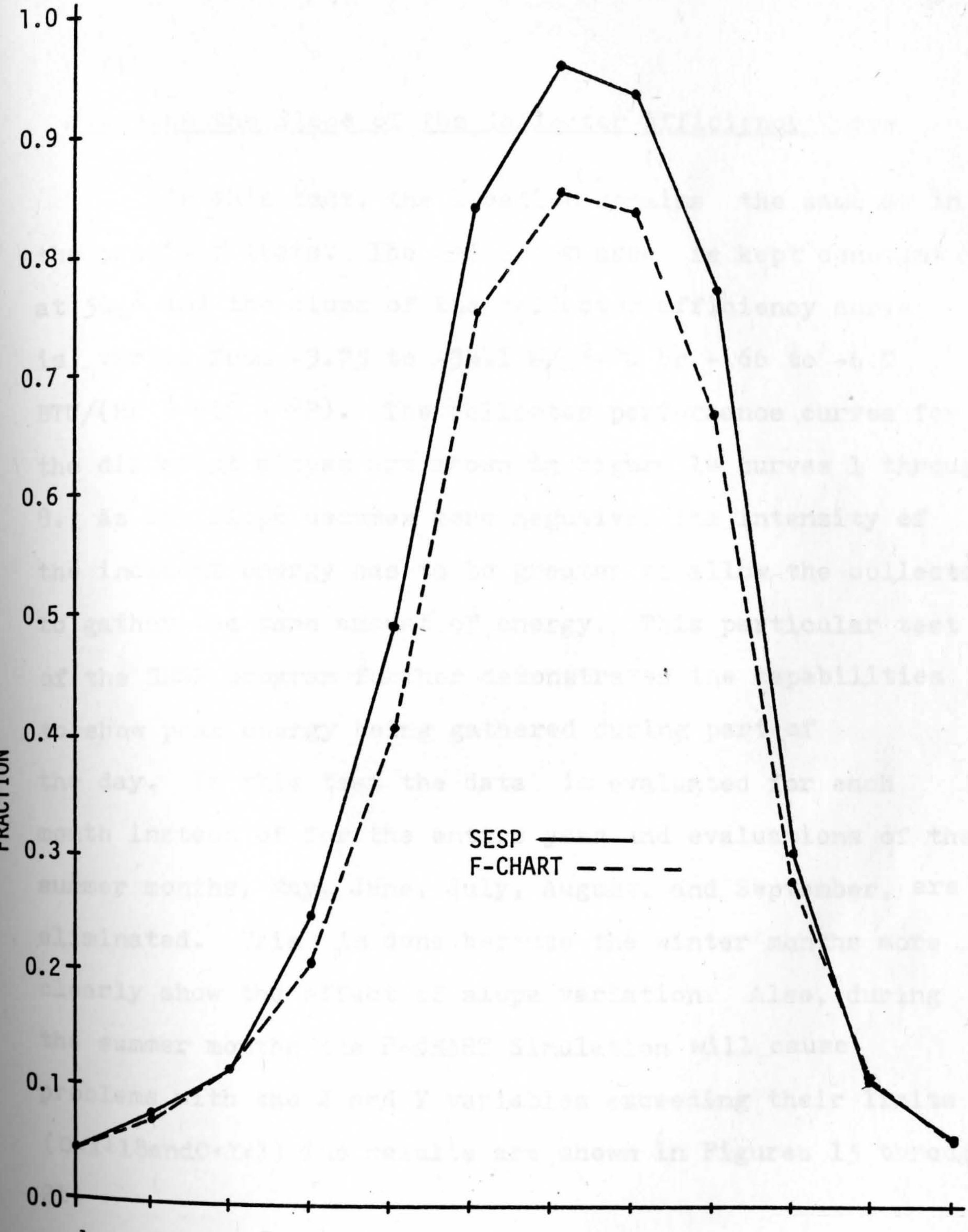

Fig. 13. Month Versus Fraction for SESP and F-CHART. Area = $10m^2$

Varying the Slope of the Collector Efficiency Curve

In this test, the location remains the same as in the previous tests. The collector area is kept constant at $50m^2$ and the slope of the collector efficiency curve is varied from -3.75 to -34.1 W/M^2-°C or -.66 to -6.0 BTU/(Hr - Ft^2 - °F). The collector performance curves for the different slopes are shown in Figure 14 curves 1 through 8. As the slope becomes more negative, the intensity of the incident energy has to be greater to allow the collector to gather the same amount of energy. This particular test of the SESP program further demonstrates the capabilities to show peak energy being gathered during part of the day. In this test the data is evaluated for each month instead of for the entire year and evaluations of the summer months, May, June, July, August, and September, are eliminated. This is done because the winter months more clearly show the effect of slope variation. Also, during the summer months the F-CHART Simulation will cause problems with the X and Y variables exceeding their limits ($0<X<18$ and $0<Y<3$) The results are shown in Figures 15 through 21.

Figure 15 shows the January fraction as a function of collector slope. Both methods start out identical in their predictions, but as the slope is made more negative, the F-CHART fraction drops excessively and becomes extremely

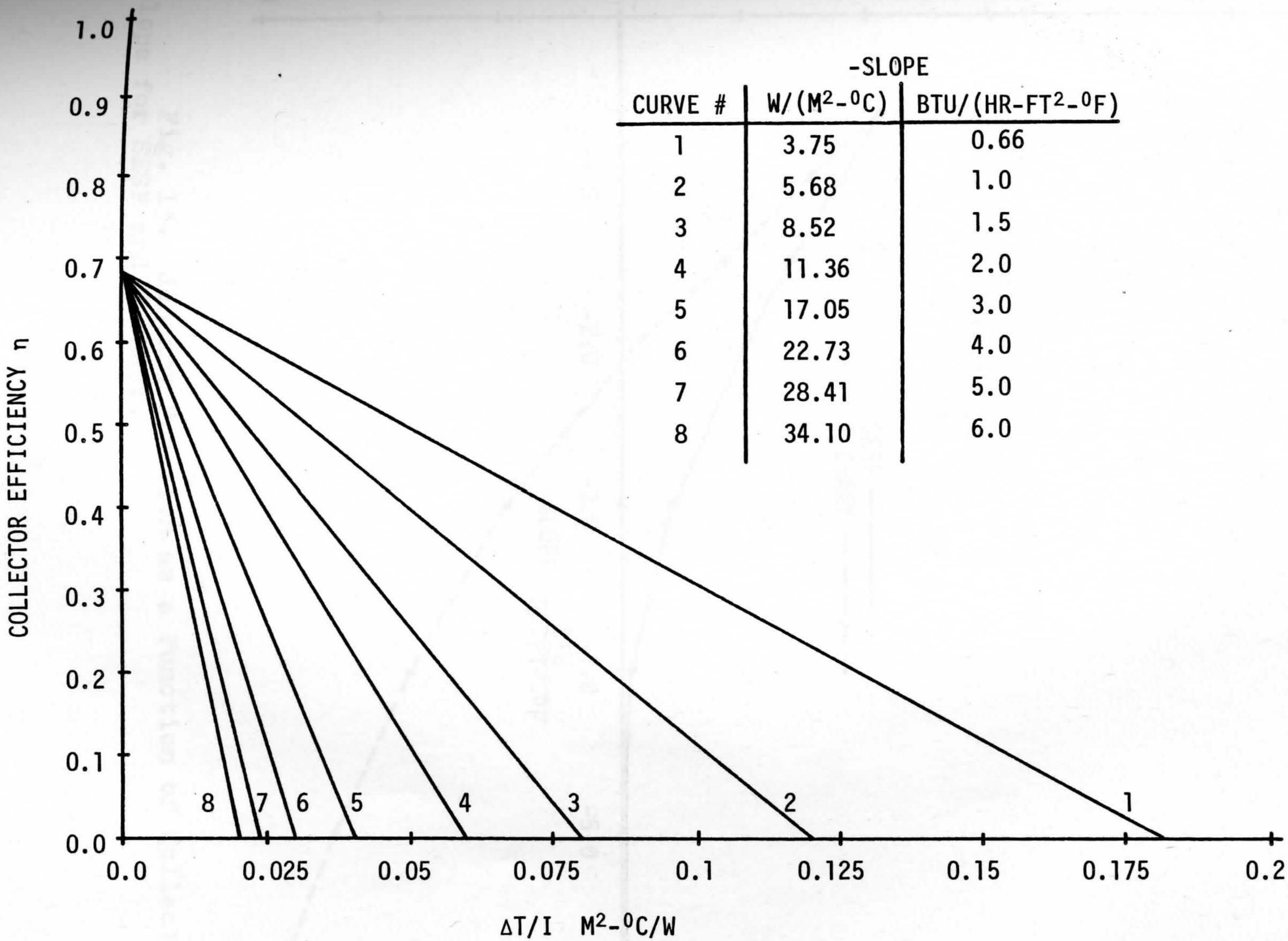

Fig. 14. Collector Efficiency Curves for Increasingly Negative Slopes.

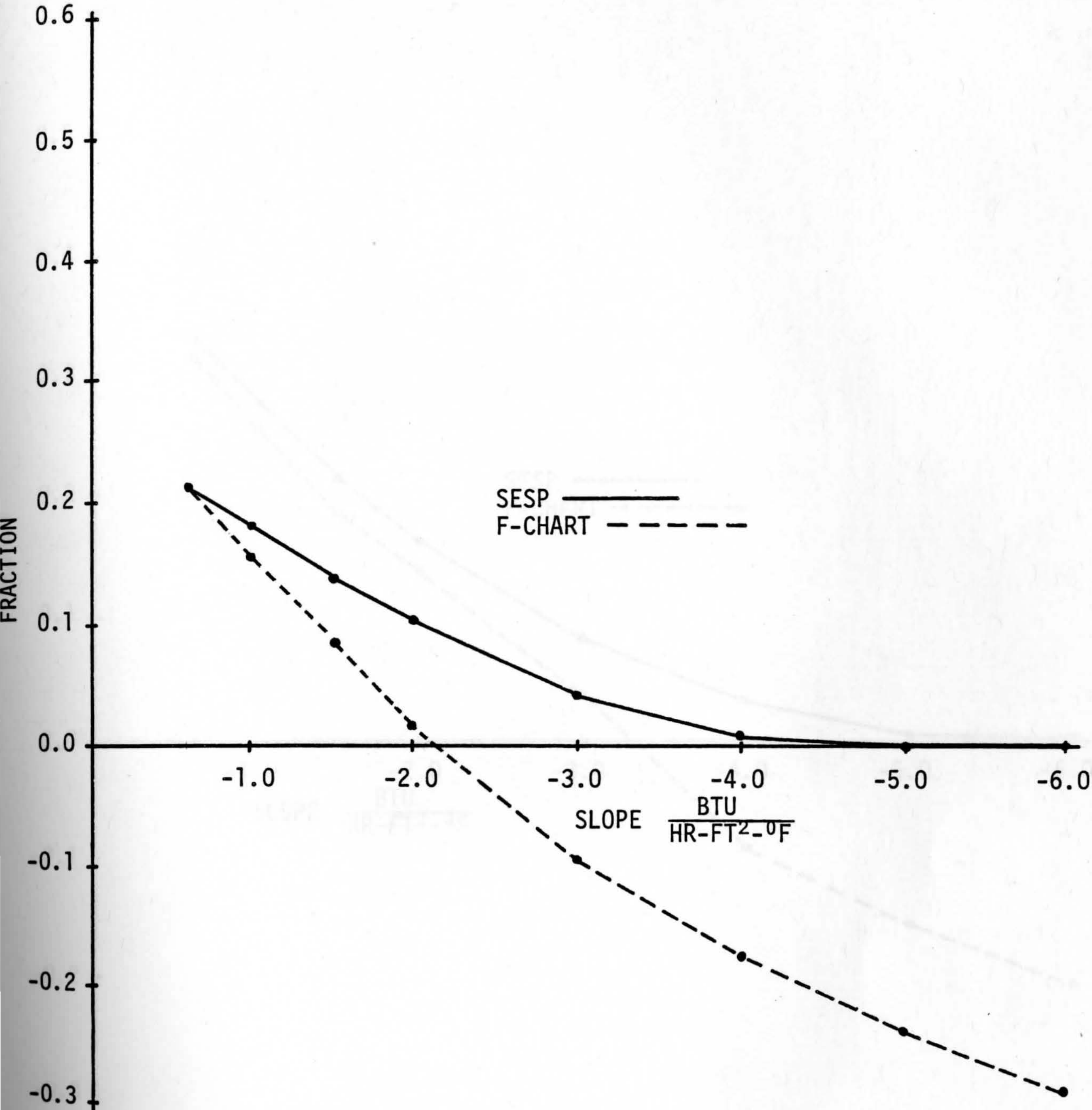

Fig. 15. January Fraction as a Function of Collector Slope for SESP and F-CHART.

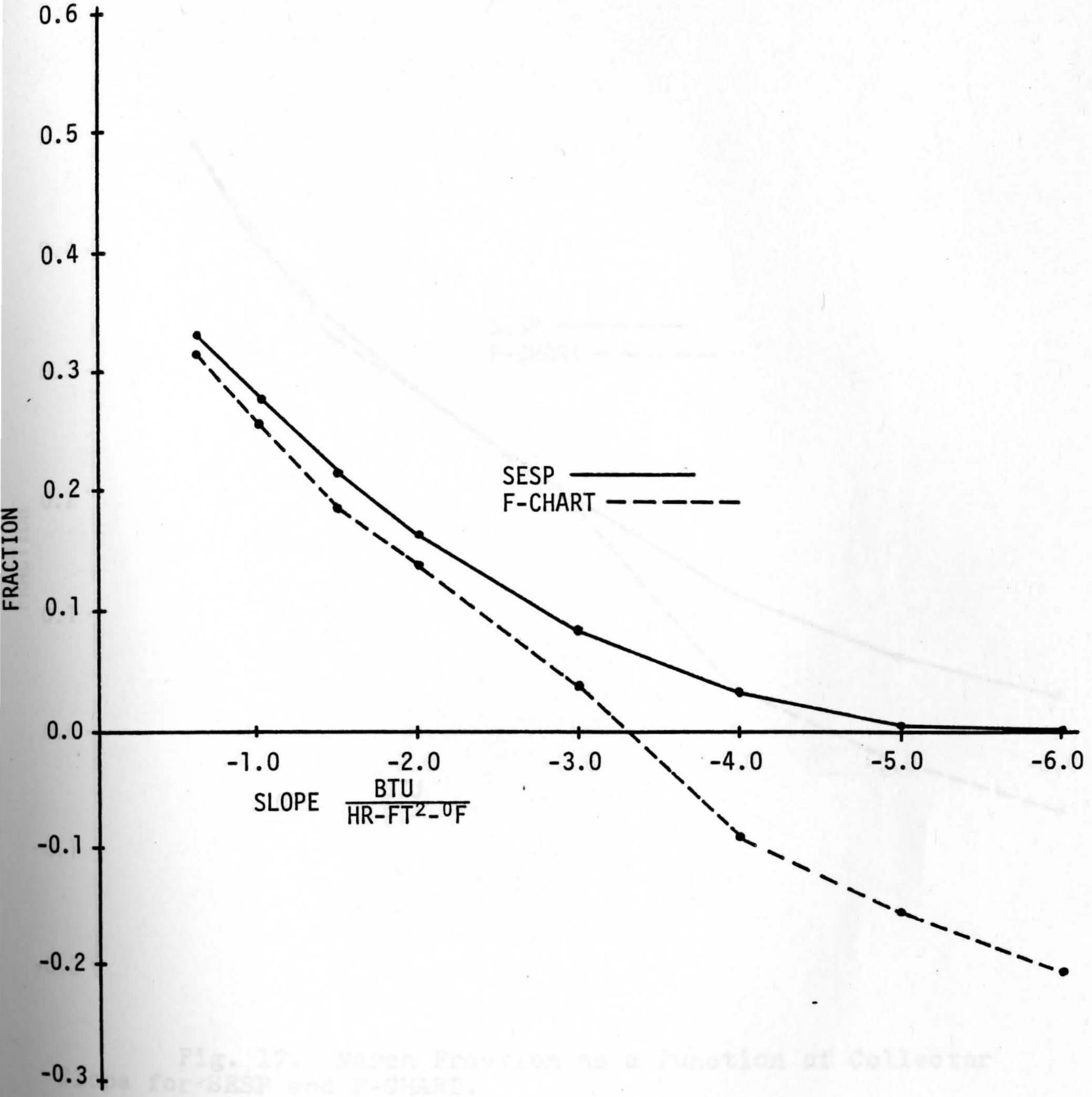

Fig. 16. February Fraction as a Function of Collector Slope for SESP and F-CHART.

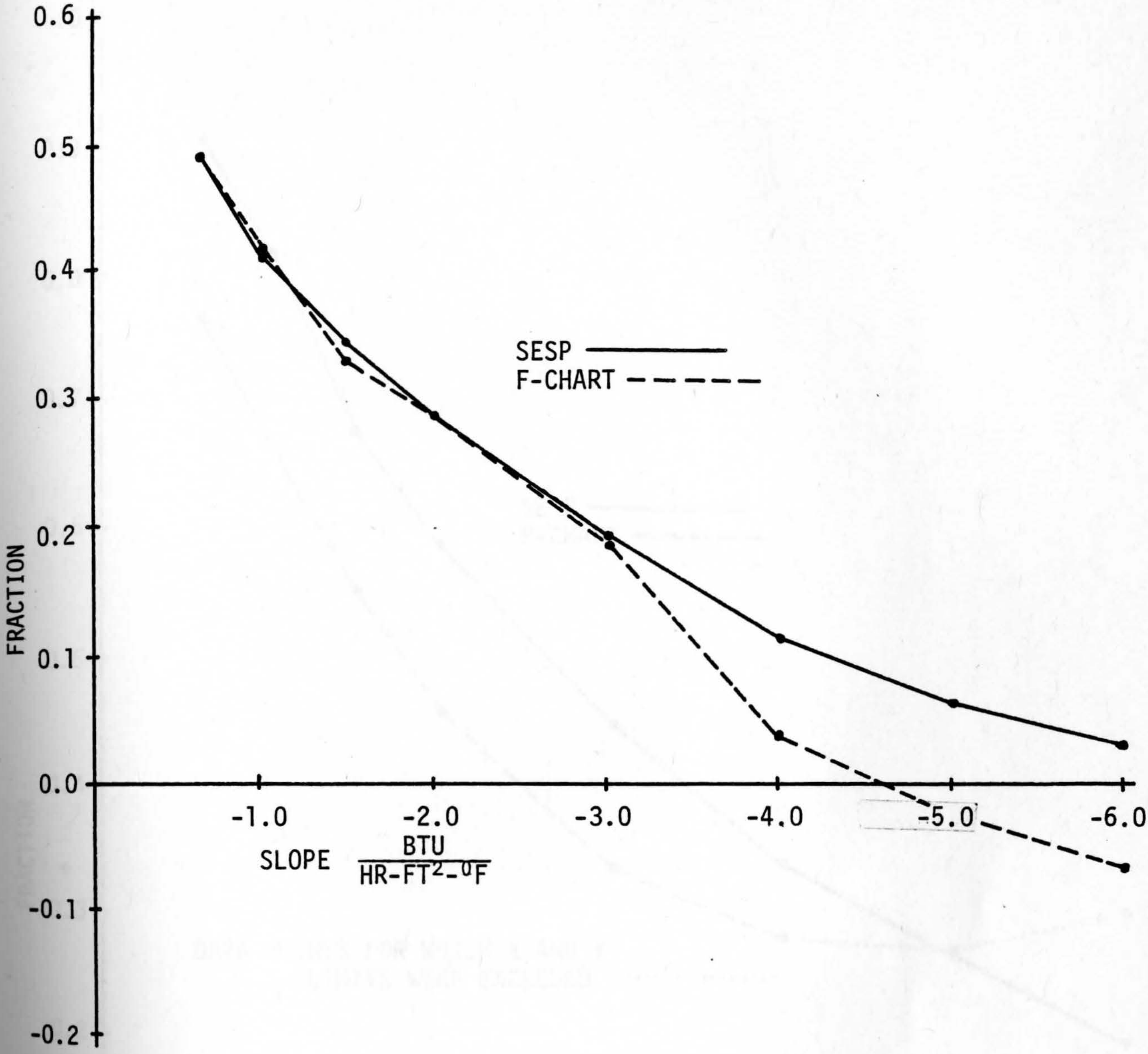

Fig. 17. March Fraction as a Function of Collector Slope for SESP and F-CHART.

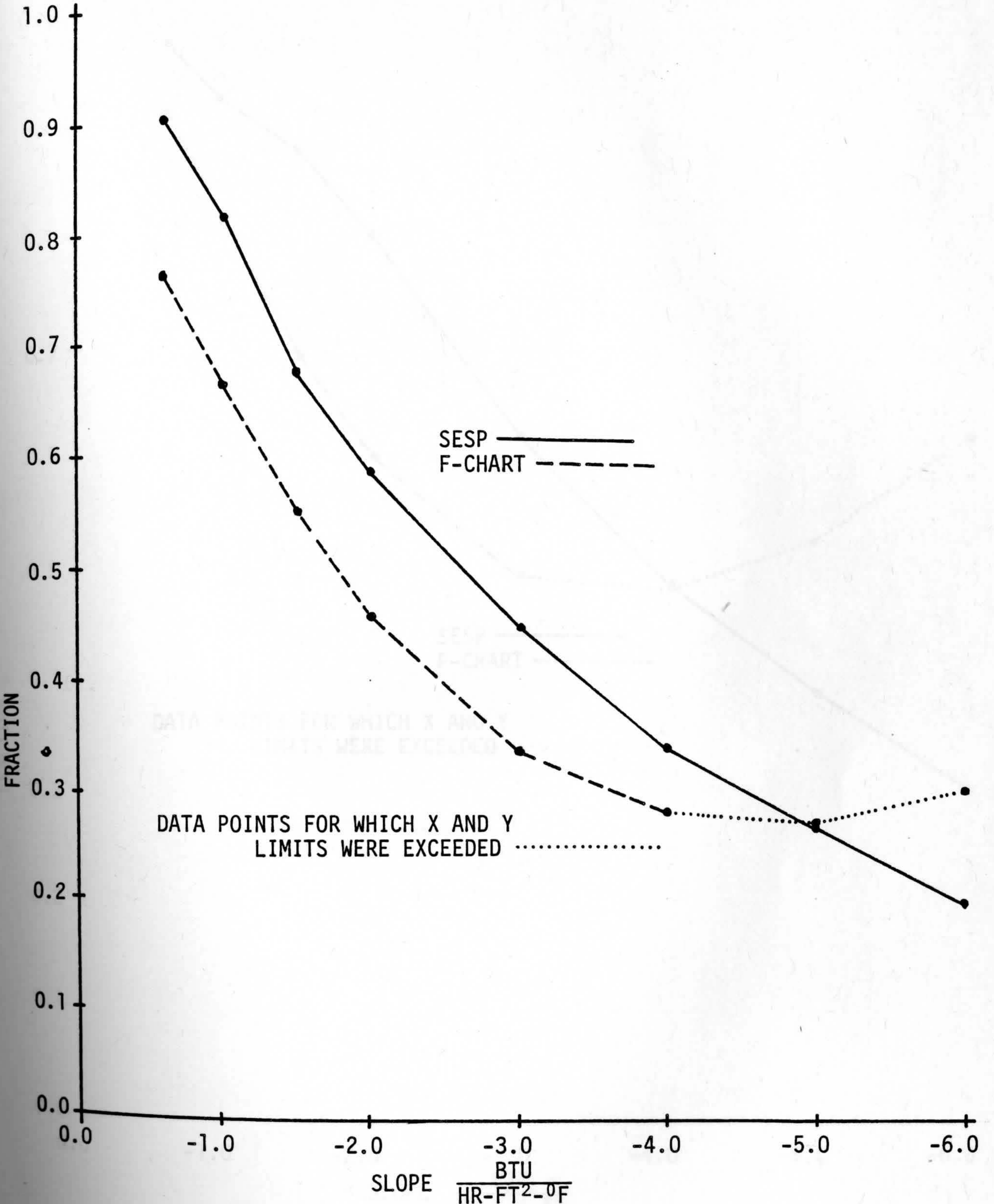

Fig. 18. April Fraction as a Function of Collector Slope for SESP and F-CHART.

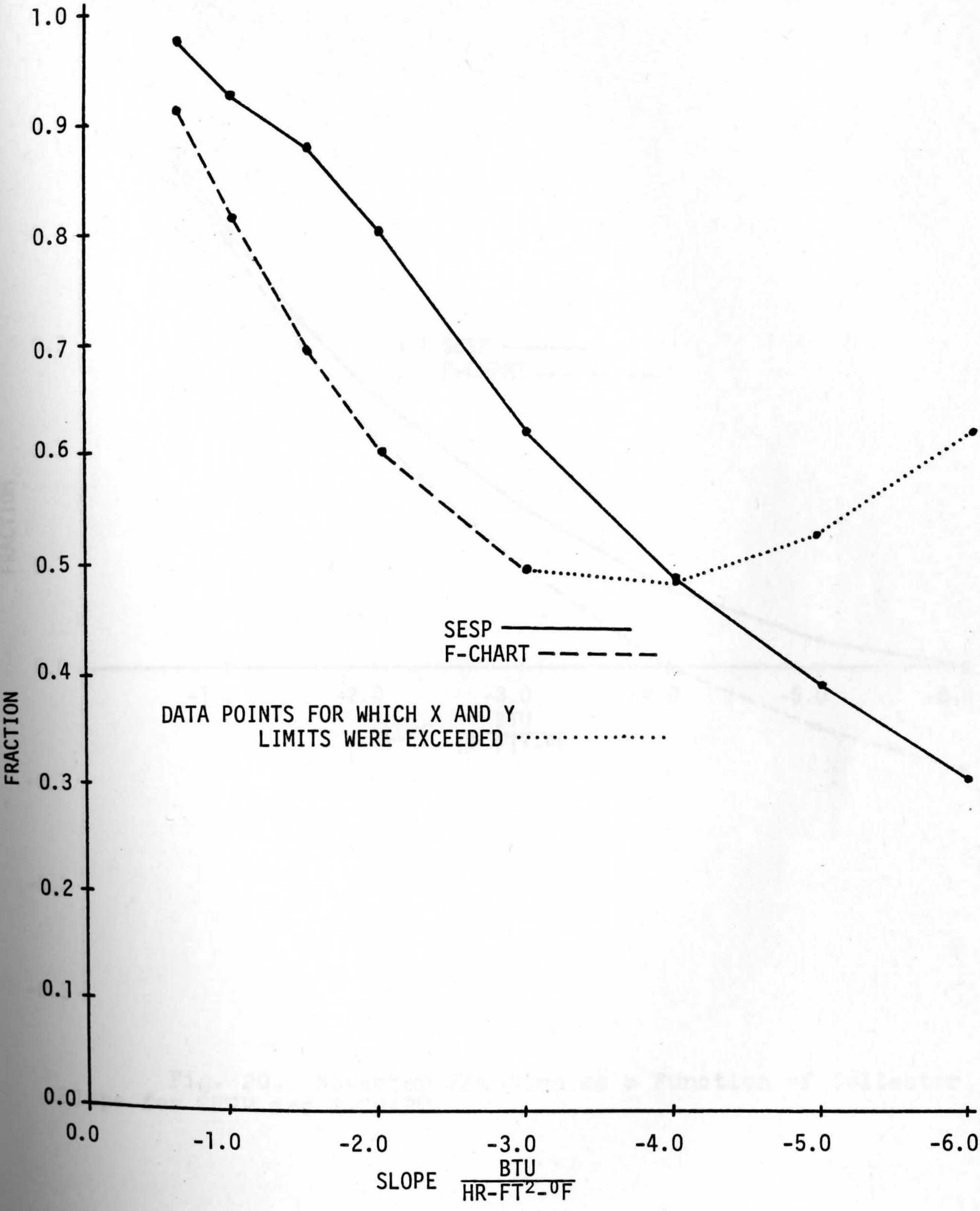

Fig. 19. October Fraction as a Function of Collector Slope for SESP and F-CHART.

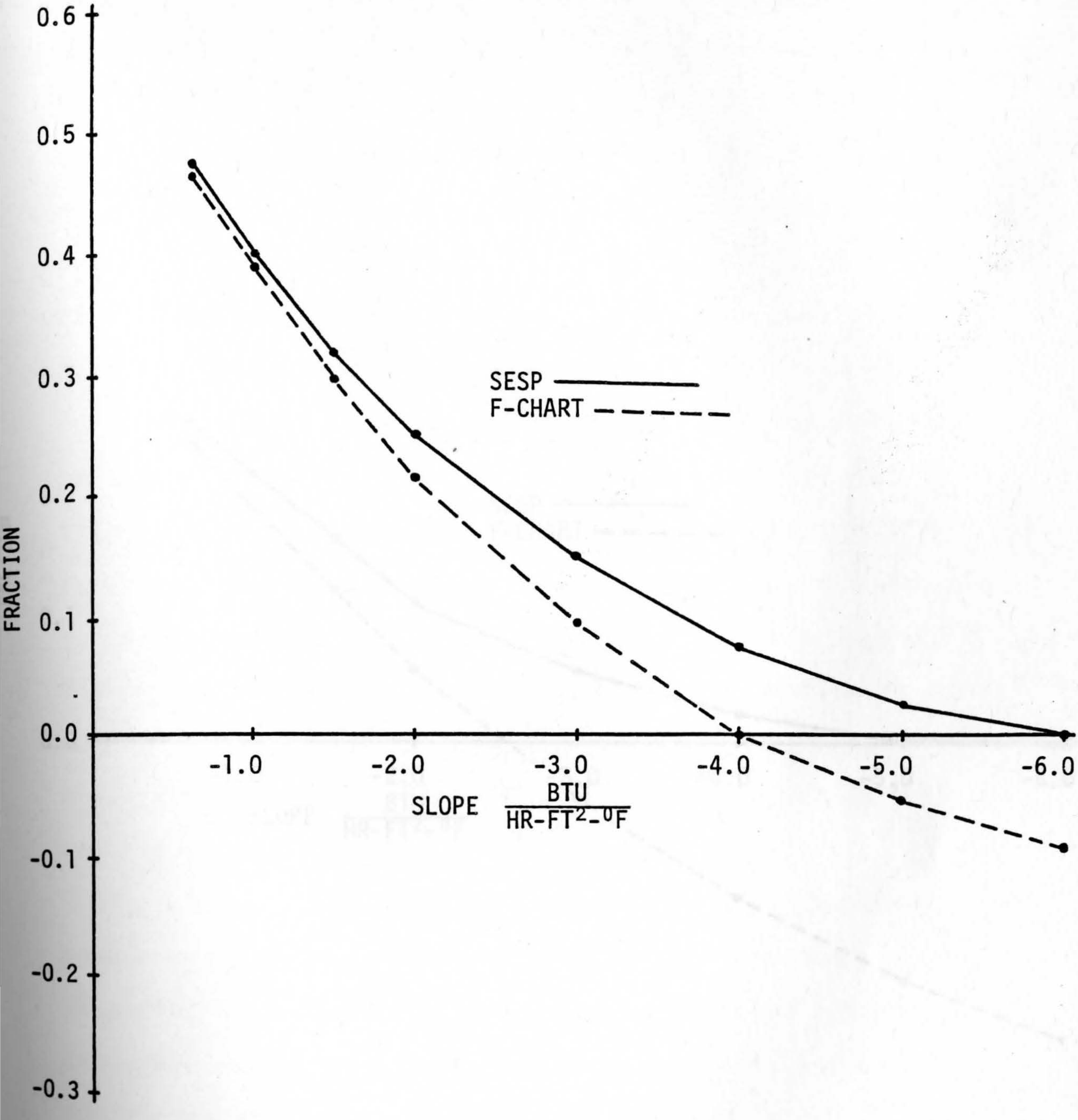

Fig. 20. November Fraction as a Function of Collector Slope for SESP and F-CHART.

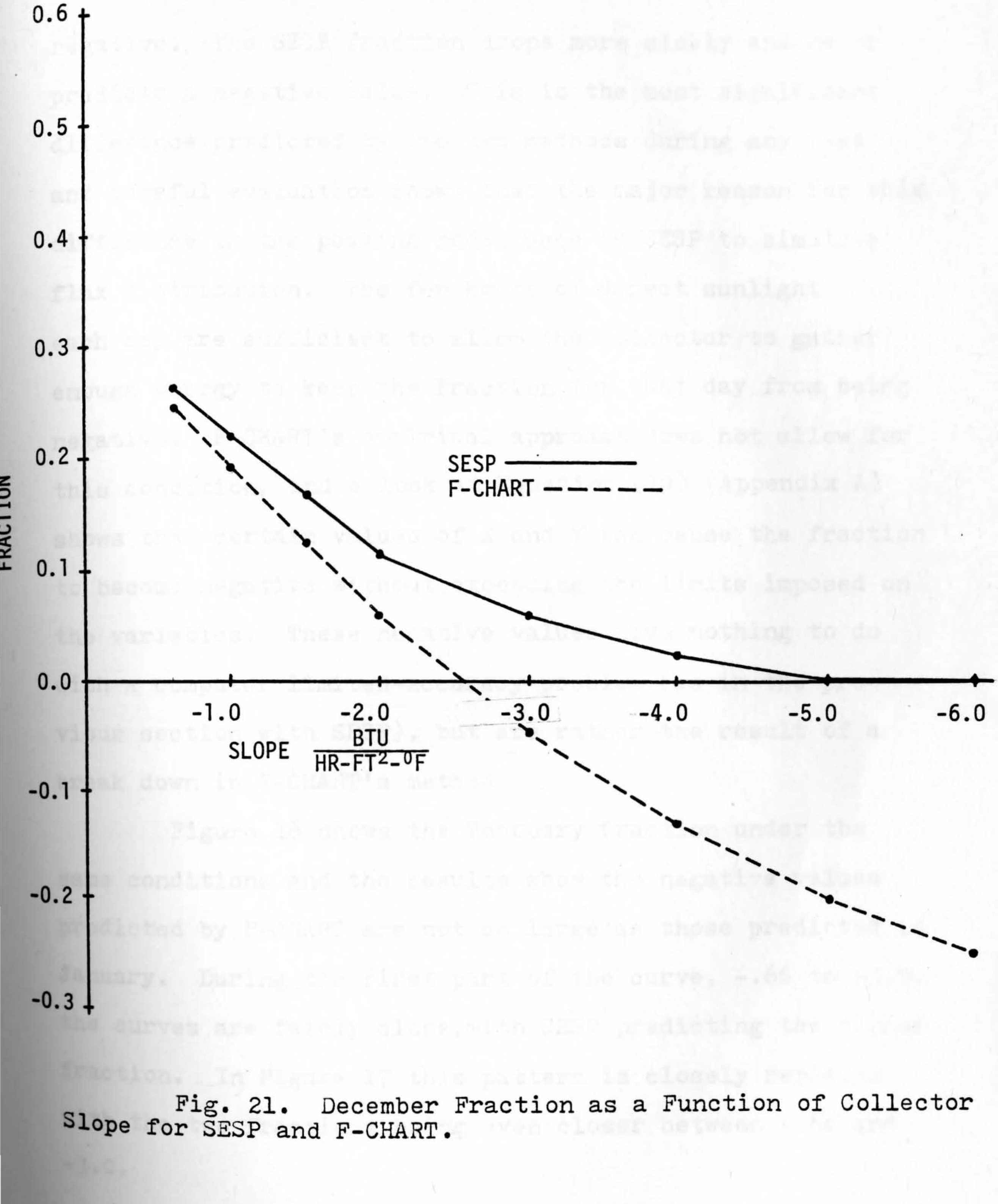

Fig. 21. December Fraction as a Function of Collector Slope for SESP and F-CHART.

negative. The SESP fraction drops more slowly and never predicts a negative value. This is the most significant difference predicted by the two methods during any test and careful evaluation shows that the major reason for this difference is the peaking model used in SESP to simulate flux distribution. The few hours of direct sunlight each day are sufficient to allow the collector to gather enough energy to keep the Fraction for that day from being negative. F-CHART's empirical approach does not allow for this condition, and a look at Equation (19) (Appendix A) shows that certain values of X and Y can cause the fraction to become negative without exceeding the limits imposed on the variables. These negative values have nothing to do with a computer limited-accuracy problem (as in the previous section with SESP), but are rather the result of a break down in F-CHART's method.

Figure 16 shows the February fraction under the same conditions and the results show the negative values predicted by F-CHART are not as large as those predicted in January. During the first part of the curve, -.66 to -3.0, the curves are fairly close,with SESP predicting the higher fraction. In Figure 17 this pattern is closely repeated with the two fractions being even closer between -.66 and -3.0.

The SESP fraction during April and October (see Figures 18 and 19) is substantially greater than the F-CHART fraction from -.66 to -3.0 for the same reasons put forth for spring and fall months in the first test. The sections of the F-CHART curve that are dotted toward the end of the curve are those data points for which the values of X and Y are greater than the allowable limits. These points are included to show the effects of exceeding these limits.

The November fractions, Figure 20, shows the F-CHART curve becoming negative again and closely parallels the February fraction. The December fraction, Figure 21, shows extremely negative fractions for F-CHART and closely parallels the January fraction.

The differences that these tests predict are due primarily to the fact that SESP does hourly simulations and shows peaking effects wtih its flux distribution model. Thus, no matter how cold it is or how inefficient the collector is, there may be enough direct energy during some point in the day to cause the collector to turn on and collect energy. The results predicted by F-CHART are somewhat expected since it uses the averaging approach to flux distribution.

Varying the Location (Climate Extremes)

In this, the last test, the location of the simulation is moved to an extremely warm climate (El Paso, Texas) and then to an extremely cold climate (Caribou, Maine). This is done in order to test the adaptability of each method to a climate different than that of the area in which the methods were developed. The slope of the collector efficiency curve is again returned to -.66 (see Figure 14 curve 1) and the collector area is set at $50 m^2$ for Caribou, Maine and $25 m^2$ and $50 m^2$ for El Paso, Texas.

The results of the cold climate test are given in Table 3 and Figure 22. Table 3 shows the annual fraction predicted by F-CHART to be greater than that predicted by SESP. Although there is a difference, it is not substantial enough to draw any conclusions from and it can therefore be assumed that the two fractions are essentially the same. A look at the monthly analysis Figure 22, shows that SESP still predicts larger fractions than F-CHART in the spring and fall, but this difference is offset by the larger fractions that F-CHART predicts in the winter months. It can be seen that even though F-CHART and SESP predict the same fractions in this case, their methods of simulation are clearly different.

The results of the hot climate test are given in Table 3 and Figure 24. There developed, however, a problem,

TABLE 3

ANNUAL FRACTIONS PREDICTED BY F-CHART AND SESP FOR EXTREME CLIMATE LOCATIONS.

LOCATION	COLL. AREA M^2	ANNUAL FRACTION F-CHART	ANNUAL FRACTION SESP
EL PASO, TEXAS	25.0	0.719	0.809
EL PASO, TEXAS	50.0	0.9227	0.9949
CARIBOU, MAINE	50.0	0.432	0.4204

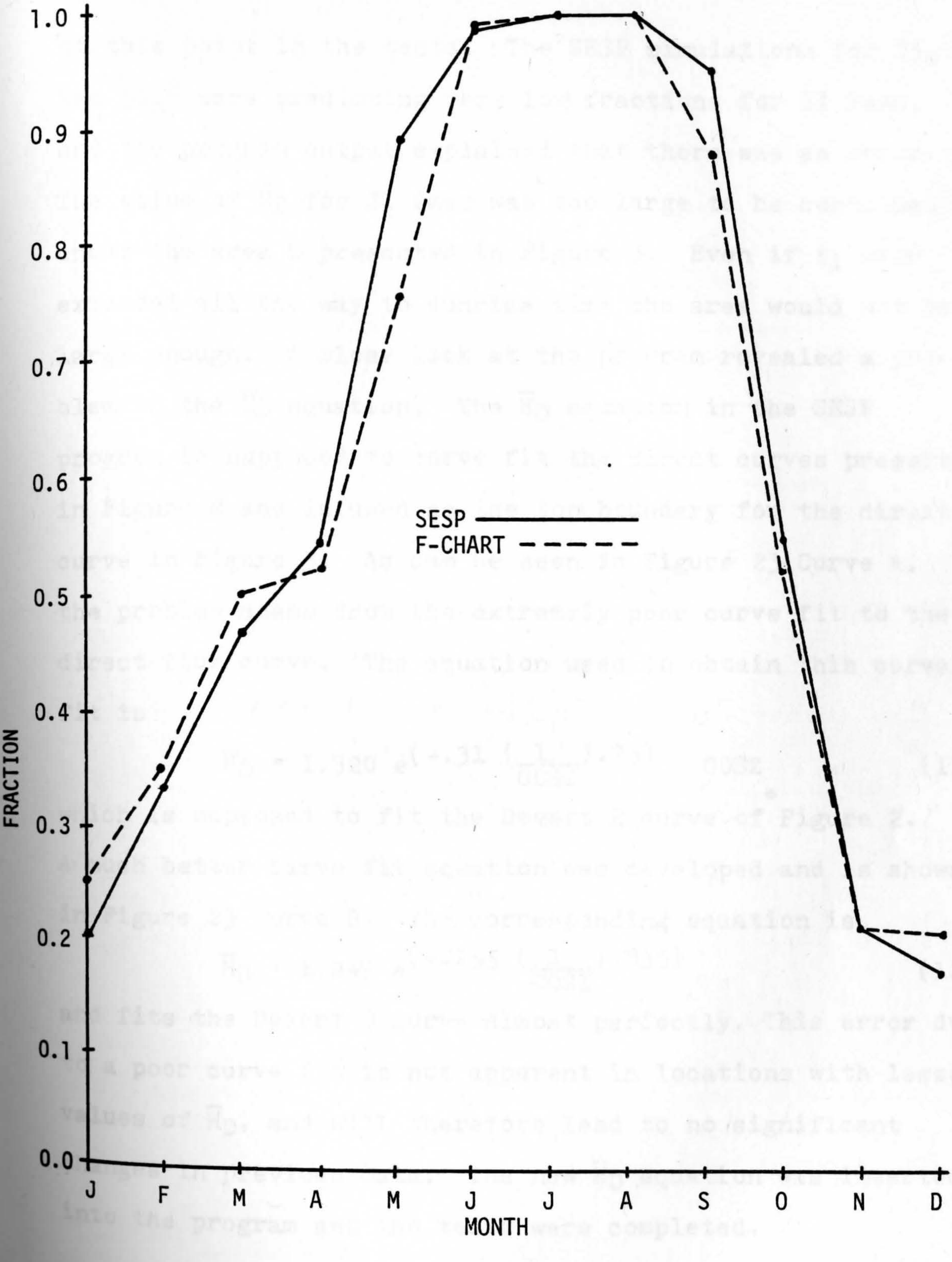

Fig. 22. Month Versus Fraction for SESP and F-CHART.
Location: Caribou, Maine.

at this point in the tests. The SESP simulations for $25m^2$ and $50m^2$ were predicting very low fractions for El Paso, and the program output explained that there was an error. The value of $\overline{H}_D$ for El Paso was too large to be contained under the area D presented in Figure 3. Even if t_1 were extended all the way to sunrise time the area would not be large enough. A close look at the program revealed a problem in the $\overline{H}_D$ equation. The $\overline{H}_D$ equation in the SESP program is supposed to curve fit the direct curves presented in Figure 2 and is used as the top boundary for the direct curve in Figure 3. As can be seen in Figure 23 Curve A, the problem stems from the extremely poor curve fit to the direct flux curve. The equation used to obtain this curve fit is

$$\overline{H}_D = 1.320\, e^{\left(-.31 \left(\frac{1}{COSZ}\right)^{.75}\right)} \quad COSZ \qquad (11)$$

which is supposed to fit the Desert D curve of Figure 2. A much better curve fit equation was developed and is shown in Figure 23 Curve B. The corresponding equation is

$$\overline{H}_D = 1.249\, e^{\left(-.255 \left(\frac{1}{COSZ}\right)^{.835}\right)} \qquad (12)$$

and fits the Desert D curve almost perfectly. This error due to a poor curve fit is not apparent in locations with lesser values of $\overline{H}_D$, and will therefore lead to no significant changes in previous data. The new $\overline{H}_D$ equation was inserted into the program and the tests were completed.

Table 3 shows that SESP predicts a higher fraction than F-CHART. For areas of $25m^2$ and $50m^2$, the error is 12.52% and 7.82% respectively. These fractions are

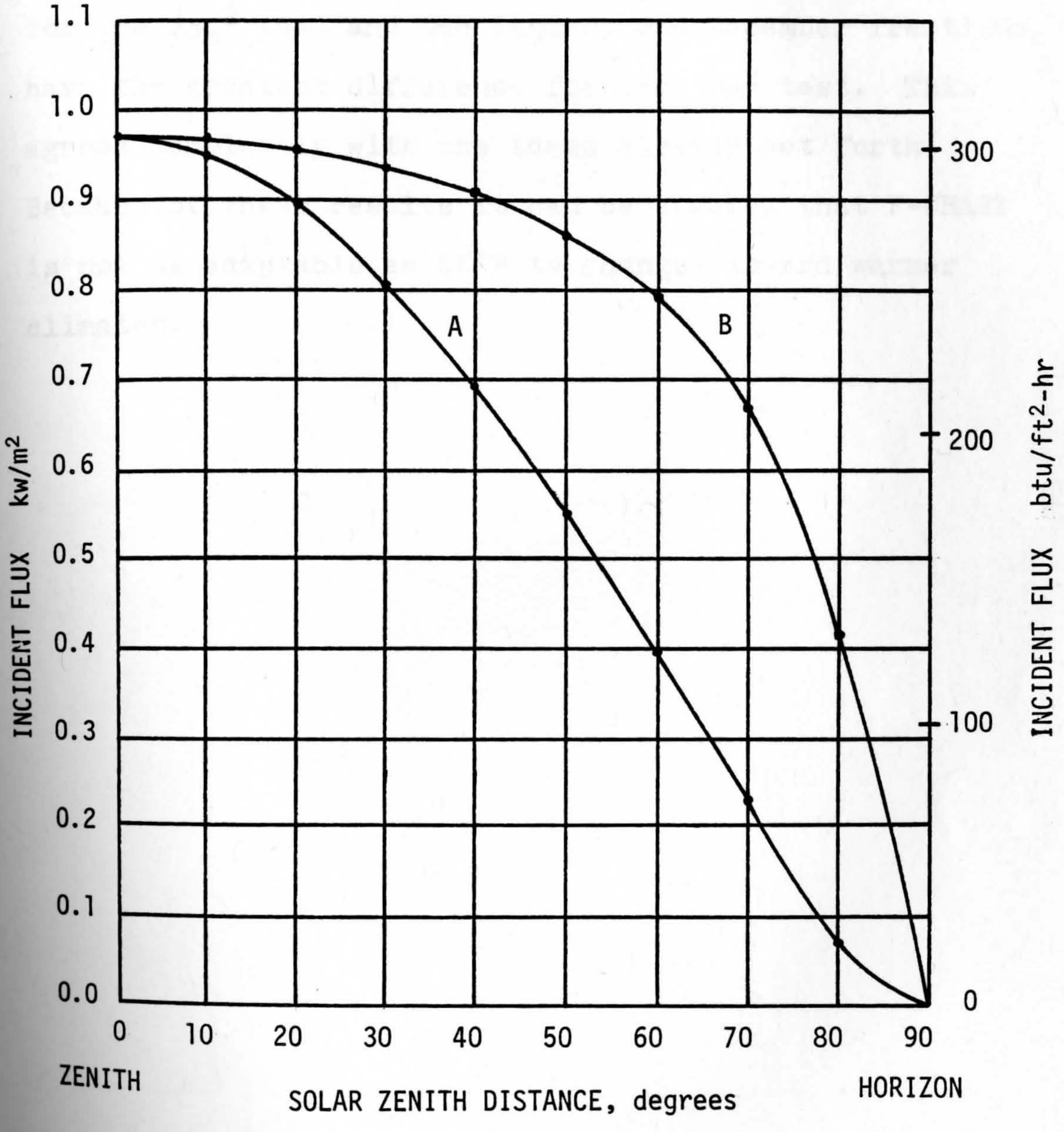

Fig. 23. Incident Flux as a Function of Zenith Angle as Shown by Two Curve Fit Equations.

substantially higher percentage wise than those from the verification run (first test) although everything except location is kept the same. A look at Figure 24 shows the February and November fractions have the most difference for the $25m^2$ test and the January and December fractions have the greatest difference for the $50m^2$ test. This agrees completely with the ideas already set forth. Because of these results it can be assumed that F-CHART is not as adaptable as SESP to changes toward warmer climates.

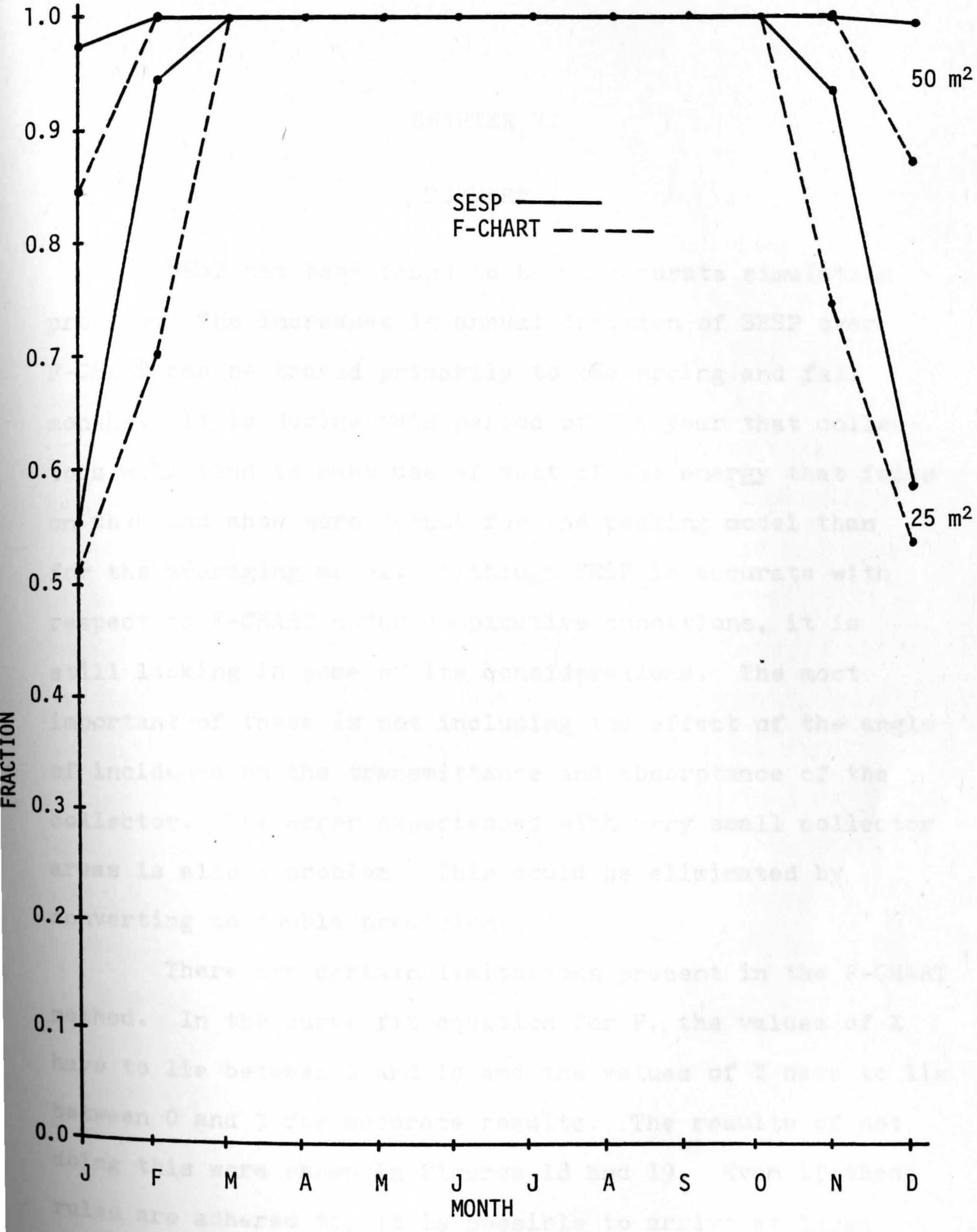

Fig. 24. Month Versus Fraction for SESP and F-CHART. Location: El Paso, Texas.

CHAPTER VI

SUMMARY

SESP has been found to be an accurate simulation program. The increases in annual fraction of SESP over F-CHART can be traced primarily to the spring and fall months. It is during this period of the year that collectors will tend to make use of most of the energy that falls on them and show more output for the peaking model than for the averaging model. Although SESP is accurate with respect to F-CHART under comparative conditions, it is still lacking in some of its considerations. The most important of these is not including the effect of the angle of incidence on the transmittance and absorptance of the collector. The error experienced with very small collector areas is also a problem. This could be eliminated by converting to double precision.

There are certain limitations present in the F-CHART method. In the curve fit equation for F, the values of X have to lie between 0 and 18 and the values of Y have to lie between 0 and 3 for accurate results. The results of not doing this were shown in Figures 18 and 19. Even if these rules are adhered to, it is possible to arrive at large negative fractions as shown most readily in Figures 15, 16, and 21, which are definitely in error. Through the course of evaluating the individual steps of F-CHART another limit was found. In the step where transmittance and absorptance are calculated, there is an equation to calculate $\bar{R}_b$. If the latitude lies above 67 degrees, the equation becomes unworkable. This can be seen graphically in Figure 25. Although the limit for ϕ does vary from 67^o to 90^o as a function of the month, the lower limit is 67^o and therefore becomes the maximum allowable value for the year.

Since F-CHART was empirically fitted to existing test results, its accuracy within that range is very high. In areas beyond F-CHART's working range SESP has the capability to perform accurately. This is most apparent in the modeling of industrial hot-water systems and industrial heating systems (especially those using concentrating collectors). F-CHART's availability in workbook form allows it to be easily used by a wide range of engineers. SESP, as a dynamic simulator, cannot be put into a workbook form. However, the use of hourly calculations and peak values of direct solar radiation allows for more accurate results to be ultimately given.

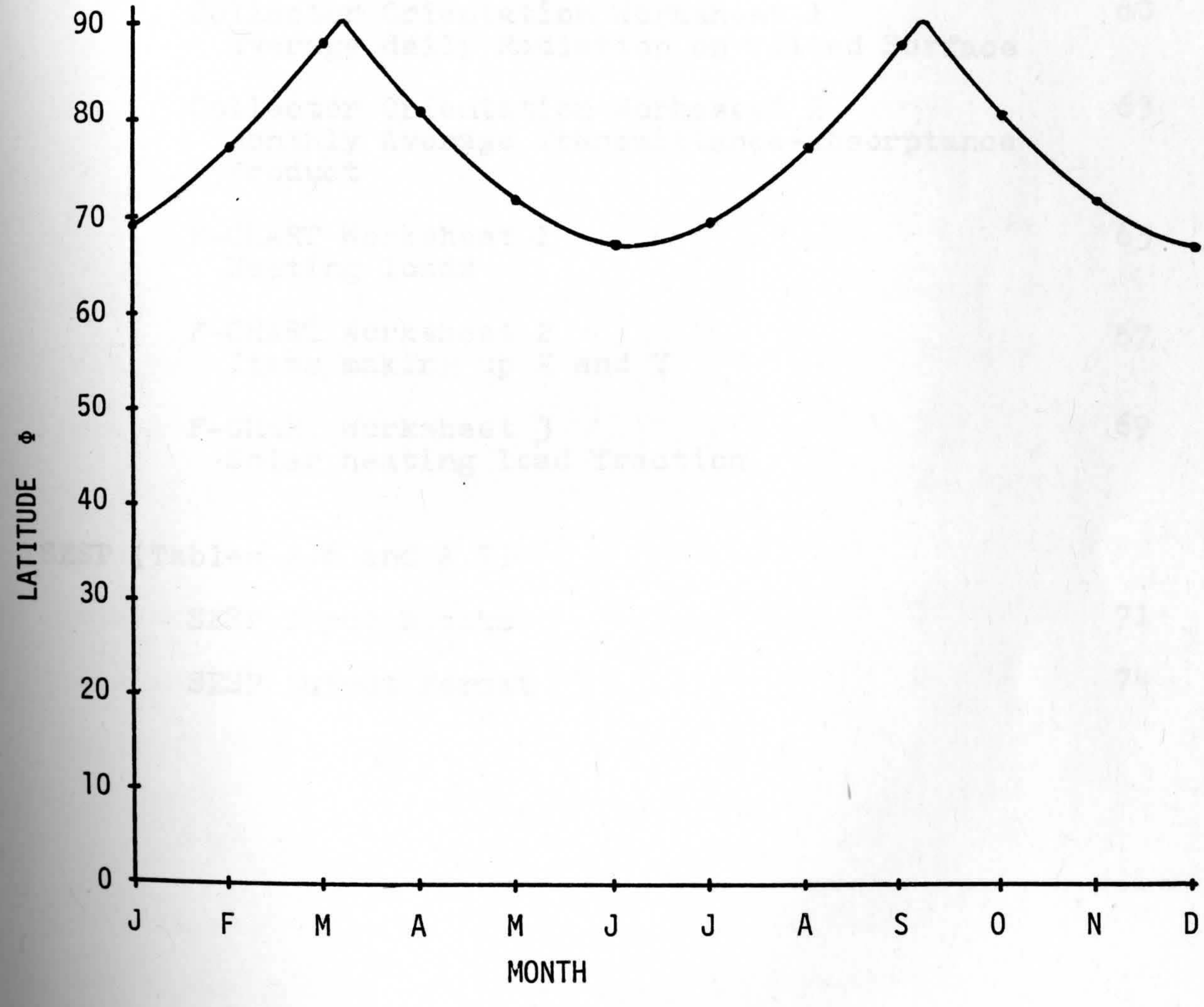

Fig. 25. Maximum Latitude Possible for Use in the $\bar{R}_b$ Equation.

APPENDIX A

Explanations for Worksheets and Input and Output Data Blocks

COLLECTOR ORIENTATION WORKSHEET 1

AVERAGE DAILY RADIATION ON TILTED SURFACES

With this worksheet as with all the other F-CHART worksheets, all calculations are carried out on a monthly basis. As the title suggests, worksheet 1 is concerned with calculating the monthly average daily radiation on a tilted surface, $\bar{H}_T$.

The values used for location and ϕ on the worksheet are self-explanatory. In choosing S, the guideline given by the F-CHART book is $\phi + 15^\circ$. This affords the greatest collection of energy for space heat in most locations. The variable ρ is dependant upon the composition of the surrounding area. In this case, an average value of 0.3 is used. The values for $\bar{H}$ and $\bar{K}_T$ are both obtained from meteorological data for that particular location. $\bar{H}_d/\bar{H}$ is calculated from $\bar{K}_T$ with the following curve fit equation.

$$\frac{\bar{H}_d}{\bar{H}} = 1.39 - 4.03\,\bar{K}_T + 5.53\,\bar{K}_T^2 - 3.11\,K_T^3 \qquad (13)$$

This equation closely fits the curve of Figure 1 which is one of the results of Liu and Jordan's work (Chapter II). $\bar{R}_b$ is approximated by the equation

$$\bar{R}_b = \frac{\cos(\phi - S)\cos\delta\sin W_s' + \frac{\pi}{180} W_s'\sin(\phi - S)\sin\delta}{\cos\phi\cos\delta\sin W_s + \frac{\pi}{180} W_s\sin\phi\sin\delta} \qquad (14)$$

where

$$W_S = \arccos(-\tan\phi \times \tan\delta) \quad (15)$$

$$W_S' = \text{MIN}\left[W_S, \arccos(-\text{Tan}(\phi - S) \times \tan\delta)\right] \quad (16)$$

$$\delta = 23.45 \sin\left[360 \times \left(\frac{284 + n}{365}\right)\right] \quad (17)$$

$\overline{R}$ is the total of F., G7. and G8. and from that ratio and the values of $\overline{H}$ the values for $\overline{H}_T$ can easily be found.

COLLECTOR ORIENTATION WORKSHEET 1
AVERAGE DAILY RADIATION ON TILTED SURFACES

A. LOCATION ______________ B. LATITUDE ϕ = ____ C. INCLINATION S = _____

D. $(1+\cos S)/2$ ______ E. GROUND REFLECTANCE ρ = _____ F. $\rho(1-\cos S)/2$ = ________

G1.	G2.	G3.	G4.	G5.	G6.	G7.	G8.	G9.	G10.
MONTH	$\bar{H}$ J/DAY-M^2	$\bar{K}_T$	$\bar{H}_d/\bar{H}$	$1-\bar{H}_d/\bar{H}$ (1-G4.)	$\bar{R}_b$	BEAM (G5.×G6.)	DIFFUSE (D.×G4.)	$\bar{R}$ (G7.+G8.+F.)	$\bar{H}_T$ J/DAY-M^2 (G9.×G2.)
JAN	$\times 10^6$								$\times 10^6$
FEB	$\times 10^6$								$\times 10^6$
MAR	$\times 10^6$								$\times 10^6$
APR	$\times 10^6$								$\times 10^6$
MAY	$\times 10^6$								$\times 10^6$
JUN	$\times 10^6$								$\times 10^6$
JUL	$\times 10^6$								$\times 10^6$
AUG	$\times 10^6$								$\times 10^6$
SEP	$\times 10^6$								$\times 10^6$
OCT	$\times 10^6$								$\times 10^6$
NOV	$\times 10^6$								$\times 10^6$
DEC	$\times 10^6$								$\times 10^6$

TABLE A. 1

COLLECTOR ORIENTATION WORKSHEET 2

MONTHLY AVERAGE TRANSMITTANCE - ABSORPTANCE PRODUCT

In this worksheet, the effect that the angle of incidence has on the transmittance and absorptance of the collector is considered. These values, which vary constantly in actual situations are reduced to monthly values through various approximations. The procedures given in the F-CHART book are valid for collector slopes up to $\pm 15^{\circ}$ from the latitude of the location. For this worksheet, let it suffice to say that values for H2., H3., H4., and H7., are obtained from figures presented in the F-CHART book that represent a standard two-cover collector. These values are factors only of ϕ - S and therefore, will remain constant for any application as long as the difference between ϕ and S remains constant. From these values and previously calculated values, beam, diffuse, and reflected component are calculated for each month. These values are then added in order to arrive at the final ratio H10. It may be noted here that this effect was ignored in most calculations due to the fact that SESP does not consider it in its simulation procedure.

COLLECTOR ORIENTATION WORKSHEET 2

MONHLY AVERAGE TRANSMITTANCE - ABSORPTANCE PRODUCT

H1. MONTH	H2. $\bar{\theta}_b$	H3. $\tau/\tau_n @ \theta_b$	H4. $\alpha/\alpha_n @ \theta_b$	H5. $\bar{R}_b / \bar{R}$ G6./G9.	H6. BEAM (G5.xH3.x H4.xH5.)	H7. $\tau/\tau_n @ 60°$	H8. DIFFUSE (D.xG4./G9. x.92xH7.)	H9. REFLECTED (F./G9.x.92 xH7.)	H10. $(\overline{\tau\alpha}/\tau\alpha)_n$ (H7.+H8.+H9.)
JAN									
FEB									
MAR									
APR									
MAY									
JUN									
JUL									
AUG									
SEP									
OCT									
NOV									
DEC									

TABLE A.2

F-CHART WORKSHEET 1

HEATING LOADS

At the start of this worksheet, two things must be known about the residence of the solar installation. The value of UA and the amount of domestic hot water usage for one day. It may be noticed that the value of UA in F-CHART does not represent the same variable as another value UA used in SESP. This difference has been shown in the symbols table and, pending a change in the SESP input parameter name, should not present a problem here. The actual value of UA (F) depends upon several factors characteristic of the residence. The domestic hot water usage is taken as an average of 400 liters per day for a family of four. The value for C2., or in other words DD, is available from meteorological data for that location. Using these values, monthly space heating and domestic water loads are calculated, which are then added to give the total monthly heating load.

F-CHART WORKSHEET 1
HEATING LOADS

A. $UA = \dfrac{\text{DESIGN SPACE HEATING LOAD [W]}}{\text{DESIGN TEMPERATURE DIFFERENCE [°C]}}$ = ______________ [W/°C]

B. WATER USAGE = __________ [LITERS/DAY] × 4190 × $(T_W - T_M)$ [J/LITER] = __________ [J/DAY]

MONTH	C1. DAYS PER MONTH	C2. HEATING DEGREE DAYS [°C-DAY]	C3. SPACE HEATING LOAD [J/MONTH] (86400)(A. × C2.)	C4. DOMESTIC WATER LOAD [J/MONTH] (B. × C1.)	C5. TOTAL LOAD [J/MONTH] (C3. + C4.)
JAN	31				
FEB	28				
MAR	31				
APR	30				
MAY	31				
JUN	30				
JUL	31				
AUG	31				
SEP	30				
OCT	31				
NOV	30				
DEC	31				
TOT	365				

TABLE A.3

F-CHART WORKSHEET 2

ITEMS MAKING UP X AND Y

In this worksheet, the characteristics of the collector used in the installation are taken into account. The product F_RU_L is equivalent to the negative of the slope of the collector efficiency curve (Figure 14) and the product $F_R(\tau\alpha)_n$ is equivalent to the intercept. By multiplying by $\frac{F_R'}{F_R}$, the effect of the heat exchanger is considered and results in an effective value for use in the subsequent calculations. In calculating C7., $\overline{T}_a$ is also available through meteorological data for the area. These values along with previously calculated values are used in obtaining monthly values for $\frac{X}{A}$ and $\frac{Y}{A}$ which are used in the last worksheet. The equation forms of $\frac{X}{A}$ and $\frac{Y}{A}$ are given in Chapter Three, Equations (9) and (10).

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R) =$ ______________ [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R) =$ ______________ [UNITLESS]

MONTH	C 6. SECONDS PER MONTH	C7. $(100 - \bar{T}_a)$ [°C]	C8. X/A [$1/M^2$] $\frac{(C.)\times(C7.)\times(C6.)}{(C5.)}$	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C 10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C 11. Y/A [$1/M^2$] $\frac{(D.)\times(C9.)\times(C10.)\times(C1.)}{(C5.)}$
JAN	2.68×10^6				$\times 10^6$	
FEB	2.42×10^6				$\times 10^6$	
MAR	2.68×10^6				$\times 10^6$	
APR	2.59×10^6				$\times 10^6$	
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6				$\times 10^6$	
NOV	2.59×10^6				$\times 10^6$	
DEC	2.68×10^6				$\times 10^6$	

TABLE A.4

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

For this, the last worksheet, it becomes necessary to know the collector area along with two correction factors, X/X_o and Y/Y_o. $\frac{X}{X_o}$ takes into account any variation in the ratio of storage size to collector area, which is assumed to be 75 liters of storage per square meter of collector for all of the standard simulations. $\frac{Y}{Y_o}$ takes into account variations in the ratio

$$\frac{\varepsilon_L C_{min}}{UA} \tag{18}$$

which is set equal to a value of two for all the standard simulations. A value of 1 is used for $\frac{X}{X_o}$ and $\frac{Y}{Y_o}$ in all simulations performed in this thesis.

In the preceeding worksheet, the values for X and Y are calculated in terms of per unit area. The next step is multiplying the corrected values of $\frac{X}{A}$ and $\frac{Y}{A}$ by the value of A being used. F is calculated next from X and Y using the following empirical equation.

$$F = 1.029\ Y - 0.065\ X - 0.245\ Y^2 + 0.0018\ X^2 + 0.0215\ Y^3$$

$$\text{for } 0 < Y < 3 \text{ and } 0 < X < 18 \tag{19}$$

The heating load supplied by solar is then calculated for each month and finally an annual fraction by solar can be determined.

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = ________ [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = ________

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = ________

MONTH	C12. CORRECTED X/A (C8.)×(F.)	C13. CORRECTED Y/A (C11.)×(G.)	C14. X (C12.)×(E.)	C15. Y (C13.)×(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN						
FEB						
MAR						
APR						
MAY						
JUN						
JUL						
AUG						
SEP						
OCT						
NOV						
DEC						
					TOTAL	

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = ________

TABLE A.5

SESP INPUT DATA

Due to the fact that SESP is in program form, all that is necessary to make a run is to supply the program with the correct input data. The input data has been broken down into convenient blocks whose components are generally of the same nature. The C block contains elements C_1 - C_5 and specifies the most basic or general parameters of the system, such as the number of runs, the beginning month of the simulation and the ending month of the simulation. Element C_4 has the option of allowing four lines to be printed at the top of the output data which contain any important information for that particular run or set of runs. Element C_5 enables the customer to receive a plot as well as printed output. The plot shows the temperatures of the liquid storage segments over a span of 1 year.

The next three blocks contain the same meteorological data used in F-CHART for each month with the exception of $\bar{K}_T$. There are twelve values for each block, the first value being that of the month which was chosen as the starting month of the simulation and the last value being that of the ending month of the simulation. For simulations that take place over fewer than twelve months, the number of values in these blocks will correspond to the number of months in the simulation.

The next data block contains a breakdown of the hot water usage over a twenty-four hour period. In order to keep both simulations as identical as possible, the values used are taken directly from a graph in the F-CHART book which represents typical water usage for a family of four over a twenty-four hour cycle.

There are six elements in the next data block. These are for the most part variables that vary with changes in collector area with the exception of tilt. The number of sets of data for this block is equal to C_1. Since the variable that is changed most frequently is collector area, these variables are grouped in one block and the program is given a multiple run capability.

The last data block contains all of the numerous initial conditions, loss factors, efficiencies, costs, etc. that are variables in the simulation. For the most part these remain constant for all of the simulation runs. A more complete explanation of all of the input elements is given on the symbols page. It may be noted here that the input variable GPH_2 is not given a value in the input runs. This is due to the fact that it has not been made variable in the program yet.

SESP INPUT DATA

LOCATION: ______________________

C	C1	C2	C3	C4	C5							
DD	1	2	3	4	5	6	7	8	9	10	11	12
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	13	14	15	16	17	18	19	20	21	22	23	24
	STO	A	CH	CC	TILT	VOL						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2

TABLE A.6

SESP OUTPUT FORMAT

The output listing for the SESP program is arranged in an easily readable form. The first twelve rows give the following information for each month of the simulation. The amount of conventional heat required for space and water for each month is given first. This represents the energy consumption by the residence if there were no solar energy system in operation. The total for the year is also given as it is for all of the data. The next two columns give the corresponding energy consumption of the same residence with the solar system in operation. Note that the summer months are for the most part equal to zero which means that all energy is being supplied by solar. The last column lists the amount of time that the solar pump is on or in other words, when the system is collecting energy. These values are highest in fall and spring.

The next twelve rows are concerned with operating and heating costs of the residence. These costs are dependant upon cost factors specified in the input blocks of the program. All values that are used are realistic. This time the first two columns show the cost of heating the residence and supplying it with hot water. The next two columns show this cost with the solar system in operation. Again, the summer months show values of zero. The last column then shows the cost of operating the solar pump.

The last twelve rows present fractions and savings figures. The first two columns show the fraction of the total heating load that is supplied by solar for space heating and water heating. The third column gives the combined fraction of these two. This is the column that is used in comparing fractions with the F-CHART simulations. The next two columns show the gross savings that have been realized through the use of the solar system for both space and water heating. Finally the last column shows the net savings. The values presented there are the sum of the preceding two columns minus the last column of the preceding twelve rows.

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	18.20	1.73	90.00
FEB	20.14	2.21	13.32	1.66	158.57
MAR	17.16	2.21	8.33	1.54	261.43
APR	9.06	2.21	0.09	1.00	309.43
MAY	3.63	2.21	0.00	0.04	161.57
JUN	0.57	2.21	0.00	0.00	151.14
JUL	0.00	2.21	0.00	0.00	150.00
AUG	0.11	2.21	0.00	0.00	150.00
SEP	1.80	2.21	0.00	0.00	150.00
OCT	7.38	2.21	0.00	0.23	174.57
NOV	15.17	2.21	7.51	1.59	191.43
DEC	22.05	2.21	16.21	1.70	120.00
TOTAL	120.16	26.48	63.65	9.49	2068.14

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	60.07	5.71	2.70
FEB	66.47	7.28	43.96	5.49	4.76
MAR	56.63	7.28	27.48	5.08	7.84
APR	29.89	7.28	0.28	3.30	9.28
MAY	11.98	7.28	0.00	0.13	4.85
JUN	1.89	7.28	0.00	0.00	4.53
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	0.75	5.24
NOV	50.07	7.28	24.78	5.25	5.74
DEC	72.77	7.28	53.49	5.62	3.60
TOTAL	396.53	87.37	210.06	31.33	62.04

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	21.14	21.64	21.19	16.11	1.58	14.98
FEB	33.87	24.56	32.95	22.51	1.79	19.54
MAR	51.48	30.17	49.05	29.15	2.20	23.51
APR	99.05	54.65	90.35	29.61	3.98	24.30
MAY	100.00	98.24	99.33	11.98	7.15	14.29
JUN	100.00	100.00	100.00	1.89	7.28	4.64
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	89.73	97.63	24.34	6.53	25.64
NOV	50.52	27.87	47.64	25.29	2.03	21.58
DEC	26.50	22.88	26.17	19.28	1.67	17.35
TOTAL	47.03	64.14	50.12	186.48	56.04	180.47

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE A.7

APPENDIX B

Worksheets and computer output pertinent to the test procedures and results

THE INITIAL COMPARISON RUNS

COLUMBUS, OHIO

F-CHART

B.1 Collector orientation with reflectance equal to 0.0

B.2 Collector orientation with reflectance equal to 0.3.

B.3 $\tau\alpha$ product with ρ = 0.0.

B.4 $\tau\alpha$ product with ρ = 0.3.

B.5 Heating loads

B.6 X/A and Y/A with $\tau\alpha$ and ρ = 0.0.

B.7 - B.9 Fractions at 25, 50, $100_m{}^2$ with $\tau\alpha$ and ρ = 0.0.

B.10 X/A and Y/A with $\tau\alpha$ and ρ = 0.3.

B.11 - B.13 Fractions at 25, 50, $100_m{}^2$ with $\tau\alpha$ and ρ = 0.3.

B.14 X/A and Y/A without $\tau\alpha$ effect and ρ = 0.0.

B.15 - B.17 Fractions at 25, 50, $100_m{}^2$ without $\tau\alpha$ effect and ρ = 0.0.

B.18 X/A and Y/A without $\tau\alpha$ effect and ρ = 0.3.

B.19 - B.21 Fractions at 25, 50, $100_m{}^2$ without $\tau\alpha$ effect and ρ = 0.3.

SESP

B.22 - B.27 Inputs and corresponding outputs for collector areas of 25, 50, $100_m{}^2$ using SESP (new).

B.28 - B.30 Outputs for collector areas of 25, 50, $100_m{}^2$ using SESP (old).

COLLECTOR ORIENTATION WORKSHEET 1
AVERAGE DAILY RADIATION ON TILTED SURFACES

A. LOCATION COLUMBUS, OHIO B. LATITUDE ϕ = 40^0 C. INCLINATION S = 55^0

D. (1+COS S)/2 .7868 E. GROUND REFLECTANCE ρ = 0.0 F. ρ(1-COS S)/2 = 0.0

G1.	G2.	G3.	G4.	G5.	G6.	G7.	G8.	G9.	G10.
MONTH	$\bar{H}$ J/DAY-M^2	$\bar{K}_T$	$\bar{H}_d/\bar{H}$	$1-\bar{H}_d/\bar{H}$ (1-G4.)	$\bar{R}_b$	BEAM (G5.xG6.)	DIFFUSE (D.xG4.)	$\bar{R}$ (G7.+G8.+F.)	$\bar{H}_T$ J/DAY-M^2 (G9.xG2.)
JAN	5.39 $\times 10^6$	.36	.5108	.4892	2.472	1.2093	.4019	1.6112	8.684 $\times 10^6$
FEB	8.28 $\times 10^6$	.41	.4529	.5471	1.879	1.028	.3563	1.3843	11.462 $\times 10^6$
MAR	12.38 $\times 10^6$	.46	.4036	.5964	1.357	.8093	.3176	1.1269	13.951 $\times 10^6$
APR	16.43 $\times 10^6$	.48	.3858	.6142	.956	.5872	.3035	.8907	14.634 $\times 10^6$
MAY	20.41 $\times 10^6$	.52	.3524	.6476	.729	.4721	.2773	.7494	15.295 $\times 10^6$
JUN	23.50 $\times 10^6$	.57	.3136	.6864	.641	.4401	.2467	.6868	16.140 $\times 10^6$
JUL	22.67 $\times 10^6$	.56	.3212	.6788	.679	.4609	.2527	.7136	16.177 $\times 10^6$
AUG	19.95 $\times 10^6$	.55	.3289	.6711	.851	.5711	.2588	.8299	16.557 $\times 10^6$
SEP	17.65 $\times 10^6$	.59	.2986	.7014	1.180	.8733	.2349	1.1082	19.560 $\times 10^6$
OCT	11.96 $\times 10^6$	.54	.3366	.6634	1.689	1.1205	.2648	1.3853	16.568 $\times 10^6$
NOV	7.44 $\times 10^6$	.46	.4036	.5964	2.298	1.3705	.3176	1.6881	12.559 $\times 10^6$
DEC	5.52 $\times 10^6$	.41	.4529	.5471	2.683	1.4678	.3563	1.8241	10.069 $\times 10^6$

TABLE B.1

COLLECTOR ORIENTATION WORKSHEET I
AVERAGE DAILY RADIATION ON TILTED SURFACES

A. LOCATION COLUMBUS, OHIO B. LATITUDE ϕ = 40^0 C. INCLINATION S = 55^0

D. (1+COS S)/2 .7868 E. GROUND REFLECTANCE ρ = 0.3 F. ρ(1-COS S)/2 = .0640

G1. MONTH	G2. $\overline{H}$ J/DAY-M^2	G3. $\overline{K}_T$	G4. $\overline{H}_d/\overline{H}$	G5. $1-\overline{H}_d/\overline{H}$ (1-G4.)	G6. $\overline{R}_b$	G7. BEAM (G5.×G6.)	G8. DIFFUSE (D.×G4.)	G9. $\overline{R}$ (G7.+G8.+F.)	G10. $\overline{H}_T$ J/DAY-M^2 (G9.×G2.)
JAN	5.39×10^6	.36	.5108	.4892	2.472	1.2093	.4019	1.6752	9.029×10^6
FEB	8.28×10^6	.41	.4529	.5471	1.879	1.028	.3563	1.4483	11.992×10^6
MAR	12.38×10^6	.46	.4036	.5964	1.357	.8093	.3176	1.1909	14.743×10^6
APR	16.43×10^6	.48	.3858	.6142	.956	.5872	.3035	.9547	15.689×10^6
MAY	20.41×10^6	.52	.3524	.6476	.729	.4721	.2773	.8134	16.601×10^6
JUN	23.50×10^6	.57	.3136	.6864	.641	.4401	.2467	.7508	17.644×10^6
JUL	22.67×10^6	.56	.3212	.6788	.679	.4609	.2527	.7776	17.628×10^6
AUG	19.95×10^6	.55	.3289	.6711	.851	.5711	.2588	.8939	17.833×10^6
SEP	17.65×10^6	.59	.2986	.7014	1.180	.8733	.2349	1.1722	20.689×10^6
OCT	11.96×10^6	.54	.3366	.6634	1.689	1.1205	.2648	1.4493	17.334×10^6
NOV	7.44×10^6	.46	.4036	.5964	2.298	1.3705	.3176	1.7521	13.036×10^6
DEC	5.52×10^6	.41	.4529	.5471	2.683	1.4678	.3563	1.8881	10.422×10^6

TABLE B.2

COLLECTOR ORIENTATION WORKSHEET 2
MONHLY AVERAGE TRANSMITTANCE - ABSORPTANCE PRODUCT

H1.	H2.	H3.	H4.	H5.	H6.	H7.	H8.	H9.	H10.
MONTH	$\bar{\theta}_b$	$\tau / \tau_n @ \theta_b$	$\alpha / \alpha_n @ \theta_b$	$\bar{R}_b / \bar{R}$ G6./G9.	BEAM (G5.xH3.x H4.xH5.)	$\tau / \tau_n @ 60^\circ$	DIFFUSE (D.xG4./G9. x.92xH7.)	REFLECTED (F./G9.x.92 xH7.)	$(\overline{\tau\alpha} / \tau\alpha)_n$ (H7.+H8.+H9.)
JAN	36	.98	.99	1.5343	.7282	.87	.1997	0.0	.9279
FEB	36	.98	.99	1.3574	.7205	.87	.2060	0.0	.9265
MAR	39	.98	.99	1.2042	.6968	.87	.2255	0.0	.9223
APR	45	.97	.98	1.0733	.6267	.87	.2728	0.0	.8995
MAY	50	.97	.98	.9728	.5989	.87	.2961	0.0	.8950
JUN	53	.97	.98	.9333	.6090	.87	.2876	0.0	.8966
JUL	51	.97	.98	.9515	.6140	.87	.2835	0.0	.8975
AUG	46	.97	.98	1.0254	.6542	.87	.2496	0.0	.9038
SEP	41	.98	.98	1.0648	.7173	.87	.1690	0.0	.8870
OCT	37	.98	.99	1.2192	.7847	.87	.1530	0.0	.9377
NOV	36	.98	.99	1.3613	.7877	.87	.1506	0.0	.9383
DEC	36	.98	.99	1.4709	.7807	.87	.1564	0.0	.9372

TABLE B.3

COLLECTOR ORIENTATION WORKSHEET 2

MONHLY AVERAGE TRANSMITTANCE - ABSORPTANCE PRODUCT

H1. MONTH	H2. $\bar{\theta}_b$	H3. $\tau / \tau_n @ \theta_b$	H4. $\alpha / \alpha_n @ \theta_b$	H5. $\bar{R}_b / \bar{R}$ G6./G9.	H6. BEAM (G5.xH3.x H4.xH5.)	H7. τ / τ_n @ 60°	H8. DIFFUSE (D.xG4./G9. x.92xH7.)	H9. REFLECTED (F./G9.x.92 xH7.)	H10. $(\overline{\tau\alpha} / \tau\alpha)_n$ (H7.+H8.+H9.)
JAN	36	.98	.99	1.476	.7005	.87	.1920	.0306	.9231
FEB	36	.98	.99	1.297	.6884	.87	.1969	.0354	.9207
MAR	39	.98	.99	1.139	.6591	.87	.2134	.0430	.9155
APR	45	.97	.98	1.001	.6101	.87	.2545	.0537	.9183
MAY	50	.97	.98	.8962	.5517	.87	.2728	.0630	.8875
JUN	53	.97	.98	.8537	.557	.87	.2876	.0746	.9192
JUL	51	.97	.98	.8732	.5634	.87	.2601	.0659	.8894
AUG	46	.97	.98	.9520	.6073	.87	.2317	.0573	.8963
SEP	41	.98	.98	1.007	.6783	.87	.1604	.0437	.8824
OCT	37	.98	.99	1.1654	.7501	.87	.1463	.0353	.9317
NOV	36	.98	.99	1.3116	.7589	.87	.1451	.0292	.9332
DEC	36	.98	.99	1.421	.7543	.87	.1511	.0271	.9325

TABLE B.4

F-CHART WORKSHEET 1
HEATING LOADS

A. $UA = \dfrac{\text{DESIGN SPACE HEATING LOAD [W]}}{\text{DESIGN TEMPERATURE DIFFERENCE [°C]}} =$ 467.0 [W/°C]

B. WATER USAGE = 400.0 [LITERS/DAY] × 4190 × $(T_W - T_M)$ [J/LITER] = 82.1×10^6 [J/DAY]

MONTH	C1. DAYS PER MONTH	C2. HEATING DEGREE DAYS [°C-DAY]	C3. SPACE HEATING LOAD [J/MONTH] (86400)(A. × C2.)	C4. DOMESTIC WATER LOAD [J/MONTH] (B. × C1.)	C5. TOTAL LOAD [J/MONTH] (C3. + C4.)
JAN	31	604	24.371×10^9	2.55×10^9	26.921×10^9
FEB	28	527	21.264×10^9	2.30×10^9	23.564×10^9
MAR	31	449	18.117×10^9	2.55×10^9	20.667×10^9
APR	30	237	9.563×10^9	2.46×10^9	12.023×10^9
MAY	31	95	3.833×10^9	2.55×10^9	20.667×10^9
JUN	30	15	$.605 \times 10^9$	2.46×10^9	12.023×10^9
JUL	31	0.0	0.0	2.55×10^9	2.55×10^9
AUG	31	3	$.121 \times 10^9$	2.55×10^9	2.671×10^9
SEP	30	47	1.896×10^9	2.46×10^9	4.356×10^9
OCT	31	193	7.787×10^9	2.55×10^9	10.337×10^9
NOV	30	397	16.018×10^9	2.46×10^9	18.478×10^9
DEC	31	577	23.281×10^9	2.55×10^9	28.831×10^9
TOT	365	3144	126.86×10^9	30.00×10^9	156.86×10^9

TABLE B-5

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R) =$ 3.64 [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R) =$ .66 [UNITLESS]

	C6.	C7.	C8.	C9.	C10.	C11.
MONTH	SECONDS PER MONTH	(100 - $\bar{T}_a$) [°C]	X/A [$1/M^2$] (C.)x(C7.)x(C6.) / (C5.)	$(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	Y/A [$1/M^2$] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.0366	.9279	8.684 $\times 10^6$	.00612
FEB	2.42×10^6	100	.0374	.9265	11.462 $\times 10^6$	.00833
MAR	2.68×10^6	96	.0453	.9223	13.951 $\times 10^6$	.0127
APR	2.59×10^6	88	.0690	.8995	14.634 $\times 10^6$	.0217
MAY	2.68×10^6	82	.1253	.8950	15.295 $\times 10^6$	.0439
JUN	2.59×10^6	77	.2368	.8966	16.140 $\times 10^6$	.0935
JUL	2.68×10^6	75	.2869	.8975	16.177 $\times 10^6$	.1165
AUG	2.68×10^6	76	.2776	.9038	16.557 $\times 10^6$	.1146
SEP	2.59×10^6	80	.1731	.8870	19.560 $\times 10^6$	.0789
OCT	2.68×10^6	86	.0812	.9377	16.568 $\times 10^6$	.0308
NOV	2.59×10^6	94	.0480	.9383	12.559 $\times 10^6$	.0126
DEC	2.68×10^6	100	.0338	.9372	10.069 $\times 10^6$	.00670

TABLE B.6

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 25.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00612	.915	.153	.094	2.531 $\times 10^9$
FEB	.0374	.00833	.935	.2083	.145	3.417 $\times 10^9$
MAR	.0453	.0127	1.1325	.3175 c	.231	4.774 $\times 10^9$
APR	.0690	.0217	1.725	.5425	.383	4.605 $\times 10^9$
MAY	.1253	.0439	3.1325	1.0975	.677	4.321 $\times 10^9$
JUN	.2368	.0935	5.92	2.3375	1.0	3.065 $\times 10^9$
JUL	.2869	.1165	7.1725	2.9125	1.0	2.55 $\times 10^9$
AUG	.2776	.1146	6.94	2.865	1.0	2.671 $\times 10^9$
SEP	.1731	.0789	4.3275	1.9725	.994	4.330 $\times 10^9$
OCT	.0812	.0308	2.03	.77	.532	5.499 $\times 10^9$
NOV	.0480	.0126	1.2	.315	.225	4.158 $\times 10^9$
DEC	.0338	.00670	.845	.1675	.112	3.229 $\times 10^9$
					TOTAL	45.15 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .288

TABLE B.7

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00612	1.83	.306	.18	4.846 $\times 10^9$
FEB	.0374	.00833	1.87	.4165	.272	6.409 $\times 10^9$
MAR	.0453	.0127	2.265	.635	.422	8.721 $\times 10^9$
APR	.0690	.0217	3.45	1.085	.653	7.851 $\times 10^9$
MAY	.1253	.0439	6.265	2.195	.969	6.185 $\times 10^9$
JUN	.2368	.0935	11.84	4.675	1.0	3.065 $\times 10^9$
JUL	.2869	.1165	14.345	5.825	1.0	2.55 $\times 10^9$
AUG	.2776	.1146	13.88	5.73	1.0	2.671 $\times 10^9$
SEP	.1731	.0789	8.655	3.945	1.0	4.356 $\times 10^9$
OCT	.0812	.0308	4.06	1.54	.848	8.766 $\times 10^9$
NOV	.0480	.0126	2.40	.63	.411	7.594 $\times 10^9$
DEC	.0338	.00670	1.69	.335	.213	6.141 $\times 10^9$
					TOTAL	69.115 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .441

TABLE B.8

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 100.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00612	3.66	.612	.329	8.857 x10^9
FEB	.0374	.00833	3.74	.833	.482	11.358 x10^9
MAR	.0453	.0127	4.53	1.27	.698	14.426 x10^9
APR	.0690	.0217	6.90	2.17	.936	11.254 x10^9
MAY	.1253	.0439	12.53	4.39	1.0	6.383 x10^9
JUN	.2368	.0935	23.68	9.35	1.0	3.065 x10^9
JUL	.2869	.1165	28.69	11.65	1.0	2.55 x10^9
AUG	.2776	.1146	27.76	11.46	1.0	2.671 x10^9
SEP	.1731	.0789	17.31	7.89	1.0	4.356 x10^9
OCT	.0812	.0308	8.12	3.08	1.0	10.337 x10^9
NOV	.0480	.0126	4.8	1.26	.68	12.565 x10^9
DEC	.0338	.00670	3.38	.67	.387	11.158 x10^9
					TOTAL	98.98 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .631

TABLE B.9

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R)$ = 3.64 [W/M²-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R)$ = .66 [UNITLESS]

	C 6.	C 7.	C 8.	C 9.	C 10.	C 11.
MONTH	SECONDS PER MONTH	(100 − $\bar{T}_a$) [°C]	X/A [1/M²] (C.)×(C7.)×(C6.) / (C 5.)	$(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	Y/A [1/M²] (D.)×(C9.)×(C 10.)×(C1.) / (C 5.)
JAN	2.68×10^6	101	.0366	.9231	9.029×10^6	.00633
FEB	2.42×10^6	100	.0374	.9207	11.992×10^6	.00866
MAR	2.68×10^6	96	.0453	.9155	14.743×10^6	.0134
APR	2.59×10^6	88	.0690	.9183	15.689×10^6	.0237
MAY	2.68×10^6	82	.1253	.8875	16.601×10^6	.0472
JUN	2.59×10^6	77	.2368	.9192	17.664×10^6	.1048
JUL	2.68×10^6	75	.2869	.8894	17.628×10^6	.1258
AUG	2.68×10^6	76	.2776	.8963	17.833×10^6	.1224
SEP	2.59×10^6	80	.1731	.8824	20.689×10^6	.0830
OCT	2.68×10^6	86	.0812	.9317	17.334×10^6	.0320
NOV	2.59×10^6	94	.0480	.9332	13.036×10^6	.0130
DEC	2.68×10^6	100	.0338	.9325	10.422×10^6	.0069

TABLE B.10

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 25.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00633	.915	.1583	.099	2.665 $\times 10^9$
FEB	.0374	.00866	.935	.2165	.152	3.582 $\times 10^9$
MAR	.0453	.0134	1.1325	.335	.247	5.105 $\times 10^9$
APR	.0690	.0237	1.725	.5925	.421	5.062 $\times 10^9$
MAY	.1253	.0472	3.1325	1.18	.722	4.609 $\times 10^9$
JUN	.2368	.1048	5.92	2.62	1.0	3.065 $\times 10^9$
JUL	.2869	.1258	7.1725	3.145	1.0	2.55 $\times 10^9$
AUG	.2776	.1224	6.94	3.06	1.0	2.671 $\times 10^9$
SEP	.1731	.0830	4.3275	2.075	1.0	4.356 $\times 10^9$
OCT	.0812	.0320	2.03	.80	.553	5.716 $\times 10^9$
NOV	.0480	.0130	1.2	.325	.234	4.324 $\times 10^9$
DEC	.0338	.0069	.845	.1725	.117	3.373 $\times 10^9$
					TOTAL	47.078 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .30

TABLE B.11

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00633	1.83	.3165	.189	5.088 $\times10^9$
FEB	.0374	.00866	1.87	.433	.286	6.739 $\times10^9$
MAR	.0453	.0134	2.265	.67	.448	9.259 $\times10^9$
APR	.0690	.0237	3.45	1.185	.708	8.512 $\times10^9$
MAY	.1253	.0472	6.265	2.36	1.0	6.383 $\times10^9$
JUN	.2368	.1048	11.84	5.24	1.0	3.065 $\times10^9$
JUL	.2869	.1258	14.345	6.29	1.0	2.55 $\times10^9$
AUG	.2776	.1224	13.88	6.12	1.0	2.671 $\times10^9$
SEP	.1731	.0830	8.655	4.15	1.0	4.356 $\times10^9$
OCT	.0812	.0320	4.06	1.6	.873	9.024 $\times10^9$
NOV	.0480	.0130	2.4	.65	.426	7.872 $\times10^9$
DEC	.0338	.0069	1.69	.345	.222	6.40 $\times10^9$
					TOTAL	71.919 $\times10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .458

TABLE B.12

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 100.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00633	3.66	.633	.345	9.288 x10^9
FEB	.0374	.00866	3.74	.866	.503	11.853 x10^9
MAR	.0453	.0134	4.53	1.34	.733	15.149 x10^9
APR	.0690	.0237	6.9	2.37	.986	11.855 x10^9
MAY	.1253	.0472	12.53	4.72	1.0	6.383 x10^9
JUN	.2368	.1048	23.68	10.48	1.0	3.065 x10^9
JUL	.2869	.1258	28.69	12.58	1.0	2.55 x10^9
AUG	.2776	.1224	27.76	12.24	1.0	2.671 x10^9
SEP	.1731	.0830	17.31	8.3	1.0	4.356 x10^9
OCT	.0812	.0320	8.12	3.2	1.0	10.337 x10^9
NOV	.0480	.0130	4.8	1.3	.70	12.935 x10^9
DEC	.0338	.00690	3.38	.69	.401	11.561 x10^9
					TOTAL	102.003 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .65

TABLE B.13

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R) =$ 3.64 [W/M^2-°C]

D. $F_R(\tau\alpha)_n (F'_R/F_R) =$ .66 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [$1/M^2$] $\frac{(C.)\times(C7.)\times(C6.)}{(C5.)}$	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [$1/M^2$] $\frac{(D.)\times(C9.)\times(C10.)\times(C1.)}{(C5.)}$
JAN	2.68×10^6	101	.0366	1.00	8.684×10^6	.0066
FEB	2.42×10^6	100	.0374	1.00	11.462×10^6	.0090
MAR	2.68×10^6	96	.0453	1.00	13.951×10^6	.0138
APR	2.59×10^6	88	.0690	1.00	14.634×10^6	.0241
MAY	2.68×10^6	82	.1253	1.00	15.295×10^6	.0490
JUN	2.59×10^6	77	.2368	1.00	16.140×10^6	.1043
JUL	2.68×10^6	75	.2869	1.00	16.117×10^6	.1298
AUG	2.68×10^6	76	.2776	1.00	16.557×10^6	.1268
SEP	2.59×10^6	80	.1731	1.00	19.560×10^6	.0889
OCT	2.68×10^6	86	.0812	1.00	16.568×10^6	.0328
NOV	2.59×10^6	94	.0480	1.00	12.559×10^6	.0135
DEC	2.68×10^6	100	.0338	1.00	10.069×10^6	.00715

TABLE B.14

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 25.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.0066	.915	.165	.105	2.827 $\times10^9$
FEB	.0374	.0090	.935	.225	.16	3.77 $\times10^9$
MAR	.0453	.0138	1.1325	.345	.255	5.27 $\times10^9$
APR	.0690	.0241	1.725	.6025	.429	5.158 $\times10^9$
MAY	.1253	.0490	3.1325	1.225	.746	4.762 $\times10^9$
JUN	.2368	.1043	5.92	2.6075	1.0	3.065 $\times10^9$
JUL	.2869	.1298	7.1725	3.245	1.0	2.55 $\times10^9$
AUG	.2776	.1268	6.94	3.17	1.0	2.671 $\times10^9$
SEP	.1731	.0889	4.3275	2.2225	1.0	4.356 $\times10^9$
OCT	.0812	.0328	2.03	.82	.566	5.851 $\times10^9$
NOV	.0480	.0135	1.2	.3375	.245	4.527 $\times10^9$
DEC	.0338	.00715	.845	.1788	.123	3.546 $\times10^9$
					TOTAL	48.353 $\times10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, $C5_H$) = .308

TABLE B.15

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.0066	1.83	.33	.201	5.411 x10^9
FEB	.0374	.0090	1.87	.45	.30	7.069 x10^9
MAR	.0453	.0138	2.265	.69	.462	9.548 x10^9
APR	.0690	.0241	3145	1.205	.719	8.645 x10^9
MAY	.1253	.0490	6.265	2.45	1.0	6.383 x10^9
JUN	.2368	.1043	11.84	5.215	1.0	3.065 x10^9
JUL	.2869	.1298	14.345	6.49	1.0	2.55 x10^9
AUG	.2776	.1268	13.88	6.34	1.0	2.671 x10^9
SEP	.1731	.0889	8.655	4.445	1.0	4.356 x10^9
OCT	.0812	.0328	4.06	1.64	.889	9.19 x10^9
NOV	.0480	.0135	2.4	.675	.444	8.204 x10^9
DEC	.0338	.00715	1.69	.3576	.233	6.718 x10^9
					TOTAL	73.81 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .471

TABLE B.16

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 100.0 $[M^2]$

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.0066	3.66	.66	.365	9.826 x10^9
FEB	.0374	.0090	3.74	.9	.525	12.371 x10^9
MAR	.0453	.0138	4.53	1.38	.572	15.542 x10^9
APR	.0690	.0241	6.9	2.41	.995	11.963 x10^9
MAY	.1253	.0490	12.53	4.9	1.0	6.383 x10^9
JUN	.2368	.1043	23.68	10.43	1.0	3.065 x10^9
JUL	.2869	.1298	28.69	12.98	1.0	2.55 x10^9
AUG	.2776	.1268	27.76	12.68	1.0	2.671 x10^9
SEP	.1731	.0889	17.31	8.89	1.0	4.356 x10^9
OCT	.0812	.0328	8.12	3.28	1.0	10.337 x10^9
NOV	.0480	.0135	4.8	1.35	.725	13.397 x10^9
DEC	.0338	.00715	3.37	.7152	.419	12.08 x10^9
					TOTAL	104.541 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .666

TABLE B.17

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R) =$ 3.64 [W/M²-°C]

D. $F_R (\tau\alpha)_n (F'_R/F_R) =$ .66 [UNITLESS]

	C6.	C7.	C8.	C9.	C10.	C11.
MONTH	SECONDS PER MONTH	(100-$\bar{T}_a$) [°C]	X/A [1/M²] (C.)x(C7.)x(C6.) / (C5.)	$(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	Y/A [1/M²] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.0366	1.00	9.029 $\times 10^6$	.00686
FEB	2.42×10^6	100	.0374	1.00	11.992 $\times 10^6$	.00940
MAR	2.68×10^6	96	.0453	1.00	14.743 $\times 10^6$	.0146
APR	2.59×10^6	88	.0690	1.00	15.589 $\times 10^6$	.0258
MAY	2.68×10^6	82	.1253	1.00	16.601 $\times 10^6$	.0532
JUN	2.59×10^6	77	.2368	1.00	17.644 $\times 10^6$	.1140
JUL	2.68×10^6	75	.2869	1.00	17.628 $\times 10^6$	.1414
AUG	2.68×10^6	76	.2776	1.00	17.833 $\times 10^6$	.1366
SEP	2.59×10^6	80	.1731	1.00	20.689 $\times 10^6$	.0940
OCT	2.68×10^6	86	.0812	1.00	17.334 $\times 10^6$	.0343
NOV	2.59×10^6	94	.0480	1.00	13.036 $\times 10^6$	.0140
DEC	2.68×10^6	100	.0338	1.00	10.422 $\times 10^6$	.00740

TABLE B.18

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 25.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.915	.1715	.111	2.988 $x10^9$
FEB	.0374	.00940	.935	.235	.169	3.982 $x10^9$
MAR	.0453	.0146	1.1325	.365	.335	6.923 $x10^9$
APR	.0690	.0258	1.725	.645	.461	5.543 $x10^9$
MAY	.1253	.0532	3.1325	1.33	.80	5.106 $x10^9$
JUN	.2368	.1140	5.92	2.85	1.0	3.065 $x10^9$
JUL	.2869	.1414	7.1725	3.538	1.0	2.55 $x10^9$
AUG	.2776	.1366	6.94	3.415	1.0	2.671 $x10^9$
SEP	.1731	.0940	4.3275	2.35	1.0	4.356 $x10^9$
OCT	.0812	.0343	2.03	.8575	.591	6.109 $x10^9$
NOV	.0480	.0140	1.2	.35	.256	4.730 $x10^9$
DEC	.0338	.00740	.845	.185	.128	3.69 $x10^9$
					TOTAL	51.713 $x10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .33

TABLE B.19

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	1.83	.343	.212	5.707 $\times 10^9$
FEB	.0374	.00940	1.87	.47	.316	7.446 $\times 10^9$
MAR	.0453	.0146	2.265	.73	.491	10.147 $\times 10^9$
APR	.0690	.0258	3.45	1.29	.763	9.174 $\times 10^9$
MAY	.1253	.0532	6.265	2.66	1.0	6.383 $\times 10^9$
JUN	.2368	.1140	11.84	5.7	1.0	3.065 $\times 10^9$
JUL	.2869	.1414	14.345	7.07	1.0	2.55 $\times 10^9$
AUG	.2776	.1366	13.88	6.83	1.0	2.671 $\times 10^9$
SEP	.1731	.0940	8.655	4.7	1.0	4.356 $\times 10^9$
OCT	.0812	.0343	4.06	1.715	.918	9.489 $\times 10^9$
NOV	.0480	.0140	2.4	.70	.462	8.537 $\times 10^9$
DEC	.0338	.00740	1.69	.37	.244	7.035 $\times 10^9$
					TOTAL	76.56 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .488

TABLE B.20

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 100.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	3.66	.686	.384	10.338 x10^9
FEB	.0374	.00940	3.74	.94	.551	12.984 x10^9
MAR	.0453	.0146	4.53	1.46	.789	16.306 x10^9
APR	.0690	.0258	6.9	2.58	1.0	12.023 x10^9
MAY	.1253	.0532	12.53	5.32	1.0	6.383 x10^9
JUN	.2368	.1140	23.68	11.4	1.0	3.065 x10^9
JUL	.2869	.1414	28.69	14.14	1.0	2.55 x10^9
AUG	.2776	.1366	27.76	13.66	1.0	2.671 x10^9
SEP	.1731	.0940	17.31	9.4	1.0	4.356 x10^9
OCT	.0812	.0343	8.12	3.43	1.0	10.337 x10^9
NOV	.0480	.0140	4.8	1.4	.749	13.84 x10^9
DEC	.0338	.00740	3.38	.74	.437	12.599 x10^9
					TOTAL	107.452 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .685

TABLE B.21

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	4133.9	269.1	310.6	330.5	55.0	495.4						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	-----

TABLE B.22

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	20.71	1.78	90.00
FEB	20.14	2.21	16.63	1.75	210.00
MAR	17.16	2.21	12.46	1.68	300.00
APR	9.06	2.21	3.73	1.48	338.57
MAY	3.63	2.21	0.03	0.69	309.43
JUN	0.57	2.21	0.00	0.01	187.86
JUL	0.00	2.21	0.00	0.00	161.29
AUG	0.11	2.21	0.00	0.00	158.57
SEP	1.80	2.21	0.00	0.00	179.57
OCT	7.38	2.21	1.88	1.26	256.57
NOV	15.17	2.21	11.37	1.73	240.00
DEC	22.05	2.21	19.17	1.77	128.57
TOTAL	120.16	26.48	85.98	12.16	2560.42

MONTH	COST OF HEAT W/O SOLAR($) SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	OPERATING COST($)
JAN	76.18	7.28	68.36	5.88	2.70
FEB	66.47	7.28	54.89	5.77	6.30
MAR	56.63	7.28	41.11	5.54	9.00
APR	29.89	7.28	12.30	4.89	10.16
MAY	11.98	7.28	0.11	2.28	9.28
JUN	1.89	7.28	0.00	0.04	5.64
JUL	0.00	7.28	0.00	0.00	4.84
AUG	0.38	7.28	0.00	0.00	4.76
SEP	5.93	7.28	0.00	0.00	5.39
OCT	24.34	7.28	6.22	4.16	7.70
NOV	50.07	7.28	37.52	5.71	7.20
DEC	72.77	7.28	63.25	5.85	3.86
TOTAL	396.53	87.37	283.75	40.12	76.81

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	10.27	19.25	11.05	7.82	1.40	6.52
FEB	17.42	20.79	17.75	11.58	1.51	6.79
MAR	27.41	23.85	27.00	15.52	1.74	8.26
APR	58.85	32.87	53.76	17.59	2.39	9.83
MAY	99.10	68.73	87.62	11.87	5.00	7.60
JUN	100.00	99.50	99.60	1.89	7.24	3.50
JUL	100.00	100.00	100.00	0.00	7.28	2.44
AUG	100.00	100.00	100.00	0.38	7.28	2.90
SEP	100.00	100.00	100.00	5.93	7.28	7.82
OCT	74.47	42.83	67.18	18.13	3.12	13.55
NOV	25.07	21.51	24.62	12.55	1.57	6.92
DEC	13.09	19.63	13.68	9.52	1.43	7.09
TOTAL	28.44	54.08	33.07	112.79	47.25	83.22

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.23

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	55.0	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.24

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	18.20	1.73	90.00
FEB	20.14	2.21	13.32	1.66	158.57
MAR	17.16	2.21	8.33	1.54	261.43
APR	9.06	2.21	0.09	1.00	309.43
MAY	3.63	2.21	0.00	0.04	161.57
JUN	0.57	2.21	0.00	0.00	151.14
JUL	0.00	2.21	0.00	0.00	150.00
AUG	0.11	2.21	0.00	0.00	150.00
SEP	1.80	2.21	0.00	0.00	150.00
OCT	7.38	2.21	0.00	0.23	174.57
NOV	15.17	2.21	7.51	1.59	191.43
DEC	22.05	2.21	16.21	1.70	120.00
TOTAL	120.16	26.48	63.65	9.49	2068.14

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	60.07	5.71	2.70
FEB	66.47	7.28	43.96	5.49	4.76
MAR	56.63	7.28	27.48	5.08	7.84
APR	29.89	7.28	0.28	3.30	9.28
MAY	11.98	7.28	0.00	0.13	4.85
JUN	1.89	7.28	0.00	0.00	4.53
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	0.75	5.24
NOV	50.07	7.28	24.78	5.25	5.74
DEC	72.77	7.28	53.49	5.62	3.60
TOTAL	396.53	87.37	210.06	31.33	62.04

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	21.14	21.64	21.19	16.11	1.58	14.98
FEB	33.87	24.56	32.95	22.51	1.79	19.54
MAR	51.48	30.17	49.05	29.15	2.20	23.51
APR	99.05	54.65	90.35	29.61	3.98	24.30
MAY	100.00	98.24	99.33	11.98	7.15	14.29
JUN	100.00	100.00	100.00	1.89	7.28	4.64
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	89.73	97.63	24.34	6.53	25.64
NOV	50.52	27.87	47.64	25.29	2.03	21.58
DEC	26.50	22.88	26.17	19.28	1.67	17.35
TOTAL	47.03	64.14	50.12	186.48	56.04	180.47

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.25

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

	C1	C2	C3	C4	C5
C	1.0	1.0	12.0	1.0	0.0

	1	2	3	4	5	6	7	8	9	10	11	12
DD	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0

	1	2	3	4	5	6	7	8	9	10	11	12
GAL	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7

STO	A	CH	CC	TILT	VOL
16535.5	1076.4	1240.8	1322.0	55.0	1981.5

UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.	51.8	21232.9	3.3
$W	**RLAT**	**TI**	**TLIM**	**$FAN**	**UATOP**	**UABOT**	**UASEG**	**ETA**	**GPH**	**ETA2**	**GPH2**
3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	-----

TABLE B.26

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	HEAT W/O SOLAR(MEGABTU) WATER	HEAT W/SOLAR(MEGABTU) SPACE	HEAT W/SOLAR(MEGABTU) WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	13.77	1.66	90.00
FEB	20.14	2.21	7.42	1.50	128.71
MAR	17.16	2.21	1.27	1.25	215.57
APR	9.06	2.21	0.00	0.08	159.71
MAY	3.63	2.21	0.00	0.00	122.00
JUN	0.57	2.21	0.00	0.00	125.43
JUL	0.00	2.21	0.00	0.00	120.00
AUG	0.11	2.21	0.00	0.00	120.00
SEP	1.80	2.21	0.00	0.00	120.14
OCT	7.38	2.21	0.00	0.00	145.00
NOV	15.17	2.21	0.77	1.15	157.57
DEC	22.05	2.21	10.87	1.60	120.00
TOTAL	120.16	26.48	34.10	7.24	1624.14

MONTH	COST OF HEAT W/O SOLAR($) SPACE	COST OF HEAT W/O SOLAR($) WATER	COST OF HEAT W/SOLAR($) SPACE	COST OF HEAT W/SOLAR($) WATER	OPERATING COST($)
JAN	76.18	7.28	45.45	5.46	2.70
FEB	66.47	7.28	24.50	4.96	3.86
MAR	56.63	7.28	4.19	4.11	6.47
APR	29.89	7.28	0.00	0.28	4.79
MAY	11.98	7.28	0.00	0.00	3.66
JUN	1.89	7.28	0.00	0.00	3.76
JUL	0.00	7.28	0.00	0.00	3.60
AUG	0.38	7.28	0.00	0.00	3.60
SEP	5.93	7.28	0.00	0.00	3.60
OCT	24.34	7.28	0.00	0.00	4.35
NOV	50.07	7.28	2.53	3.79	4.73
DEC	72.77	7.28	35.87	5.27	3.60
TOTAL	396.53	87.37	112.54	23.88	48.72

MONTH	SOLAR FRACTION SPACE	SOLAR FRACTION WATER	SOLAR FRACTION COMBINED	GROSS SAVINGS($) SPACE	GROSS SAVINGS($) WATER	NET SAVINGS($)
JAN	40.33	24.97	38.99	30.73	1.82	29.84
FEB	63.14	31.86	60.06	41.97	2.32	40.43
MAR	92.59	43.52	87.00	52.44	3.17	49.14
APR	100.00	96.18	99.25	29.89	7.00	32.10
MAY	100.00	100.00	100.00	11.98	7.28	15.60
JUN	100.00	100.00	100.00	1.89	7.28	5.41
JUL	100.00	100.00	100.00	0.00	7.28	3.68
AUG	100.00	100.00	100.00	0.38	7.28	4.06
SEP	100.00	100.00	100.00	5.93	7.28	9.60
OCT	100.00	100.00	100.00	24.34	7.28	27.27
NOV	94.95	47.93	88.98	47.54	3.49	46.31
DEC	50.71	27.60	48.61	36.90	2.01	35.31
TOTAL	71.62	72.67	71.81	283.99	63.49	298.76

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.27

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.084	2.2063	20.644	1.7965	120.00
FEB	20.142	2.2063	16.522	1.7662	210.00
MAR	17.160	2.2063	12.332	1.6873	300.00
APR	9.0580	2.2063	3.6728	1.4340	347.14
MAY	3.6308	2.2063	0.32419E-01	0.68848	306.28
JUN	0.57329	2.2063	0.00000	0.11076E-01	187.86
JUL	0.21233E-04	2.2063	0.00000	0.00000	161.29
AUG	0.11466	2.2063	0.00000	0.00000	158.57
SEP	1.7963	2.2063	0.00000	0.00000	179.57
OCT	7.3763	2.2063	1.8723	1.2316	264.57
NOV	15.173	2.2063	11.266	1.7402	240.00
DEC	22.053	2.2063	19.090	1.7756	180.00
TOTAL	120.16	26.475	85.432	12.131	2655.3

MONTH	COST OF HEAT W/O SOLAR($) SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	COST OF OPERATING SYSTEM($)
JAN	76.18	7.28	68.13	5.93	3.60
FEB	66.47	7.28	54.52	5.83	6.30
MAR	56.63	7.28	40.70	5.57	9.00
APR	29.89	7.28	12.12	4.73	10.41
MAY	11.98	7.28	0.11	2.27	9.19
JUN	1.89	7.28	0.00	0.04	5.64
JUL	0.00	7.28	0.00	0.00	4.84
AUG	0.38	7.28	0.00	0.00	4.76
SEP	5.93	7.28	0.00	0.00	5.39
OCT	24.34	7.28	6.18	4.06	7.94
NOV	50.07	7.28	37.18	5.74	7.20
DEC	72.77	7.28	63.00	5.86	5.40
TOTAL	396.53	87.368	281.93	40.032	79.658

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	10.57	18.57	11.27	8.05	1.35	5.81
FEB	17.97	19.94	18.16	11.94	1.45	7.10
MAR	28.13	23.52	27.61	15.93	1.71	8.65
APR	59.45	35.00	54.66	17.77	2.55	9.91
MAY	99.11	68.79	87.65	11.87	5.01	7.69
JUN	100.00	99.50	99.60	1.89	7.24	3.50
JUL	100.00	100.00	100.00	0.00	7.28	2.44
AUG	100.00	100.00	100.00	0.38	7.28	2.90
SEP	100.00	100.00	100.00	5.93	7.28	7.82
OCT	74.62	44.18	67.61	18.16	3.22	13.44
NOV	25.75	21.12	25.17	12.89	1.54	7.23
DEC	13.43	19.52	13.99	9.78	1.42	5.80
TOTAL	28.90	54.18	33.47	114.61	47.34	82.28

FUEL RATES($/BTU DELIVERED) SPACE 0.33000E-05 WATER 0.33000E-05 FAN ON-TIME RATE($/HR) 0.30000E-01

TABLE B.28

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.084	2.2063	18.127	1.7407	98.571
FEB	20.142	2.2063	13.170	1.6834	180.00
MAR	17.160	2.2063	8.2404	1.5096	265.71
APR	9.0580	2.2063	0.86880E-01	0.99840	309.57
MAY	3.6308	2.2063	0.00000	0.38497E-01	161.57
JUN	0.57329	2.2063	0.00000	0.00000	151.14
JUL	0.21233E-04	2.2063	0.00000	0.00000	150.00
AUG	0.11466	2.2063	0.00000	0.00000	150.00
SEP	1.7963	2.2063	0.00000	0.00000	150.00
OCT	7.3763	2.2063	0.00000	0.22428	174.57
NOV	15.173	2.2063	7.3744	1.6071	199.71
DEC	22.053	2.2063	16.121	1.7167	137.14
TOTAL	120.16	26.475	63.120	9.5186	2128.0

MONTH	COST OF HEAT W/O SOLAR($) SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	COST OF OPERATING SYSTEM($)
JAN	76.18	7.28	59.82	5.74	2.96
FEB	66.47	7.28	43.46	5.56	5.40
MAR	56.63	7.28	27.19	4.98	7.97
APR	29.89	7.28	0.29	3.29	9.29
MAY	11.98	7.28	0.00	0.13	4.85
JUN	1.89	7.28	0.00	0.00	4.53
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	0.74	5.24
NOV	50.07	7.28	24.34	5.30	5.99
DEC	72.77	7.28	53.20	5.67	4.11
TOTAL	396.53	87.368	208.30	31.411	63.840

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	21.47	21.10	21.44	16.36	1.54	14.94
FEB	34.61	23.70	33.53	23.00	1.73	19.33
MAR	51.98	31.58	49.66	29.44	2.30	23.76
APR	99.04	54.75	90.37	29.60	3.99	24.30
MAY	100.00	98.26	99.34	11.98	7.15	14.29
JUN	100.00	100.00	100.00	1.89	7.28	4.64
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	89.83	97.66	24.34	6.54	25.65
NOV	51.40	27.16	48.32	25.74	1.98	21.72
DEC	26.90	22.19	26.47	19.57	1.62	17.08
TOTAL	47.47	64.05	50.46	188.24	55.96	180.35

FUEL RATES($/BTU DELIVERED) SPACE 0.33000E-05 WATER 0.33000E-05 FAN ON-TIME RATE($/HR) 0.30000E-01

TABLE B.29

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.084	2.2063	13.672	1.6747	90.000
FEB	20.142	2.2063	7.3241	1.4872	132.86
MAR	17.160	2.2063	1.0307	1.2684	240.00
APR	9.0580	2.2063	0.00000	0.85799E-01	159.71
MAY	3.6308	2.2063	0.00000	0.00000	122.00
JUN	0.57329	2.2063	0.00000	0.00000	125.43
JUL	0.21233E-04	2.2063	0.00000	0.00000	120.00
AUG	0.11466	2.2063	0.00000	0.00000	120.00
SEP	1.7963	2.2063	0.00000	0.00000	120.14
OCT	7.3763	2.2063	0.00000	0.00000	145.00
NOV	15.173	2.2063	0.12877	1.1712	166.57
DEC	22.053	2.2063	10.728	1.6222	124.29
TOTAL	120.16	26.475	32.884	7.3094	1666.0

MONTH	COST OF HEAT W/O SOLAR($) SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	COST OF OPERATING SYSTEM
JAN	76.18	7.28	45.12	5.53	2.70
FEB	66.47	7.28	24.17	4.91	3.99
MAR	56.63	7.28	3.40	4.19	7.20
APR	29.89	7.28	0.00	0.28	4.79
MAY	11.98	7.28	0.00	0.00	3.66
JUN	1.89	7.28	0.00	0.00	3.76
JUL	0.00	7.28	0.00	0.00	3.60
AUG	0.38	7.28	0.00	0.00	3.60
SEP	5.93	7.28	0.00	0.00	3.60
OCT	24.34	7.28	0.00	0.00	4.35
NOV	50.07	7.28	0.42	3.86	5.00
DEC	72.77	7.28	35.40	5.35	3.73
TOTAL	396.53	87.368	108.52	24.121	49.980

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	40.77	24.09	39.32	31.06	1.75	30.11
FEB	63.64	32.59	60.57	42.30	2.37	40.68
MAR	93.99	42.51	88.13	53.23	3.10	49.12
APR	100.00	96.11	99.24	29.89	7.00	32.10
MAY	100.00	100.00	100.00	11.98	7.28	15.60
JUN	100.00	100.00	100.00	1.89	7.28	5.41
JUL	100.00	100.00	100.00	0.00	7.28	3.68
AUG	100.00	100.00	100.00	0.38	7.28	4.06
SEP	100.00	100.00	100.00	5.93	7.28	9.60
OCT	100.00	100.00	100.00	24.34	7.28	27.27
NOV	99.15	46.92	92.52	49.65	3.42	48.06
DEC	51.35	26.47	49.09	37.37	1.93	35.57
TOTAL	72.63	72.39	72.59	288.02	63.25	301.28

FUEL RATES($/BTU DELIVERED) SPACE 0.33000E-05 WATER 0.33000E-05 FAN ON-TIME RATE($/HR) 0.30000E-01

TABLE B.30

SMALL COLLECTOR AREAS

COLUMBUS, OHIO

F-CHART

B.31 - B.36 Fractions at 1.0, 2.0, 4.0, 6.0, 8.0, 10.0m^2 without $\tau\alpha$ effect and = 0.3.

SESP

B.37 - B.48 Inputs and corresponding outputs for collector areas of 1.0, 2.0, 4.0, 6.0, 8.0, 10.0m^2 using SESP (new).

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 1.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)x(F.)	C13. CORRECTED Y/A (C11.)x(G.)	C14. X (C12.)x(E.)	C15. Y (C13.)x(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.0366	.00686	.0047	.1265 x10^9
FEB	.0374	.00940	.0374	.0094	.0072	.1619 x10^9
MAR	.0453	.0146	.0453	.0146	.012	.248 x10^9
APR	.0690	.0258	.0690	.0258	.022	.2465 x10^9
MAY	.1253	.0532	.1253	.0532	.046	.2936 x10^9
JUN	.2368	.1140	.2368	.1140	.099	.3034 x10^9
JUL	.2869	.1414	.2869	.1414	.122	.3111 x10^9
AUG	.2776	.1366	.2776	.1366	.1181	.3154 x10^9
SEP	.1731	.0940	.1731	.0940	.0834	.3633 x10^9
OCT	.0812	.0343	.0812	.0343	.0297	.3070 x10^9
NOV	.0480	.0140	.0480	.0140	.0112	.207 x10^9
DEC	.0338	.00740	.0338	.0074	.0054	.1557 x10^9
					TOTAL	3.0652 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .0195

TABLE B.31

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 2.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_o) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_o) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.0732	.0137	.0093	.2504 $\times 10^9$
FEB	.0374	.00940	.0748	.0188	.0144	.3393 $\times 10^9$
MAR	.0453	.0146	.0906	.0292	.024	.496 $\times 10^9$
APR	.0690	.0258	.138	.0516	.0435	.523 $\times 10^9$
MAY	.1253	.0532	.2506	.1064	.0906	.5783 $\times 10^9$
JUN	.2368	.1140	.4736	.228	.1918	.5879 $\times 10^9$
JUL	.2869	.1414	.5738	.2828	.2352	.5998 $\times 10^9$
AUG	.2776	.1366	.5552	.2732	.2277	.6082 $\times 10^9$
SEP	.1731	.0940	.3462	.188	.1626	.7083 $\times 10^9$
OCT	.0812	.0343	.1624	.0686	.0589	.6088 $\times 10^9$
NOV	.0480	.0140	.096	.028	.0224	.4139 $\times 10^9$
DEC	.0338	.00740	.0676	.0148	.0108	.3114 $\times 10^9$
					TOTAL	6.0253 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .0384

TABLE B.32

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 4.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.1464	.0274	.0185	.498 x10^9
FEB	.0374	.00940	.1496	.0376	.0287	.6763 x10^9
MAR	.0453	.0146	.1812	.0584	.0287	.6763 x10^9
APR	.0690	.0258	.276	.1052	.0858	1.0316 x10^9
MAY	.1253	.0532	.5012	.2128	.1760	1.1234 x10^9
JUN	.2368	.1140	.9472	.4560	.3604	1.1046 x10^9
JUL	.2869	.1414	1.1476	.5656	.4353	1.110 x10^9
AUG	.2776	.1366	1.1104	.5464	.4227	1.129 x10^9
SEP	.1731	.0940	.6924	.3760	.3093	1.3473 x10^9
OCT	.0812	.0343	.3248	.1372	.1157	1.196 x10^9
NOV	.0480	.0140	.1920	.056	.0444	.8204 x10^9
DEC	.0338	.00740	.1352	.0296	.0215	.6199 x10^9
					TOTAL	11.6382 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .0742

TABLE B.33

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 6.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.2196	.0411	.0277	.7457 x10^9
FEB	.0374	.00940	.2244	.0564	.0428	1.0085 x10^9
MAR	.0453	.0146	.2718	.0876	.0707	1.4612 x10^9
APR	.0690	.0258	.4140	.1548	.1269	1.5257 x10^9
MAY	.1253	.0532	.7518	.3192	.2563	1.636 x10^9
JUN	.2368	.1140	1.4208	.684	.5074	1.5552 x10^9
JUL	.2869	.1414	1.7214	.8484	.6032	1.5382 x10^9
AUG	.2776	.1366	1.6656	.8196	.5874	1.5689 x10^9
SEP	.1731	.0940	1.0386	.564	.4407	1.9197 x10^9
OCT	.0812	.0343	.4872	.2058	.1703	1.7604 x10^9
NOV	.0480	.0140	.288	.084	.0661	1.2214 x10^9
DEC	.0338	.00740	.2028	.0444	.0321	.9255 x10^9
					TOTAL	16.8664 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .1075

TABLE B.34

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 8.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.2928	.0548	.0368	.9907 x10^9
FEB	.0374	.00940	.2992	.0752	.0567	1.3361 x10^9
MAR	.0453	.0146	.3624	.1168	.0936	1.9344 x10^9
APR	.0690	.0258	.552	.2064	.1668	2.0054 x10^9
MAY	.1253	.0532	1.0024	.4256	.3319	2.1185 x10^9
JUN	.2368	.1140	1.8944	.912	.6343	1.9441 x10^9
JUL	.2869	.1414	2.2952	1.1312	.7419	1.8918 x10^9
AUG	.2776	.1366	2.2208	1.0928	.7245	1.9351 x10^9
SEP	.1731	.0940	1.3848	.752	.5578	2.4298 x10^9
OCT	.0812	.0343	.6496	.2744	.2229	2.3041 x10^9
NOV	.0480	.0140	.384	.112	.0875	1.6168 x10^9
DEC	.0338	.00740	.2704	.0592	.0426	1.2282 x10^9
					TOTAL	21.735 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .1386

TABLE B.35

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 10.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_o) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_o) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	.366	.0686	.0458	1.233 $\times 10^9$
FEB	.0374	.00940	.374	.094	.0705	1.6613 $\times 10^9$
MAR	.0453	.0146	.4530	.146	.1160	2.3974 $\times 10^9$
APR	.0690	.0258	.69	.258	.2056	2.4719 $\times 10^9$
MAY	.1253	.0532	1.253	.532	.4027	2.5704 $\times 10^9$
JUN	.2368	.1140	2.368	1.14	.7427	2.2764 $\times 10^9$
JUL	.2869	.1414	2.869	1.414	.8543	2.1785 $\times 10^9$
AUG	.2776	.1366	2.776	1.366	.8367	2.2348 $\times 10^9$
SEP	.1731	.0940	1.731	.940	.6615	2.8815 $\times 10^9$
OCT	.0812	.0343	.812	.343	.2734	2.8261 $\times 10^9$
NOV	.0480	.0140	.480	.140	.1085	2.0049 $\times 10^9$
DEC	.0338	.00740	.338	.074	.053	1.5280 $\times 10^9$
					TOTAL	26.2642 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .1674

TABLE B.36

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1 1.0	C2 1.0	C3 12.0	C4 1.0	C5 0.0							
DD	1 1087.2	2 948.6	3 808.2	4 426.6	5 171.0	6 27.0	7 .001	8 5.4	9 84.6	10 347.4	11 714.6	12 1038.6
HBAR	1 474.6	2 729.0	3 1090.0	4 1446.7	5 1797.1	6 2069.2	7 1996.0	8 1756.6	9 1554.0	10 1053.0	11 655.0	12 486.0
TAMB	1 30.2	2 32.0	3 39.2	4 51.8	5 60.8	6 69.8	7 73.4	8 71.6	9 64.4	10 53.6	11 41.0	12 32.0
GAL	1 2.0	2 0.0	3 0.0	4 0.0	5 0.0	6 0.0	7 1.4	8 4.8	9 7.3	10 8.4	11 6.9	12 4.6
	13 3.5	14 5.3	15 2.5	16 2.3	17 2.0	18 3.8	19 6.9	20 11.8	21 9.6	22 6.9	23 5.4	24 4.7
	STO 165.36	A 10.76	CH 12.41	CC 13.22	TILT 55.0	VOL 19.82						
	UA 4262.5	XM .66	B .68	AZ 0.0	DENH 8.89	DENC 8.34	SPHTH .8	SPHTC 1.0	THOT 140.0	TCOLD 51.8	RLOSS 21232.9	$S 3.3
	$W 3.3	RLAT 40.0	TI 70.0	TLIM 68.0	$FAN .03	UATOP 1.41	UABOT 1.41	UASEG .141	ETA .7	GPH 480.0	ETA2 .6	GPH2 ------

TABLE B.37

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	23.62	1.80	167.14
FEB	20.14	2.21	20.63	1.80	240.00
MAR	17.16	2.21	17.58	1.80	325.71
APR	9.06	2.21	9.42	1.80	390.00
MAY	3.63	2.21	3.94	1.80	535.71
JUN	0.57	2.21	0.84	1.80	719.99
JUL	0.00	2.21	0.30	1.73	719.99
AUG	0.11	2.21	0.47	1.73	719.99
SEP	1.80	2.21	2.06	1.80	484.28
OCT	7.38	2.21	7.73	1.80	432.86
NOV	15.17	2.21	15.64	1.80	274.28
DEC	22.05	2.21	22.57	1.80	218.57
TOTAL	120.16	26.48	124.79	21.46	5228.52

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	77.95	5.94	5.01
FEB	66.47	7.28	68.06	5.94	7.20
MAR	56.63	7.28	58.03	5.94	9.77
APR	29.89	7.28	31.10	5.94	11.70
MAY	11.98	7.28	12.99	5.94	16.07
JUN	1.89	7.28	2.76	5.93	21.60
JUL	0.00	7.28	0.98	5.70	21.60
AUG	0.38	7.28	1.55	5.70	21.60
SEP	5.93	7.28	6.79	5.94	14.53
OCT	24.34	7.28	25.52	5.94	12.99
NOV	50.07	7.28	51.61	5.94	8.23
DEC	72.77	7.28	74.47	5.94	6.56
TOTAL	396.53	87.37	411.80	70.82	156.86

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	-2.32	18.37	-0.52	-1.77	1.34	-5.45
FEB	-2.40	18.37	-0.35	-1.60	1.34	-7.46
MAR	-2.47	18.37	-0.09	-1.40	1.34	-9.83
APR	-4.03	18.37	0.36	-1.20	1.34	-11.57
MAY	-8.44	18.37	1.69	-1.01	1.34	-15.75
JUN	-45.65	18.57	5.32	-0.86	1.35	-21.11
JUL	*******	21.72	8.32	-0.98	1.58	-20.99
AUG	-310.89	21.76	5.32	-1.18	1.58	-21.19
SEP	-14.51	18.37	3.61	-0.86	1.34	-14.05
OCT	-4.84	18.37	0.51	-1.18	1.34	-12.83
NOV	-3.08	18.37	-0.35	-1.54	1.34	-8.43
DEC	-2.33	18.37	-0.44	-1.69	1.34	-6.91
TOTAL	-3.85	18.94	0.27	-15.26	16.55	-155.57

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.38

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

	C1	C2	C3	C4	C5
C	1.0	1.0	12.0	1.0	0.0

	1	2	3	4	5	6	7	8	9	10	11	12
DD	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0

	1	2	3	4	5	6	7	8	9	10	11	12
GAL	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7

STO	A	CH	CC	TILT	VOL
330.71	21.53	24.82	26.44	55.0	39.64

UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
$W	**RLAT**	**TI**	**TLIM**	**$FAN**	**UATOP**	**UABOT**	**UASEG**	**ETA**	**GPH**	**ETA2**	**GPH2**
3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.39

SOLAR ENERGY AÑALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	23.46	1.80	137.14
FEB	20.14	2.21	20.42	1.80	222.86
MAR	17.16	2.21	17.32	1.80	308.57
APR	9.06	2.21	9.10	1.80	385.71
MAY	3.63	2.21	3.59	1.80	484.28
JUN	0.57	2.21	0.58	1.68	719.99
JUL	0.00	2.21	0.21	1.49	711.42
AUG	0.11	2.21	0.34	1.54	715.71
SEP	1.80	2.21	1.66	1.79	428.57
OCT	7.38	2.21	7.40	1.80	364.28
NOV	15.17	2.21	15.42	1.80	252.86
DEC	22.05	2.21	22.38	1.80	197.14
TOTAL	120.16	26.48	121.89	20.91	4928.52

MONTH	COST OF HEAT W/O SOLAR($) SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	OPERATING COST($)
JAN	76.18	7.28	77.43	5.94	4.11
FEB	66.47	7.28	67.37	5.94	6.69
MAR	56.63	7.28	57.15	5.94	9.26
APR	29.89	7.28	30.04	5.94	11.57
MAY	11.98	7.28	11.85	5.94	14.53
JUN	1.89	7.28	1.93	5.55	21.60
JUL	0.00	7.28	0.71	4.92	21.34
AUG	0.38	7.28	1.11	5.07	21.47
SEP	5.93	7.28	5.49	5.90	12.86
OCT	24.34	7.28	24.44	5.94	10.93
NOV	50.07	7.28	50.87	5.94	7.59
DEC	72.77	7.28	73.87	5.94	5.91
TOTAL	396.53	87.37	402.24	68.99	147.86

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	-1.64	18.37	0.11	-1.25	1.34	-4.03
FEB	-1.36	18.37	0.59	-0.91	1.34	-6.25
MAR	-0.92	18.37	1.28	-0.52	1.34	-8.44
APR	-0.49	18.37	3.20	-0.15	1.34	-10.38
MAY	1.14	18.37	7.65	0.14	1.34	-13.06
JUN	-1.80	23.79	18.51	-0.03	1.73	-19.90
JUL	*******	32.40	22.66	-0.71	2.36	-19.69
AUG	-193.79	30.42	19.34	-0.73	2.21	-19.99
SEP	7.41	18.94	13.76	0.44	1.38	-11.04
OCT	-0.38	18.37	3.93	-0.09	1.34	-9.68
NOV	-1.61	18.37	0.93	-0.80	1.34	-7.05
DEC	-1.50	18.37	0.30	-1.09	1.34	-5.67
TOTAL	-1.44	21.04	2.62	-5.71	18.38	-135.19

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.40

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	661.42	43.06	49.63	52.88	55.0	79.28						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.41

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	23.10	1.80	128.57
FEB	20.14	2.21	19.95	1.80	214.28
MAR	17.16	2.21	16.74	1.80	300.00
APR	9.06	2.21	8.42	1.80	368.57
MAY	3.63	2.21	2.87	1.77	454.28
JUN	0.57	2.21	0.32	1.28	664.28
JUL	0.00	2.21	0.00	1.02	642.85
AUG	0.11	2.21	0.00	1.13	638.56
SEP	1.80	2.21	1.13	1.57	399.28
OCT	7.38	2.21	6.71	1.80	317.14
NOV	15.17	2.21	14.93	1.80	240.00
DEC	22.05	2.21	21.98	1.80	184.29
TOTAL	120.16	26.48	116.15	19.39	4552.10

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	76.24	5.94	3.86
FEB	66.47	7.28	65.85	5.94	6.43
MAR	56.63	7.28	55.25	5.94	9.00
APR	29.89	7.28	27.79	5.94	11.06
MAY	11.98	7.28	9.46	5.85	13.63
JUN	1.89	7.28	1.07	4.24	19.93
JUL	0.00	7.28	0.00	3.38	19.29
AUG	0.38	7.28	0.00	3.73	19.16
SEP	5.93	7.28	3.72	5.19	11.98
OCT	24.34	7.28	22.14	5.94	9.51
NOV	50.07	7.28	49.26	5.94	7.20
DEC	72.77	7.28	72.53	5.94	5.53
TOTAL	396.53	87.37	383.30	63.99	136.56

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	-0.08	18.37	1.53	-0.06	1.34	-2.58
FEB	0.93	18.37	2.65	0.62	1.34	-4.47
MAR	2.43	18.37	4.25	1.38	1.34	-6.29
APR	7.04	18.37	9.26	2.11	1.34	-7.61
MAY	21.02	19.63	20.50	2.52	1.43	-9.68
JUN	43.38	41.82	42.14	0.82	3.05	-16.06
JUL	100.00	53.58	53.58	0.00	3.90	-15.38
AUG	100.00	48.82	51.35	0.38	3.55	-15.22
SEP	37.28	28.65	32.53	2.21	2.09	-7.68
OCT	9.06	18.37	11.20	2.20	1.34	-5.97
NOV	1.62	18.37	3.75	0.81	1.34	-5.05
DEC	0.34	18.37	1.98	0.25	1.34	-3.95
TOTAL	3.34	26.76	7.57	13.23	23.38	-99.96

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.42

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	992.13	64.59	74.45	79.32	55.0	118.92						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.43

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	22.78	1.80	124.29
FEB	20.14	2.21	19.53	1.80	210.00
MAR	17.16	2.21	16.21	1.80	300.00
APR	9.06	2.21	7.78	1.80	360.00
MAY	3.63	2.21	2.32	1.66	441.43
JUN	0.57	2.21	0.00	0.97	470.71
JUL	0.00	2.21	0.00	0.55	446.86
AUG	0.11	2.21	0.00	0.65	415.57
SEP	1.80	2.21	0.68	1.31	373.57
OCT	7.38	2.21	6.06	1.80	304.28
NOV	15.17	2.21	14.48	1.80	240.00
DEC	22.05	2.21	21.61	1.80	184.29
TOTAL	120.16	26.48	111.46	17.74	3870.98

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	75.18	5.94	3.73
FEB	66.47	7.28	64.46	5.94	6.30
MAR	56.63	7.28	53.49	5.94	9.00
APR	29.89	7.28	25.67	5.94	10.80
MAY	11.98	7.28	7.65	5.49	13.24
JUN	1.89	7.28	0.02	3.20	14.12
JUL	0.00	7.28	0.00	1.83	13.41
AUG	0.38	7.28	0.00	2.13	12.47
SEP	5.93	7.28	2.26	4.31	11.21
OCT	24.34	7.28	20.00	5.92	9.13
NOV	50.07	7.28	47.77	5.94	7.20
DEC	72.77	7.28	71.32	5.94	5.53
TOTAL	396.53	87.37	367.81	58.53	116.13

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	1.31	18.39	2.80	1.00	1.34	-1.39
FEB	3.02	18.39	4.54	2.01	1.34	-2.95
MAR	5.55	18.40	7.01	3.14	1.34	-4.52
APR	14.13	18.41	14.97	4.22	1.34	-5.24
MAY	36.13	24.62	31.78	4.33	1.79	-7.12
JUN	99.19	56.04	64.94	1.88	4.08	-8.16
JUL	100.00	74.93	74.93	0.00	5.46	-7.95
AUG	100.00	70.69	72.14	0.38	5.15	-6.94
SEP	61.93	40.83	50.30	3.67	2.97	-4.56
OCT	17.85	18.64	18.03	4.35	1.36	-3.43
NOV	4.59	18.39	6.34	2.30	1.34	-3.56
DEC	1.99	18.39	3.49	1.45	1.34	-2.74
TOTAL	7.24	33.01	11.90	28.72	28.84	-58.57

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.44

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	1322.84	86.11	99.26	105.76	55.0	158.56						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.45

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	22.56	1.80	124.29
FEB	20.14	2.21	19.21	1.80	210.00
MAR	17.16	2.21	15.77	1.80	300.00
APR	9.06	2.21	7.25	1.78	360.00
MAY	3.63	2.21	1.90	1.59	428.57
JUN	0.57	2.21	0.00	0.69	408.28
JUL	0.00	2.21	0.00	0.30	373.57
AUG	0.11	2.21	0.00	0.38	359.14
SEP	1.80	2.21	0.30	1.12	349.43
OCT	7.38	2.21	5.56	1.76	300.00
NOV	15.17	2.21	14.12	1.80	240.00
DEC	22.05	2.21	21.34	1.80	180.00
TOTAL	120.16	26.48	108.02	16.60	3633.27

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	74.44	5.94	3.73
FEB	66.47	7.28	63.39	5.94	6.30
MAR	56.63	7.28	52.04	5.93	9.00
APR	29.89	7.28	23.94	5.89	10.80
MAY	11.98	7.28	6.25	5.23	12.86
JUN	1.89	7.28	0.01	2.29	12.25
JUL	0.00	7.28	0.00	0.98	11.21
AUG	0.38	7.28	0.00	1.24	10.77
SEP	5.93	7.28	1.00	3.69	10.48
OCT	24.34	7.28	18.34	5.79	9.00
NOV	50.07	7.28	46.61	5.94	7.20
DEC	72.77	7.28	70.43	5.94	5.40
TOTAL	396.53	87.37	356.45	54.79	109.00

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	2.29	18.43	3.70	1.74	1.34	-0.64
FEB	4.63	18.46	6.00	3.08	1.34	-1.88
MAR	8.10	18.49	9.28	4.58	1.35	-3.07
APR	19.92	19.11	19.76	5.96	1.39	-3.45
MAY	47.80	28.13	40.37	5.73	2.05	-5.08
JUN	99.24	68.60	74.92	1.88	4.99	-5.38
JUL	100.00	86.53	86.53	0.00	6.30	-4.91
AUG	100.00	82.96	83.80	0.38	6.04	-4.36
SEP	83.11	49.34	64.50	4.93	3.59	-1.96
OCT	24.65	20.45	23.69	6.00	1.49	-1.51
NOV	6.92	18.46	8.39	3.47	1.34	-2.39
DEC	3.22	18.45	4.60	2.34	1.34	-1.71
TOTAL	10.11	37.28	15.01	40.08	32.57	-36.34

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.46

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1..0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	1653.55	107.64	124.08	132.20	55.0	198.55						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.47

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	22.33	1.80	124.29
FEB	20.14	2.21	18.89	1.79	210.00
MAR	17.16	2.21	15.34	1.79	300.00
APR	9.06	2.21	6.77	1.75	360.00
MAY	3.63	2.21	1.52	1.48	398.57
JUN	0.57	2.21	0.00	0.46	325.71
JUL	0.00	2.21	0.00	0.10	297.14
AUG	0.11	2.21	0.00	0.15	282.86
SEP	1.80	2.21	0.00	0.93	310.43
OCT	7.38	2.21	5.09	1.70	300.00
NOV	15.17	2.21	13.78	1.79	240.00
DEC	22.05	2.21	21.08	1.80	180.00
TOTAL	120.16	26.48	104.80	15.55	3328.99

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	73.70	5.93	3.73
FEB	66.47	7.28	62.33	5.92	6.30
MAR	56.63	7.28	50.63	5.91	9.00
APR	29.89	7.28	22.34	5.77	10.80
MAY	11.98	7.28	5.03	4.88	11.96
JUN	1.89	7.28	0.01	1.50	9.77
JUL	0.00	7.28	0.00	0.34	8.91
AUG	0.38	7.28	0.00	0.51	8.49
SEP	5.93	7.28	0.00	3.07	9.31
OCT	24.34	7.28	16.79	5.62	9.00
NOV	50.07	7.28	45.46	5.92	7.20
DEC	72.77	7.28	69.55	5.92	5.40
TOTAL	396.53	87.37	345.85	51.30	99.87

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	3.25	18.58	4.59	2.47	1.35	0.10
FEB	6.22	18.68	7.45	4.13	1.36	-0.81
MAR	10.60	18.77	11.53	6.00	1.37	-1.63
APR	25.25	20.71	24.36	7.55	1.51	-1.74
MAY	58.04	32.96	48.56	6.95	2.40	-2.60
JUN	99.26	79.34	83.45	1.88	5.78	-2.12
JUL	100.00	95.35	95.35	0.00	6.94	-1.97
AUG	100.00	93.05	93.39	0.38	6.77	-1.33
SEP	100.00	57.81	76.75	5.93	4.21	0.82
OCT	31.03	22.81	29.14	7.55	1.66	0.21
NOV	9.21	18.67	10.41	4.61	1.36	-1.23
DEC	4.42	18.63	5.72	3.22	1.36	-0.82
TOTAL	12.78	41.28	17.93	50.68	36.07	-13.12

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.48

VARYING COLLECTOR EFFICIENCY CURVE SLOPES
COLUMBUS, OHIO

Note: Months May through September were not included in these simulations due to the fact that values for X and Y exceeded allowable limits for use in the F equation. This became more apparent as slope was made more negative.

F-CHART

B.49 - B.64 X/A and Y/A with corresponding fractions for slopes of .66, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0 $BTU/H_r - Ft^2 - {}^oF$

AREA = $50m^2$

SESP

B.65 - B.80 Inputs and corresponding outputs for slopes of .66, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0 $BTU/H_r - Ft^2 - {}^oF$

AREA = $50m^2$

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R)$ = 3.64 [W/M^2-°C]

D. $F_R(\tau\alpha)_n(F'_R/F_R)$ = .66 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [$1/M^2$] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [$1/M^2$] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.0366	1.00	9.029 $\times 10^6$	.00686
FEB	2.42×10^6	100	.0374	1.00	11.992 $\times 10^6$	.00940
MAR	2.68×10^6	96	.0453	1.00	14.743 $\times 10^6$	.0146
APR	2.59×10^6	88	.0690	1.00	15.689 $\times 10^6$	.0258
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.0812	1.00	17.334 $\times 10^6$	.0343
NOV	2.59×10^6	94	.0480	1.00	13.036 $\times 10^6$	.0140
DEC	2.68×10^6	100	.0338	1.00	10.422 $\times 10^6$	.00740

TABLE B.49

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0366	.00686	1.83	.343	.212	
FEB	.0374	.00940	1.87	.47	.316	
MAR	.0453	.0146	2.265	.73	.491	
APR	.0690	.0258	3.45	1.29	.763	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.0812	.0343	4.06	1.715	.918	
NOV	.0480	.0140	2.40	.700	.462	
DEC	.0338	.00740	1.69	.37	.244	
					TOTAL	

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = ______

TABLE B.50

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R)$ = 5.40 [W/M²-°C]

D. $F_R (\tau\alpha)_n (F'_R/F_R)$ = .646 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. (100-$\bar{T}_a$) [°C]	C8. X/A [1/M²] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	C11. Y/A [1/M²] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.0543	1.00	9.029 $\times 10^6$	.00672
FEB	2.42×10^6	100	.0555	1.00	11.992 $\times 10^6$	.0092
MAR	2.68×10^6	96	.0672	1.00	14.743 $\times 10^6$	.0143
APR	2.59×10^6	88	.10236	1.00	15.689 $\times 10^6$	.02528
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.12046	1.00	17.334 $\times 10^6$	.0336
NOV	2.59×10^6	94	.0712	1.00	13.036 $\times 10^6$	.0137
DEC	2.68×10^6	100	.0501	1.00	10.422 $\times 10^6$	.0072

TABLE B.51

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0543	.00672	2.715	.336	.1557	
FEB	.0555	.0092	2.775	.46	.257	
MAR	.0672	.0143	3.36	.715	.42	
APR	.10236	.02528	5.118	1.264	.6671	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.12046	.0336	6.023	1.68	.813	
NOV	.0712	.0137	3.56	.685	.388	
DEC	.0501	.0072	2.51	.36	.1879	
					TOTAL	

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = ______

TABLE B.52

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R)$ = 7.9 [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R/F_R)$ = .631 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. (100-$\bar{T}_a$) [°C]	C8. X/A [1/M^2] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [1/M^2] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68 x10^6	101	.07943	1.00	9.029 x10^6	.00656
FEB	2.42 x10^6	100	.08117	1.00	11.992 x10^6	.00899
MAR	2.68 x10^6	96	.09831	1.00	14.743 x10^6	.01396
APR	2.59 x10^6	88	.14975	1.00	15.689 x10^6	.02466
MAY	2.68 x10^6				x10^6	
JUN	2.59 x10^6				x10^6	
JUL	2.68 x10^6				x10^6	
AUG	2.68 x10^6				x10^6	
SEP	2.59 x10^6				x10^6	
OCT	2.68 x10^6	86	.17623	1.00	17.334 x10^6	.03279
NOV	2.59 x10^6	94	.10417	1.00	13.036 x10^6	.01338
DEC	2.68 x10^6	100	.07336	1.00	10.422 x10^6	.00707

TABLE B.53

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA= 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)x(F.)	C13. CORRECTED Y/A (C11.)x(G.)	C14. X (C12.)x(E.)	C15. Y (C13.)x(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.07943	.00656	3.97	.328	.082	
FEB	.08117	.00899	4.06	.45	.1812	
MAR	.09831	.01396	4.92	.698	.33	
APR	.14975	.02466	7.488	1.233	.551	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.17623	.03279	8.812	1.64	.69	
NOV	.10417	.01338	5.21	.669	.295	
DEC	.07336	.00707	3.67	.354	.12	
ANNUAL FRACTION BY SOLAR (TOTAL,C17.)/(TOTAL,C5.) = ______					TOTAL	

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R)$ = 10.28 [W/M²-°C]

D. $F_R(\tau\alpha)_n (F'_R/F_R)$ = .616 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. (100-$\bar{T}_a$) [°C]	C8. X/A [1/M²] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	C11. Y/A [1/M²] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.10336	1.00	9.029 $\times 10^6$	.0064
FEB	2.42×10^6	100	.10563	1.00	11.992 $\times 10^6$	.0094
MAR	2.68×10^6	96	.12794	1.00	14.743 $\times 10^6$	.0146
APR	2.59×10^6	88	.19487	1.00	15.689 $\times 10^6$	.02408
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.2293	1.00	17.334 $\times 10^6$	.03201
NOV	2.59×10^6	94	.13556	1.00	13.036 $\times 10^6$	.01307
DEC	2.68×10^6	100	.09546	1.00	10.422 $\times 10^6$	.00691

TABLE B.55

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.10336	.0064	5.168	.32	.017	
FEB	.10563	.0094	5.28	.47	.1387	
MAR	.12794	.0146	6.4	.73	.2867	
APR	.19487	.02408	9.74	1.204	.458	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.2293	.03201	11.47	1.6	.598	
NOV	.13556	.01307	6.78	.654	.2162	
DEC	.09546	.00691	4.77	.346	.0585	
					TOTAL	

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = ______

TABLE B.56

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R)$ = 14.74 [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R)$ = .588 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. (100 - $\bar{T}_a$) [°C]	C8. X/A [$1/M^2$] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [$1/M^2$] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.1482	1.00	9.029 $\times 10^6$	.00611
FEB	2.42×10^6	100	.15145	1.00	11.992 $\times 10^6$	.0094
MAR	2.68×10^6	96	.18344	1.00	14.743 $\times 10^6$	.0146
APR	2.59×10^6	88	.27941	1.00	15.689 $\times 10^6$	.02299
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.3288	1.00	17.334 $\times 10^6$	.03057
NOV	2.59×10^6	94	.19438	1.00	13.036 $\times 10^6$	.01247
DEC	2.68×10^6	100	.13687	1.00	10.422 $\times 10^6$	.00659

TABLE B.57

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)×(F.)	C13. CORRECTED Y/A (C11.)×(G.)	C14. X (C12.)×(E.)	C15. Y (C13.)×(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.1482	.00611	7.41	.3055	-.0907	
FEB	.15145	.0094	7.725	.47	.037	
MAR	.18344	.0146	9.172	.73	.184	
APR	.27941	.02299	13.97	1.15	.335	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.3288	.03057	16.44	1.53	.495	
NOV	.19438	.01247	9.72	.624	.0902	
DEC	.13687	.00659	6.84	.33	-.0467	
ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = ______					TOTAL	

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R)$ = 18.80 [W/M²-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R)$ = .562 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [1/M²] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	C11. Y/A [1/M²] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.189	1.00	9.029×10^6	.00585
FEB	2.42×10^6	100	.19316	1.00	11.992×10^6	.008
MAR	2.68×10^6	96	.23397	1.00	14.743×10^6	.01243
APR	2.59×10^6	88	.35637	1.00	15.689×10^6	.022
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.41938	1.00	17.334×10^6	.02924
NOV	2.59×10^6	94	.24791	1.00	13.036×10^6	.01192
DEC	2.68×10^6	100	.17457	1.00	10.422×10^6	.0063

TABLE B.59

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)×(F.)	C13. CORRECTED Y/A (C11.)×(G.)	C14. X (C12.)×(E.)	C15. Y (C13.)×(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.189	.00585	9.45	.2925	-.1729	
FEB	.19316	.008	9.66	.40	-.0862	
MAR	.23397	.01243	11.7	.622	.0363	
APR	.35637	.022	17.82	1.1	.277	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.41938	.02924	20.97	1.462	.476	
NOV	.24791	.01192	12.396	.596	.0017	
DEC	.17457	.0063	8.729	.315	-.1297	
ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = ______					TOTAL	

TABLE B.60

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R) =$ 22.52 [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R) =$ .539 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [$1/M^2$] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [$1/M^2$] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.22644	1.00	9.029 $\times 10^6$	.00561
FEB	2.42×10^6	100	.23127	1.00	11.992 $\times 10^6$	.00768
MAR	2.68×10^6	96	.28031	1.00	14.743 $\times 10^6$	.01192
APR	2.59×10^6	88	.42689	1.00	15.689 $\times 10^6$	.02108
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.5024	1.00	17.334 $\times 10^6$	.02803
NOV	2.59×10^6	94	.29671	1.00	13.036 $\times 10^6$	.01143
DEC	2.68×10^6	100	.20932	1.00	10.422 $\times 10^6$	.00604

TABLE B.61

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA= 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)x(F.)	C13. CORRECTED Y/A (C11.)x(G.)	C14. X (C12.)x(E.)	C15. Y (C13.)x(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.22644	.00561	11.32	.28	-.2354	
FEB	.23127	.00768	11.56	.384	-.1506	
MAR	.28031	.01192	14.016	.596	-.0266	
APR	.42689	.02108	21.34	1.05	.27	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.5024	.02803	25.12	1.4	.523	
NOV	.29671	.01143	14.836	.5715	-.0561	
DEC	.20932	.00604	10.47	.302	-.1942	

ANNUAL FRACTION BY SOLAR (TOTAL,C17.)/(TOTAL,C5.) = ______ TOTAL ______

TABLE B.62

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R) =$ 25.95 [W/M^2-°C]

D. $F_R(\tau\alpha)_n (F'_R/F_R) =$ .518 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [$1/M^2$] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M^2-DAY] = G10.	C11. Y/A [$1/M^2$] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68×10^6	101	.2609	1.00	9.029 $\times 10^6$	.00538
FEB	2.42×10^6	100	.2665	1.00	11.992 $\times 10^6$	.00738
MAR	2.68×10^6	96	.3230	1.00	14.743 $\times 10^6$	.01146
APR	2.59×10^6	88	.4919	1.00	15.689 $\times 10^6$	.02024
MAY	2.68×10^6				$\times 10^6$	
JUN	2.59×10^6				$\times 10^6$	
JUL	2.68×10^6				$\times 10^6$	
AUG	2.68×10^6				$\times 10^6$	
SEP	2.59×10^6				$\times 10^6$	
OCT	2.68×10^6	86	.5789	1.00	17.334 $\times 10^6$	.02691
NOV	2.59×10^6	94	.3419	1.00	13.036 $\times 10^6$	.01096
DEC	2.68×10^6	100	.2412	1.00	10.422 $\times 10^6$	.00580

TABLE B.63

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)x(F.)	CORRECTED Y/A (C11.)x(G.)	X (C12.)x(E.)	Y (C13.)x(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.2609	.00538	13.045	.269	-.2821	
FEB	.2665	.00738	13.325	.369	-.199	
MAR	.3230	.01146	16.15	.573	-.067	
APR	.4919	.02024	24.6	1.012	.303	
MAY						
JUN						
JUL						
AUG						
SEP						
OCT	.5789	.02691	29.0	1.346	.6202	
NOV	.3419	.01096	17.095	.548	-.0913	
DEC	.2412	.00580	12.06	.29	-.2438	
					TOTAL	

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = ______

TABLE B.64

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1 1.0	C2 1.0	C3 12.0	C4 1.0	C5 0.0							
DD	1 1087.2	2 948.6	3 808.2	4 426.6	5 171.0	6 27.0	7 .001	8 5.4	9 84.6	10 347.4	11 714.6	12 1038.6
HBAR	1 474.6	2 729.0	3 1090.0	4 1446.7	5 1797.1	6 2069.2	7 1996.0	8 1756.6	9 1554.0	10 1053.0	11 655.0	12 486.0
TAMB	1 30.2	2 32.0	3 39.2	4 51.8	5 60.8	6 69.8	7 73.4	8 71.6	9 64.4	10 53.6	11 41.0	12 32.0
GAL	1 2.0	2 0.0	3 0.0	4 0.0	5 0.0	6 0.0	7 1.4	8 4.8	9 7.3	10 8.4	11 6.9	12 4.6
	13 3.5	14 5.3	15 2.5	16 2.3	17 2.0	18 3.8	19 6.9	20 11.8	21 9.6	22 6.9	23 5.4	24 4.7
	STO 8267.8	A 538.2	CH 620.4	CC 661.0	TILT 55.0	VOL 990.75						
	UA 4262.5	XM .66	B .68	AZ 0.0	DENH 8.89	DENC 8.34	SPHTH .8	SPHTC 1.0	THOT 140.0	TCOLD 51.8	RLOSS 21232.9	$S 3.3
	$W 3.3	RLAT 40.0	TI 70.0	TLIM 68.0	$FAN .03	UATOP 1.41	UABOT 1.41	UASEG .141	ETA .7	GPH 480.0	ETA2 .6	GPH2 -----

TABLE B.65

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	18.20	1.73	90.00
FEB	20.14	2.21	13.32	1.66	158.57
MAR	17.16	2.21	8.33	1.54	261.43
APR	9.06	2.21	0.09	1.00	309.43
MAY	3.63	2.21	0.00	0.04	161.57
JUN	0.57	2.21	0.00	0.00	151.14
JUL	0.00	2.21	0.00	0.00	150.00
AUG	0.11	2.21	0.00	0.00	150.00
SEP	1.80	2.21	0.00	0.00	150.00
OCT	7.38	2.21	0.00	0.23	174.57
NOV	15.17	2.21	7.51	1.59	191.43
DEC	22.05	2.21	16.21	1.70	120.00
TOTAL	120.16	26.48	63.65	9.49	2068.14

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	60.07	5.71	2.70
FEB	66.47	7.28	43.96	5.49	4.76
MAR	56.63	7.28	27.48	5.08	7.84
APR	29.89	7.28	0.28	3.30	9.28
MAY	11.98	7.28	0.00	0.13	4.85
JUN	1.89	7.28	0.00	0.00	4.53
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	0.75	5.24
NOV	50.07	7.28	24.78	5.25	5.74
DEC	72.77	7.28	53.49	5.62	3.60
TOTAL	396.53	87.37	210.06	31.33	62.04

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	21.14	21.64	21.19	16.11	1.58	14.98
FEB	33.87	24.56	32.95	22.51	1.79	19.54
MAR	51.48	30.17	49.05	29.15	2.20	23.51
APR	99.05	54.65	90.35	29.61	3.98	24.30
MAY	100.00	98.24	99.33	11.98	7.15	14.29
JUN	100.00	100.00	100.00	1.89	7.28	4.64
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	89.73	97.63	24.34	6.53	25.64
NOV	50.52	27.87	47.64	25.29	2.03	21.58
DEC	26.50	22.88	26.17	19.28	1.67	17.35
TOTAL	47.03	64.14	50.12	186.48	56.04	180.47

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.66

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

	C1	C2	C3	C4	C5
C	1.0	1.0	12.0	1.0	0.0

	1	2	3	4	5	6	7	8	9	10	11	12
DD	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0

GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7

STO	A	CH	CC	TILT	VOL
8267.8	538.2	620.4	661.0	55.0	990.75

UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
4262.5	1.0	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
$W	**RLAT**	**TI**	**TLIM**	**$FAN**	**UATOP**	**UABOT**	**UASEG**	**ETA**	**GPH**	**ETA2**	**GPH2**
3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.67

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	19.02	1.74	90.00
FEB	20.14	2.21	14.42	1.70	120.00
MAR	17.16	2.21	9.73	1.62	141.43
APR	9.06	2.21	0.76	1.28	291.43
MAY	3.63	2.21	0.00	0.23	156.14
JUN	0.57	2.21	0.00	0.00	151.00
JUL	0.00	2.21	0.00	0.00	142.86
AUG	0.11	2.21	0.00	0.00	141.43
SEP	1.80	2.21	0.00	0.00	150.00
OCT	7.38	2.21	0.00	0.73	174.43
NOV	15.17	2.21	8.73	1.67	150.00
DEC	22.05	2.21	17.22	1.73	120.00
TOTAL	120.16	26.48	69.88	10.70	1828.71

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	62.75	5.76	2.70
FEB	66.47	7.28	47.59	5.60	3.60
MAR	56.63	7.28	32.11	5.33	4.24
APR	29.89	7.28	2.52	4.23	8.74
MAY	11.98	7.28	0.00	0.77	4.68
JUN	1.89	7.28	0.00	0.01	4.53
JUL	0.00	7.28	0.00	0.00	4.29
AUG	0.38	7.28	0.00	0.00	4.24
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	2.40	5.23
NOV	50.07	7.28	28.82	5.50	4.50
DEC	72.77	7.28	56.81	5.70	3.60
TOTAL	396.53	87.37	230.60	35.31	54.86

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	17.63	20.91	17.91	13.43	1.52	12.25
FEB	28.41	23.04	27.88	18.88	1.68	16.96
MAR	43.29	26.78	41.41	24.51	1.95	22.22
APR	91.56	41.88	81.83	27.37	3.05	21.67
MAY	100.00	89.45	96.01	11.98	6.51	13.81
JUN	100.00	99.91	99.93	1.89	7.27	4.64
JUL	100.00	100.00	100.00	0.00	7.28	3.00
AUG	100.00	100.00	100.00	0.38	7.28	3.42
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	67.00	92.40	24.34	4.88	23.99
NOV	42.45	24.40	40.16	21.26	1.78	18.53
DEC	21.93	21.67	21.91	15.96	1.58	13.94
TOTAL	41.85	59.59	45.05	165.93	52.06	163.13

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.68

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	55.0	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	1.5	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.69

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	20.07	1.76	90.00
FEB	20.14	2.21	15.77	1.74	120.00
MAR	17.16	2.21	11.03	1.67	120.00
APR	9.06	2.21	2.20	1.43	175.86
MAY	3.63	2.21	0.01	0.69	153.29
JUN	0.57	2.21	0.00	0.02	136.71
JUL	0.00	2.21	0.00	0.00	125.00
AUG	0.11	2.21	0.00	0.00	124.14
SEP	1.80	2.21	0.00	0.00	148.86
OCT	7.38	2.21	0.00	1.15	175.86
NOV	15.17	2.21	10.15	1.72	150.00
DEC	22.05	2.21	18.51	1.75	120.00
TOTAL	120.16	26.48	77.74	11.94	1639.71

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	66.22	5.81	2.70
FEB	66.47	7.28	52.04	5.73	3.60
MAR	56.63	7.28	36.41	5.51	3.60
APR	29.89	7.28	7.25	4.73	5.28
MAY	11.98	7.28	0.05	2.28	4.60
JUN	1.89	7.28	0.00	0.08	4.10
JUL	0.00	7.28	0.00	0.00	3.75
AUG	0.38	7.28	0.00	0.00	3.72
SEP	5.93	7.28	0.00	0.00	4.47
OCT	24.34	7.28	0.00	3.81	5.28
NOV	50.07	7.28	33.50	5.66	4.50
DEC	72.77	7.28	61.08	5.78	3.60
TOTAL	396.53	87.37	256.55	39.39	49.19

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	13.07	20.18	13.69	9.96	1.47	8.72
FEB	21.70	21.33	21.67	14.43	1.55	12.38
MAR	35.71	24.36	34.42	20.22	1.77	18.40
APR	75.73	35.07	67.77	22.64	2.55	19.91
MAY	99.60	68.63	87.89	11.93	5.00	12.33
JUN	100.00	98.95	99.17	1.89	7.20	4.99
JUL	100.00	100.00	100.00	0.00	7.28	3.53
AUG	100.00	100.00	100.00	0.38	7.28	3.93
SEP	100.00	100.00	100.00	5.93	7.28	8.74
OCT	100.00	47.66	87.95	24.34	3.47	22.54
NOV	33.10	22.19	31.72	16.58	1.62	13.69
DEC	16.07	20.61	16.49	11.70	1.50	9.60
TOTAL	35.30	54.92	38.84	139.99	47.98	138.77

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.70

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	55.0	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	2.0	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B-71

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	20.97	1.77	90.00
FEB	20.14	2.21	16.94	1.76	120.00
MAR	17.16	2.21	12.12	1.71	120.00
APR	9.06	2.21	3.14	1.54	154.43
MAY	3.63	2.21	0.03	0.97	151.14
JUN	0.57	2.21	0.00	0.27	128.57
JUL	0.00	2.21	0.00	0.06	120.57
AUG	0.11	2.21	0.00	0.07	120.00
SEP	1.80	2.21	0.00	0.22	146.86
OCT	7.38	2.21	0.56	1.35	176.29
NOV	15.17	2.21	11.31	1.75	150.00
DEC	22.05	2.21	19.56	1.77	90.00
TOTAL	120.16	26.48	84.64	13.23	1567.85

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	69.21	5.85	2.70
FEB	66.47	7.28	55.89	5.79	3.60
MAR	56.63	7.28	39.98	5.64	3.60
APR	29.89	7.28	10.37	5.08	4.63
MAY	11.98	7.28	0.10	3.19	4.53
JUN	1.89	7.28	0.00	0.89	3.86
JUL	0.00	7.28	0.00	0.20	3.62
AUG	0.38	7.28	0.00	0.22	3.60
SEP	5.93	7.28	0.00	0.73	4.41
OCT	24.34	7.28	1.86	4.47	5.29
NOV	50.07	7.28	37.34	5.77	4.50
DEC	72.77	7.28	64.56	5.84	2.70
TOTAL	396.53	87.37	279.30	43.67	47.04

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	9.14	19.61	10.06	6.97	1.43	5.69
FEB	15.91	20.43	16.36	10.58	1.49	8.47
MAR	29.40	22.52	28.61	16.65	1.64	14.69
APR	65.32	30.17	58.44	19.53	2.20	17.09
MAY	99.16	56.24	82.94	11.88	4.09	11.44
JUN	100.00	87.74	90.27	1.89	6.39	4.42
JUL	100.00	97.21	97.21	0.00	7.08	3.46
AUG	100.00	97.04	97.18	0.38	7.07	3.84
SEP	100.00	89.96	94.46	5.93	6.55	8.07
OCT	92.36	38.65	79.99	22.48	2.81	20.01
NOV	25.43	20.81	24.85	12.74	1.51	9.75
DEC	11.29	19.84	12.07	8.22	1.44	6.96
TOTAL	29.56	50.02	33.26	117.23	43.70	113.89

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.72

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	55.0	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	3.0	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.73

SOLAR ENERGY AÑALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	22.44	1.79	90.00
FEB	20.14	2.21	18.69	1.78	90.00
MAR	17.16	2.21	13.92	1.75	120.00
APR	9.06	2.21	4.58	1.67	150.00
MAY	3.63	2.21	0.04	1.28	150.00
JUN	0.57	2.21	0.00	0.71	124.43
JUL	0.00	2.21	0.00	0.53	120.43
AUG	0.11	2.21	0.00	0.55	120.00
SEP	1.80	2.21	0.00	0.73	146.57
OCT	7.38	2.21	2.10	1.54	177.00
NOV	15.17	2.21	13.12	1.78	120.00
DEC	22.05	2.21	21.03	1.79	90.00
TOTAL	120.16	26.48	95.91	15.91	1498.42

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	74.05	5.92	2.70
FEB	66.47	7.28	61.67	5.88	2.70
MAR	56.63	7.28	45.93	5.79	3.60
APR	29.89	7.28	15.12	5.51	4.50
MAY	11.98	7.28	0.12	4.22	4.50
JUN	1.89	7.28	0.00	2.35	3.73
JUL	0.00	7.28	0.00	1.76	3.61
AUG	0.38	7.28	0.00	1.82	3.60
SEP	5.93	7.28	0.00	2.42	4.40
OCT	24.34	7.28	6.92	5.08	5.31
NOV	50.07	7.28	43.29	5.86	3.60
DEC	72.77	7.28	69.39	5.90	2.70
TOTAL	396.53	87.37	316.49	52.49	44.95

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	2.80	18.75	4.19	2.13	1.37	0.80
FEB	7.22	19.23	8.41	4.80	1.40	3.50
MAR	18.89	20.51	19.08	10.70	1.49	8.59
APR	49.42	24.37	44.51	14.77	1.77	12.05
MAY	99.01	42.09	77.49	11.86	3.06	10.43
JUN	100.00	67.69	74.35	1.89	4.93	3.09
JUL	100.00	75.88	75.88	0.00	5.52	1.91
AUG	100.00	75.04	76.27	0.38	5.46	2.24
SEP	100.00	66.75	81.67	5.93	4.86	6.39
OCT	71.56	30.28	62.06	17.42	2.20	14.31
NOV	13.55	19.46	14.30	6.78	1.42	4.60
DEC	4.64	18.98	5.95	3.38	1.38	2.06
TOTAL	20.19	39.92	23.75	80.04	34.88	69.97

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.74

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1 1.0	C2 1.0	C3 12.0	C4 1.0	C5 0.0							
DD	1 1087.2	2 948.6	3 808.2	4 426.6	5 171.0	6 27.0	7 .001	8 5.4	9 84.6	10 347.4	11 714.6	12 1038.6
HBAR	1 474.6	2 729.0	3 1090.0	4 1446.7	5 1797.1	6 2069.2	7 1996.0	8 1756.6	9 1554.0	10 1053.0	11 655.0	12 486.0
TAMB	1 30.2	2 32.0	3 39.2	4 51.8	5 60.8	6 69.8	7 73.4	8 71.6	9 64.4	10 53.6	11 41.0	12 32.0
GAL	1 2.0	2 0.0	3 0.0	4 0.0	5 0.0	6 0.0	7 1.4	8 4.8	9 7.3	10 8.4	11 6.9	12 4.6
	13 3.5	14 5.3	15 2.5	16 2.3	17 2.0	18 3.8	19 6.9	20 11.8	21 9.6	22 6.9	23 5.4	24 4.7
	STO 8267.8	A 538.2	CH 620.4	CC 661.0	TILT 55.0	VOL 990.75						
	UA 4262.5	XM 4.0	B .68	AZ 0.0	DENH 8.89	DENC 8.34	SPHTH .8	SPHTC 1.0	THOT 140.0	TCOLD 51.8	RLOSS 21232.9	$S 3.3
	$W 3.3	RLAT 40.0	TI 70.0	TLIM 68.0	$FAN .03	UATOP 1.41	UABOT 1.41	UASEG .141	ETA .7	GPH 480.0	ETA2 .6	GPH2 ------

TABLE B.75

SOLAR ENERGY ANALYSIS

HEAT W/O SOLAR(MEGABTU) MONTH	SPACE	WATER	HEAT W/SOLAR(MEGABTU) SPACE	WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	23.27	1.80	55.14
FEB	20.14	2.21	19.83	1.80	60.00
MAR	17.16	2.21	15.34	1.78	120.00
APR	9.06	2.21	5.73	1.72	150.00
MAY	3.63	2.21	0.04	1.45	150.00
JUN	0.57	2.21	0.00	0.96	123.86
JUL	0.00	2.21	0.00	0.79	120.43
AUG	0.11	2.21	0.00	0.82	120.00
SEP	1.80	2.21	0.00	1.01	147.71
OCT	7.38	2.21	3.25	1.66	149.00
NOV	15.17	2.21	14.36	1.79	120.00
DEC	22.05	2.21	21.97	1.80	60.00
TOTAL	120.16	26.48	103.79	17.38	1376.14

COST OF HEAT W/O SOLAR($) MONTH	SPACE	WATER	COST OF HEAT W/SOLAR($) SPACE	WATER	OPERATING COST($)
JAN	76.18	7.28	76.81	5.94	1.65
FEB	66.47	7.28	65.44	5.93	1.80
MAR	56.63	7.28	50.62	5.86	3.60
APR	29.89	7.28	18.90	5.69	4.50
MAY	11.98	7.28	0.12	4.79	4.50
JUN	1.89	7.28	0.00	3.16	3.72
JUL	0.00	7.28	0.00	2.61	3.61
AUG	0.38	7.28	0.00	2.70	3.60
SEP	5.93	7.28	0.00	3.33	4.43
OCT	24.34	7.28	10.71	5.49	4.47
NOV	50.07	7.28	47.38	5.91	3.60
DEC	72.77	7.28	72.51	5.94	1.80
TOTAL	396.53	87.37	342.49	57.34	41.28

MONTH	SOLAR FRACTION SPACE	WATER	COMBINED	GROSS SAVINGS($) SPACE	WATER	NET SAVINGS($)
JAN	-0.82	18.36	0.85	-0.63	1.34	-0.94
FEB	1.55	18.58	3.23	1.03	1.35	0.58
MAR	10.61	19.48	11.62	6.01	1.42	3.83
APR	36.76	21.83	33.84	10.99	1.59	8.08
MAY	98.98	34.21	74.50	11.86	2.49	9.85
JUN	100.00	56.65	65.59	1.89	4.12	2.30
JUL	100.00	64.16	64.16	0.00	4.67	1.06
AUG	100.00	62.97	64.80	0.38	4.58	1.36
SEP	100.00	54.33	74.82	5.93	3.96	5.45
OCT	55.99	24.54	48.75	13.63	1.79	10.94
NOV	5.38	18.79	7.08	2.69	1.37	0.46
DEC	0.36	18.48	2.01	0.26	1.35	-0.19
TOTAL	13.63	34.36	17.37	54.04	30.02	42.78

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.76

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

C	C1 1.0	C2 1.0	C3 12.0	C4 1.0	C5 0.0							
DD	1 1087.2	2 948.6	3 808.2	4 426.6	5 171.0	6 27.0	7 .001	8 5.4	9 84.6	10 347.4	11 714.6	12 1038.6
HBAR	1 474.6	2 729.0	3 1090.0	4 1446.7	5 1797.1	6 2069.2	7 1996.0	8 1756.6	9 1554.0	10 1053.0	11 655.0	12 486.0
TAMB	1 30.2	2 32.0	3 39.2	4 51.8	5 60.8	6 69.8	7 73.4	8 71.6	9 64.4	10 53.6	11 41.0	12 32.0
GAL	1 2.0	2 0.0	3 0.0	4 0.0	5 0.0	6 0.0	7 1.4	8 4.8	9 7.3	10 8.4	11 6.9	12 4.6
	13 3.5	14 5.3	15 2.5	16 2.3	17 2.0	18 3.8	19 6.9	20 11.8	21 9.6	22 6.9	23 5.4	24 4.7
	STO 8267.8	A 538.2	CH 620.4	CC 661.0	TILT 55.0	VOL 990.75						
	UA 4262.5	XM 5.0	B .68	AZ 0.0	DENH 8.89	DENC 8.34	SPHTH .8	SPHTC 1.0	THOT 140.0	TCOLD 51.8	RLOSS 21232.9	$S 3.3
	$W 3.3	RLAT 40.0	TI 70.0	TLIM 68.0	$FAN .03	UATOP 1.41	UABOT 1.41	UASEG .141	ETA .7	GPH 480.0	ETA2 .6	GPH2 ------

TABLE B.77

SOLAR ENERGY ANALYSIS

HEAT W/O SOLAR(MEGABTU)			HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	23.46	1.80	0.00
FEB	20.14	2.21	20.54	1.80	0.00
MAR	17.16	2.21	16.98	1.80	60.00
APR	9.06	2.21	7.27	1.77	120.00
MAY	3.63	2.21	0.64	1.61	150.00
JUN	0.57	2.21	0.00	1.22	129.43
JUL	0.00	2.21	0.00	1.07	121.14
AUG	0.11	2.21	0.00	1.10	120.00
SEP	1.80	2.21	0.00	1.30	148.14
OCT	7.38	2.21	4.89	1.76	149.00
NOV	15.17	2.21	15.57	1.80	0.00
DEC	22.05	2.21	22.46	1.80	0.00
TOTAL	120.16	26.48	111.82	18.83	997.71

COST OF HEAT W/O SOLAR($)			COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	77.43	5.94	0.00
FEB	66.47	7.28	67.80	5.95	0.00
MAR	56.63	7.28	56.04	5.93	1.80
APR	29.89	7.28	23.98	5.85	3.60
MAY	11.98	7.28	2.11	5.32	4.50
JUN	1.89	7.28	0.00	4.01	3.88
JUL	0.00	7.28	0.00	3.52	3.63
AUG	0.38	7.28	0.00	3.63	3.60
SEP	5.93	7.28	0.00	4.29	4.44
OCT	24.34	7.28	16.14	5.79	4.47
NOV	50.07	7.28	51.39	5.95	0.00
DEC	72.77	7.28	74.10	5.95	0.00
TOTAL	396.53	87.37	368.99	62.14	29.93

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	-1.64	18.35	0.10	-1.25	1.34	0.08
FEB	-2.00	18.35	0.01	-1.33	1.34	0.01
MAR	1.04	18.51	3.03	0.59	1.35	0.14
APR	19.76	19.64	19.74	5.91	1.43	3.74
MAY	82.39	26.87	61.41	9.87	1.96	7.33
JUN	100.00	44.89	56.25	1.89	3.27	1.28
JUL	100.00	51.65	51.65	0.00	3.76	0.13
AUG	100.00	50.11	52.57	0.38	3.65	0.43
SEP	100.00	41.03	67.50	5.93	2.99	4.47
OCT	33.70	20.42	30.64	8.20	1.49	5.22
NOV	-2.64	18.35	0.02	-1.32	1.34	0.01
DEC	-1.83	18.35	0.01	-1.33	1.34	0.01
TOTAL	6.94	28.88	10.90	27.54	25.23	22.83

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.78

SESP INPUT DATA

LOCATION: COLUMBUS, OHIO

	C1	C2	C3	C4	C5
C	1.0	1.0	12.0	1.0	0.0

	1	2	3	4	5	6	7	8	9	10	11	12
DD	1087.2	948.6	808.2	426.6	171.0	27.0	.001	5.4	84.6	347.4	714.6	1038.6
HBAR	474.6	729.0	1090.0	1446.7	1797.1	2069.2	1996.0	1756.6	1554.0	1053.0	655.0	486.0
TAMB	30.2	32.0	39.2	51.8	60.8	69.8	73.4	71.6	64.4	53.6	41.0	32.0

	1	2	3	4	5	6	7	8	9	10	11	12
GAL	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7

STO	A	CH	CC	TILT	VOL
8267.8	538.2	620.4	661.0	55.0	990.75

UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
4262.5	6.0	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3

$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
3.3	40.0	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.79

SOLAR ENERGY AÑALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	HEAT W/O SOLAR(MEGABTU) WATER	HEAT W/SOLAR(MEGABTU) SPACE	HEAT W/SOLAR(MEGABTU) WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	23.46	1.80	0.00
FEB	20.14	2.21	20.44	1.80	30.00
MAR	17.16	2.21	16.29	1.79	90.00
APR	9.06	2.21	6.57	1.75	120.00
MAY	3.63	2.21	0.13	1.56	150.00
JUN	0.57	2.21	0.00	1.11	125.14
JUL	0.00	2.21	0.00	0.95	121.14
AUG	0.11	2.21	0.00	0.98	120.00
SEP	1.80	2.21	0.00	1.18	148.00
OCT	7.38	2.21	4.13	1.72	149.00
NOV	15.17	2.21	15.16	1.80	90.00
DEC	22.05	2.21	22.45	1.80	21.29
TOTAL	120.16	26.48	108.64	18.26	1164.57

MONTH	COST OF HEAT W/O SOLAR($) SPACE	COST OF HEAT W/O SOLAR($) WATER	COST OF HEAT W/SOLAR($) SPACE	COST OF HEAT W/SOLAR($) WATER	OPERATING COST($)
JAN	76.18	7.28	77.43	5.94	0.00
FEB	66.47	7.28	67.45	5.94	0.90
MAR	56.63	7.28	53.74	5.90	2.70
APR	29.89	7.28	21.68	5.79	3.60
MAY	11.98	7.28	0.44	5.14	4.50
JUN	1.89	7.28	0.00	3.66	3.75
JUL	0.00	7.28	0.00	3.15	3.63
AUG	0.38	7.28	0.00	3.25	3.60
SEP	5.93	7.28	0.00	3.90	4.44
OCT	24.34	7.28	13.64	5.69	4.47
NOV	50.07	7.28	50.04	5.94	2.70
DEC	72.77	7.28	74.07	5.94	0.64
TOTAL	396.53	87.37	358.50	60.26	34.94

MONTH	SOLAR FRACTION SPACE	SOLAR FRACTION WATER	SOLAR FRACTION COMBINED	GROSS SAVINGS($) SPACE	GROSS SAVINGS($) WATER	NET SAVINGS($)
JAN	-1.64	18.35	0.10	-1.25	1.34	0.08
FEB	-1.48	18.35	0.48	-0.99	1.34	-0.55
MAR	5.10	18.91	6.67	2.89	1.38	1.56
APR	27.49	20.46	26.11	8.22	1.49	6.11
MAY	96.34	29.39	71.03	11.54	2.14	9.18
JUN	100.00	49.69	60.06	1.89	3.62	1.76
JUL	100.00	56.75	56.75	0.00	4.13	0.50
AUG	100.00	55.36	57.56	0.38	4.03	0.81
SEP	100.00	46.47	70.50	5.93	3.38	4.87
OCT	43.95	21.83	38.86	10.70	1.59	7.82
NOV	0.07	18.43	2.40	0.03	1.34	-1.32
DEC	-1.79	18.35	0.04	-1.30	1.34	-0.60
TOTAL	9.59	31.03	13.46	38.04	27.11	30.21

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.80

EXTREME CLIMATE VARIATIONS

F-CHART

B.81 - B.84 F-CHART worksheets for Caribou, Maine for collector area of $50m^2$.

SESP

B.85 - B.86 Input and corresponding output for Caribou, Maine for collector area of $50m^2$.

B.87 Output for El Paso, Texas using improper curve fit equation for HDIR. Area = $25m^2$.

B.88 Output for Columbus, Ohio using improper curve fit equation for HDIR. Area = $50m^2$ (For test purpose)

B.89 Output for Columbus, Ohio using correct curve fit equation for HDIR. Area = $50m^2$ (Shows almost no variation for standard climates)

F-CHART

B.90 - B.92 Work sheets for El Paso, Texas

B.93 - B.94 Fractions at 25, $50m^2$ for El Paso, Texas

SESP

B.95 - B.98 Inputs and corresponding outputs for 25 and $50m^2$ for El Paso, Texas using the correct curve fit equation for HDIR.

COLLECTOR ORIENTATION WORKSHEET I

AVERAGE DAILY RADIATION ON TILTED SURFACES

A. LOCATION CARIBOU, MAINE B. LATITUDE ϕ = 46.5^0 C. INCLINATION S = 61.5^0

D. (1+COS S)/2 .7386 E. GROUND REFLECTANCE ρ = 0.3 F. ρ(1-COS S)/2 = .0784

G1. MONTH	G2. $\bar{H}$ J/DAY-M²	G3. $\bar{K}_T$	G4. $\bar{H}_d/\bar{H}$	G5. $1-\bar{H}_d/\bar{H}$ (1-G4.)	G6. $\bar{R}_b$	G7. BEAM (G5.×G6.)	G8. DIFFUSE (D.×G4.)	G9. $\bar{R}$ (G7.+G8.+F.)	G10. $\bar{H}_T$ J/DAY-M² (G9.×G2.)
JAN	5.73×10^6	.52	.3524	.6476	3.2262	2.0893	.2603	2.428	13.912×10^6
FEB	9.62×10^6	.58	.3061	.6939	2.2752	1.5788	.2261	1.8833	18.117×10^6
MAR	15.35×10^6	.64	.2606	.7394	1.5316	1.1325	.1925	1.4034	21.542×10^6
APR	16.73×10^6	.52	.3524	.6476	1.0131	.6561	.2603	.9948	16.643×10^6
MAY	19.82×10^6	.51	.3605	.6395	.7420	.4745	.2663	.8192	16.237×10^6
JUN	20.07×10^6	.49	.3772	.6228	.6419	.3998	.2786	.7568	15.189×10^6
JUL	21.29×10^6	.53	.3445	.6555	.6847	.4488	.2544	.7816	16.640×10^6
AUG	18.82×10^6	.54	.3366	.6634	.8857	.5876	.2486	.9146	17.313×10^6
SEP	13.93×10^6	.52	.3524	.6476	1.2963	.8395	.2603	1.1782	16.412×10^6
OCT	8.78×10^6	.47	.3946	.6054	1.9964	1.2086	.2915	1.5785	13.859×10^6
NOV	4.60×10^6	.37	.4984	.5016	2.9338	1.4716	.3681	1.9181	8.823×10^6
DEC	4.43×10^6	.46	.4036	.5964	3.5959	2.1446	.2981	2.5211	11.169×10^6

TABLE B.81

F-CHART WORKSHEET 1

HEATING LOADS

A. UA = DESIGN SPACE HEATING LOAD [W] / DESIGN TEMPERATURE DIFFERENCE [°C] = 467.0 [W/°C]

B. WATER USAGE = 400.0 [LITERS/DAY] x 4190 x (T_W-T_M) [J/LITER] = 82.1 x10^6 [J/DAY]

C1.		C2.	C3.	C4.	C5.
MONTH	DAYS PER MONTH	HEATING DEGREE DAYS [°C-DAY]	SPACE HEATING LOAD [J/MONTH] (86400)(A. x C2.)	DOMESTIC WATER LOAD [J/MONTH] (B. x C1.)	TOTAL LOAD [J/MONTH] (C3. + C4.)
JAN	31	939	37.888 x10^9	2.55 x10^9	40.438 x10^9
FEB	28	817	32.965 x10^9	2.30 x10^9	35.265 x10^9
MAR	31	727	29.334 x10^9	2.55 x10^9	31.884 x10^9
APR	30	477	19.246 x10^9	2.46 x10^9	21.706 x10^9
MAY	31	260	10.491 x10^9	2.55 x10^9	13.041 x10^9
JUN	30	102	4.1156 x10^9	2.46 x10^9	6.756 x10^9
JUL	31	43	1.735 x10^9	2.55 x10^9	4.285 x10^9
AUG	31	64	2.5823 x10^9	2.55 x10^9	5.132 x10^9
SEP	30	187	7.545 x10^9	2.46 x10^9	10.005 x10^9
OCT	31	379	15.292 x10^9	2.55 x10^9	17.842 x10^9
NOV	30	580	23.402 x10^9	2.46 x10^9	25.862 x10^9
DEC	31	853	34.418 x10^9	2.55 x10^9	36.968 x10^9
TOT	365	5428	219.013 x10^9	30.00 x10^9	249.013 x10^9

TABLE B.83

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R/F_R) =$ 3.64 [W/M²-°C]

D. $F_R(\tau\alpha)_n (F'_R/F_R) =$ .66 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. (100-$\bar{T}_a$) [°C]	C8. X/A [1/M²] (C.)x(C7.)x(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	C11. Y/A [1/M²] (D.)x(C9.)x(C10.)x(C1.) / (C5.)
JAN	2.68 x10⁶	111	.0268	1.00	13.912 x10⁶	.00704
FEB	2.42 x10⁶	110	.0275	1.00	18.117 x10⁶	.00949
MAR	2.68 x10⁶	104	.0318	1.00	21.542 x10⁶	.01382
APR	2.59 x10⁶	97	.0421	1.00	16.643 x10⁶	.01518
MAY	2.68 x10⁶	90	.0673	1.00	16.237 x10⁶	.02547
JUN	2.59 x10⁶	85	.1186	1.00	15.189 x10⁶	.04451
JUL	2.68 x10⁶	82	.1867	1.00	16.640 x10⁶	.07945
AUG	2.68 x10⁶	83	.1578	1.00	17.213 x10⁶	.06862
SEP	2.59 x10⁶	88	.0829	1.00	16.412 x10⁶	.03248
OCT	2.68 x10⁶	93	.0508	1.00	13.859 x10⁶	.01589
NOV	2.59 x10⁶	100	.0365	1.00	8.823 x10⁶	.00676
DEC	2.68 x10⁶	108	.0285	1.00	11.169 x10⁶	.00618

TABLE B.83

F-CHART WORKSHEET 3
SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M²]

F. STORAGE SIZE CORRECTION FACTOR (X/X_0) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_0) = 1.0

MONTH	C12. CORRECTED X/A (C8.)×(F.)	C13. CORRECTED Y/A (C11.)×(G.)	C14. X (C12.)×(E.)	C15. Y (C13.)×(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.0268	.00704	1.34	.352	.2489	10.069 $\times 10^9$
FEB	.0275	.00949	1.375	.4745	.349	12.307 $\times 10^9$
MAR	.0318	.01382	1.59	.691	.502	16.006 $\times 10^9$
APR	.0421	.01518	2.105	.759	.520	11.287 $\times 10^9$
MAY	.0673	.02547	3.365	1.2735	.759	9.898 $\times 10^9$
JUN	.1186	.04451	5.93	2.2255	.991	6.695 $\times 10^9$
JUL	.1867	.07945	9.335	3.9725	1.0	4.285 $\times 10^9$
AUG	.1578	.06862	7.89	3.431	1.0	5.132 $\times 10^9$
SEP	.0829	.03248	4.145	1.624	.879	8.794 $\times 10^9$
OCT	.0508	.01589	2.54	.7945	.520	9.278 $\times 10^9$
NOV	.0365	.00676	1.825	.338	.208	5.379 $\times 10^9$
DEC	.0285	.00618	1.425	.309	.206	7.624 $\times 10^9$

ANNUAL FRACTION BY SOLAR (TOTAL, C17.) / (TOTAL, C5.) = .432

TOTAL 106.754 $\times 10^9$

SESP INPUT DATA

LOCATION: CARIBOU, MAINE

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	1690.2	1470.6	1308.6	858.6	468.0	183.6	77.4	115.2	336.6	682.2	1044.0	1535.4
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	504.53	847.04	1351.6	1473.1	1745.15	1767.16	1874.58	1657.1	1226.54	773.08	405.03	390.06
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	12.2	14.0	24.8	37.4	50.0	59.0	64.4	62.6	53.6	44.6	32.0	17.6
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	61.5	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	46.5	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.85

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	35.89	2.21	28.67	1.72	180.00
FEB	31.23	2.21	20.76	1.66	210.00
MAR	27.79	2.21	14.38	1.53	240.00
APR	18.23	2.21	7.85	1.51	295.71
MAY	9.94	2.21	0.15	1.16	342.86
JUN	3.90	2.21	0.00	0.09	167.43
JUL	1.64	2.21	0.00	0.00	152.71
AUG	2.45	2.21	0.00	0.00	150.00
SEP	7.15	2.21	0.00	0.41	187.57
OCT	14.49	2.21	6.10	1.51	228.86
NOV	22.17	2.21	17.59	1.73	90.00
DEC	32.60	2.21	27.04	1.73	150.00
TOTAL	207.45	26.48	122.54	13.06	2395.13

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	118.43	7.28	94.62	5.66	5.40
FEB	103.04	7.28	68.50	5.49	6.30
MAR	91.69	7.28	47.45	5.05	7.20
APR	60.16	7.28	25.91	4.98	8.87
MAY	32.79	7.28	0.49	3.81	10.29
JUN	12.86	7.28	0.00	0.29	5.02
JUL	5.42	7.28	0.00	0.00	4.58
AUG	8.07	7.28	0.00	0.00	4.50
SEP	23.59	7.28	0.00	1.36	5.63
OCT	47.80	7.28	20.11	4.99	6.87
NOV	73.15	7.28	58.05	5.72	2.70
DEC	107.58	7.28	89.23	5.72	4.50
TOTAL	684.60	87.37	404.37	43.08	71.85

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	20.10	22.21	20.22	23.81	1.62	20.02
FEB	33.52	24.58	32.93	34.54	1.79	30.03
MAR	48.25	30.66	46.95	44.24	2.23	39.27
APR	56.93	31.62	54.19	34.25	2.30	27.68
MAY	98.52	47.61	89.27	32.31	3.47	25.49
JUN	100.00	96.01	98.56	12.86	6.99	14.83
JUL	100.00	99.98	99.99	5.42	7.28	8.12
AUG	100.00	100.00	100.00	8.07	7.28	10.85
SEP	100.00	81.28	95.58	23.59	5.92	23.88
OCT	57.92	31.50	54.43	27.69	2.29	23.11
NOV	20.65	21.42	20.72	15.11	1.56	13.96
DEC	17.06	21.39	17.33	18.35	1.56	15.41
TOTAL	40.93	50.69	42.04	280.23	44.29	252.66

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.86

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	14.56	2.21	14.26	1.80	90.00
FEB	9.44	2.21	8.58	1.79	120.00
MAR	6.76	2.21	3.96	1.71	218.57
APR	2.22	2.21	0.02	1.41	244.28
MAY	0.00	2.21	0.00	1.03	166.00
JUN	0.00	2.21	0.00	0.87	149.00
JUL	0.00	2.21	0.00	0.88	171.29
AUG	0.00	2.21	0.00	0.86	167.14
SEP	0.00	2.21	0.00	0.95	142.57
OCT	1.80	2.21	0.00	1.34	212.00
NOV	8.79	2.21	7.73	1.79	120.00
DEC	13.76	2.21	13.47	1.80	90.00
TOTAL	57.33	26.48	48.02	16.22	1930.85

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	48.05	7.28	47.07	5.93	2.70
FEB	31.15	7.28	28.31	5.91	3.60
MAR	22.32	7.28	13.00	5.64	6.56
APR	7.32	7.28	0.08	4.66	7.33
MAY	0.00	7.28	0.00	3.41	4.98
JUN	0.00	7.28	0.00	2.88	5.07
JUL	0.00	7.28	0.00	2.90	5.14
AUG	0.00	7.28	0.00	2.83	5.01
SEP	0.00	7.28	0.00	3.14	4.88
OCT	5.93	7.28	0.00	4.41	6.36
NOV	29.01	7.28	25.50	5.89	3.60
DEC	45.40	7.28	44.44	5.93	2.70
TOTAL	189.19	87.37	158.47	53.53	57.93

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	2.04	18.55	4.21	0.98	1.35	-0.37
FEB	9.13	18.82	10.97	2.85	1.37	0.62
MAR	41.43	22.55	36.79	9.25	1.64	4.33
APR	98.96	35.96	67.53	7.24	2.62	2.53
MAY	100.00	53.21	53.21	0.00	3.87	-1.11
JUN	100.00	60.49	60.49	0.00	4.40	-0.67
JUL	100.00	60.21	60.21	0.00	4.38	-0.75
AUG	100.00	61.16	61.16	0.00	4.45	-0.56
SEP	100.00	56.81	56.81	0.00	4.14	-0.74
OCT	100.00	39.46	66.63	5.93	2.87	2.44
NOV	12.11	19.06	13.50	3.51	1.39	1.30
DEC	2.12	18.55	4.39	0.96	1.35	-0.39
TOTAL	16.24	38.74	23.34	30.72	33.84	6.63

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.87

SOLAR ENERGY ANALYSIS

MONTH	HEAT W/O SOLAR(MEGABTU) SPACE	HEAT W/O SOLAR(MEGABTU) WATER	HEAT W/SOLAR(MEGABTU) SPACE	HEAT W/SOLAR(MEGABTU) WATER	SOLAR PUMP ON-TIME(HRS)
JAN	23.08	2.21	18.22	1.73	60.00
FEB	20.14	2.21	13.42	1.65	98.57
MAR	17.16	2.21	8.44	1.50	252.86
APR	9.06	2.21	0.09	0.96	290.57
MAY	3.63	2.21	0.00	0.03	128.86
JUN	0.57	2.21	0.00	0.00	150.00
JUL	0.00	2.21	0.00	0.00	150.00
AUG	0.11	2.21	0.00	0.00	150.00
SEP	1.80	2.21	0.00	0.00	120.00
OCT	7.38	2.21	0.00	0.01	90.00
NOV	15.17	2.21	7.53	1.50	89.00
DEC	22.05	2.21	16.36	1.70	60.00
TOTAL	120.16	26.48	64.07	9.08	1639.85

MONTH	COST OF HEAT W/O SOLAR($) SPACE	COST OF HEAT W/O SOLAR($) WATER	COST OF HEAT W/SOLAR($) SPACE	COST OF HEAT W/SOLAR($) WATER	OPERATING COST($)
JAN	76.18	7.28	60.13	5.70	1.80
FEB	66.47	7.28	44.30	5.44	2.96
MAR	56.63	7.28	27.85	4.96	7.59
APR	29.89	7.28	0.31	3.18	8.72
MAY	11.98	7.28	0.00	0.09	3.87
JUN	1.89	7.28	0.00	0.00	4.50
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	3.60
OCT	24.34	7.28	0.00	0.04	2.70
NOV	50.07	7.28	24.86	4.96	2.67
DEC	72.77	7.28	53.99	5.59	1.80
TOTAL	396.53	87.37	211.43	29.97	49.20

MONTH	SOLAR FRACTION SPACE	SOLAR FRACTION WATER	SOLAR FRACTION COMBINED	GROSS SAVINGS($) SPACE	GROSS SAVINGS($) WATER	NET SAVINGS($)
JAN	21.07	21.77	21.13	16.05	1.58	15.84
FEB	33.35	25.33	32.56	22.17	1.84	21.05
MAR	50.82	31.81	48.65	28.78	2.32	23.51
APR	98.97	56.35	90.62	29.58	4.10	24.97
MAY	100.00	98.77	99.53	11.98	7.19	15.31
JUN	100.00	100.00	100.00	1.89	7.28	4.67
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	9.61
OCT	100.00	99.40	99.86	24.34	7.24	28.88
NOV	50.35	31.81	48.00	25.21	2.32	24.86
DEC	25.82	23.17	25.58	18.79	1.69	18.68
TOTAL	46.68	65.70	50.11	185.11	57.40	193.31

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.88

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	23.08	2.21	18.20	1.73	90.00
FEB	20.14	2.21	13.32	1.66	158.57
MAR	17.16	2.21	8.33	1.54	261.45
APR	9.06	2.21	0.09	1.00	309.43
MAY	3.63	2.21	0.00	0.04	161.57
JUN	0.57	2.21	0.00	0.00	151.14
JUL	0.00	2.21	0.00	0.00	150.00
AUG	0.11	2.21	0.00	0.00	150.00
SEP	1.80	2.21	0.00	0.00	150.00
OCT	7.38	2.21	0.00	0.23	174.57
NOV	15.17	2.21	7.51	1.59	191.43
DEC	22.05	2.21	16.21	1.70	120.00
TOTAL	120.16	26.48	63.65	9.49	2068.14

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	76.18	7.28	60.07	5.71	2.70
FEB	66.47	7.28	43.96	5.49	4.76
MAR	56.63	7.28	27.48	5.08	7.84
APR	29.89	7.28	0.28	3.30	9.28
MAY	11.98	7.28	0.00	0.13	4.85
JUN	1.89	7.28	0.00	0.00	4.53
JUL	0.00	7.28	0.00	0.00	4.50
AUG	0.38	7.28	0.00	0.00	4.50
SEP	5.93	7.28	0.00	0.00	4.50
OCT	24.34	7.28	0.00	0.75	5.24
NOV	50.07	7.28	24.78	5.25	5.74
DEC	72.77	7.28	53.49	5.62	3.60
TOTAL	396.53	87.37	210.06	31.33	62.04

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	21.14	21.64	21.19	16.11	1.58	14.98
FEB	33.87	24.56	32.95	22.51	1.79	19.54
MAR	51.48	30.17	49.05	29.15	2.20	23.51
APR	99.05	54.65	90.35	29.61	3.98	24.30
MAY	100.00	98.24	99.33	11.98	7.15	14.29
JUN	100.00	100.00	100.00	1.89	7.28	4.64
JUL	100.00	100.00	100.00	0.00	7.28	2.78
AUG	100.00	100.00	100.00	0.38	7.28	3.16
SEP	100.00	100.00	100.00	5.93	7.28	8.71
OCT	100.00	89.73	97.63	24.34	6.53	25.64
NOV	50.52	27.87	47.64	25.29	2.03	21.58
DEC	26.50	22.88	26.17	19.28	1.67	17.35
TOTAL	47.03	64.14	50.12	186.48	56.04	180.47

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.89

COLLECTOR ORIENTATION WORKSHEET 1
AVERAGE DAILY RADIATION ON TILTED SURFACES

A. LOCATION EL PASO, TEXAS B. LATITUDE ϕ = 31.5^0 C. INCLINATION S = 46.5^0

D. (1+COS S)/2 .8442 E. GROUND REFLECTANCE ρ = 0.3 F. ρ(1-COS S)/2 = .0467

G1. MONTH	G2. $\bar{H}$ J/DAY-M^2	G3. $\bar{K}_T$	G4. $\bar{H}_d/\bar{H}$	G5. $1-\bar{H}_d/\bar{H}$ (1-G4.)	G6. $\bar{R}_b$	G7. BEAM (G5.xG6.)	G8. DIFFUSE (D.xG4.)	G9. $\bar{R}$ (G7.+G8.+F.)	G10. $\bar{H}_T$ J/DAY-M^2 (G9.x G2.)
JAN	13.84 $\times 10^6$	.69	.2205	.7795	1.904	1.4842	.1861	1.7170	23.76 $\times 10^6$
FEB	18.07 $\times 10^6$	.72	.1944	.8056	1.549	1.2479	.1641	1.4587	26.36 $\times 10^6$
MAR	22.96 $\times 10^6$	.75	.1661	.8339	1.2007	1.0013	.1402	1.1882	27.28 $\times 10^6$
APR	27.39 $\times 10^6$	.76	.1561	.8439	.9057	.7643	.1318	.9428	25.82 $\times 10^6$
MAY	29.90 $\times 10^6$	.75	.1661	.8339	.7228	.6027	.1402	.7896	23.61 $\times 10^6$
JUN	30.53 $\times 10^6$	.75	.1661	.8339	.6486	.5409	.1402	.7278	22.22 $\times 10^6$
JUL	28.02 $\times 10^6$	.70	.2120	.7880	.6809	.5365	.1790	.7622	21.36 $\times 10^6$
AUG	26.72 $\times 10^6$	.71	.2033	.7967	.8228	.6555	.1716	.8738	23.35 $\times 10^6$
SEP	24.05 $\times 10^6$	.74	.1758	.8242	1.074	.8852	.1484	1.0803	25.98 $\times 10^6$
OCT	19.32 $\times 10^6$	.73	.1852	.8148	1.4267	1.1625	.1563	1.3655	26.38 $\times 10^6$
NOV	15.35 $\times 10^6$	.72	.1944	.8056	1.804	1.4533	.1641	1.6641	25.54 $\times 10^6$
DEC	13.09 $\times 10^6$	.70	.2120	.7880	2.0212	1.5927	.1790	1.8184	23.80 $\times 10^6$

TABLE B.90

F-CHART WORKSHEET 1
HEATING LOADS

A. $UA = \dfrac{\text{DESIGN SPACE HEATING LOAD [W]}}{\text{DESIGN TEMPERATURE DIFFERENCE [°C]}}$ = 467.0 [W/°C]

B. WATER USAGE = 400.0 [LITERS/DAY] × 4190 × (T_W - T_M) [J/LITER] = 82.1 x10^6 [J/DAY]

MONTH	C1. DAYS PER MONTH	C2. HEATING DEGREE DAYS [°C-DAY]	C3. SPACE HEATING LOAD [J/MONTH] (86400)(A. × C2.)	C4. DOMESTIC WATER LOAD [J/MONTH] (B. × C1.)	C5. TOTAL LOAD [J/MONTH] (C3. + C4.)
JAN	31	381	15.373 x10^9	2.55 x10^9	17.923 x10^9
FEB	28	247	9.966 x10^9	2.30 x10^9	12.266 x10^9
MAR	31	177	7.142 x10^9	2.55 x10^9	7.692 x10^9
APR	30	58	2.34 x10^9	2.46 x10^9	4.80 x10^9
MAY	31	0.0	0.0	2.55 x10^9	2.55 x10^9
JUN	30	0.0	0.0	2.46 x10^9	2.46 x10^9
JUL	31	0.0	0.0	2.55 x10^9	2.55 x10^9
AUG	31	0.0	0.0	2.55 x10^9	2.55 x10^9
SEP	30	0.0	0.0	2.46 x10^9	2.46 x10^9
OCT	31	47	1.896 x10^9	2.55 x10^9	4.446 x10^9
NOV	30	230	9.28 x10^9	2.46 x10^9	11.74 x10^9
DEC	31	360	14.526 x10^9	2.55 x10^9	17.076 x10^9
TOT	365	1500	60.523 x10^9	30.00 x10^9	90.523 x10^9

TABLE B.91

F-CHART WORKSHEET 2
ITEMS MAKING UP X AND Y

C. $F_R U_L (F'_R / F_R) =$ 3.64 [W/M^2-°C]

D. $F_R (\tau\alpha)_n (F'_R / F_R) =$ .66 [UNITLESS]

MONTH	C6. SECONDS PER MONTH	C7. $(100-\bar{T}_a)$ [°C]	C8. X/A [1/M²] (C.)×(C7.)×(C6.) / (C5.)	C9. $(\overline{\tau\alpha})/(\tau\alpha)_n$ = H10.	C10. DAILY RADIATION ON COLLECTOR [J/M²-DAY] = G10.	C11. Y/A [1/M²] (D.)×(C9.)×(C10.)×(C1.) / (C5.)
JAN	2.68×10^6	93	.051	1.00	23.76×10^6	.0271
FEB	2.42×10^6	91	.065	1.00	26.36×10^6	.0397
MAR	2.68×10^6	87	.110	1.00	27.28×10^6	.0726
APR	2.59×10^6	83	.163	1.00	25.82×10^6	.1065
MAY	2.68×10^6	78	.298	1.00	23.61×10^6	.1894
JUN	2.59×10^6	73	.280	1.00	22.22×10^6	.1788
JUL	2.68×10^6	73	.279	1.00	21.36×10^6	.1714
AUG	2.68×10^6	74	.283	1.00	23.35×10^6	.1873
SEP	2.59×10^6	77	.295	1.00	25.98×10^6	.2091
OCT	2.68×10^6	82	.180	1.00	26.38×10^6	.1214
NOV	2.59×10^6	89	.071	1.00	25.54×10^6	.0431
DEC	2.68×10^6	93	.053	1.00	23.80×10^6	.0285

TABLE B.92

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 25.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_o) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_o) = 1.0

MONTH	C12. CORRECTED X/A (C8.)x(F.)	C13. CORRECTED Y/A (C11.)x(G.)	C14. X (C12.)x(E.)	C15. Y (C13.)x(E.)	C16. F	C17. HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.051	.0271	1.275	.6775	.5114	9.1658×10^9
FEB	.065	.0397	1.625	.9925	.7001	8.5874×10^9
MAR	.110	.0726	2.75	1.815	1.0	7.692×10^9
APR	.163	.1065	4.075	2.6625	1.0	4.80×10^9
MAY	.298	.1894	7.45	4.735	1.0	2.55×10^9
JUN	.280	.1788	7.0	4.47	1.0	2.46×10^9
JUL	.279	.1714	6.975	4.285	1.0	2.55×10^9
AUG	.283	.1873	7.075	4.6825	1.0	2.55×10^9
SEP	.295	.2091	7.375	5.2275	1.0	2.46×10^9
OCT	.180	.1214	4.5	3.035	1.0	4.446×10^9
NOV	.071	.0431	1.775	1.0775	.7415	8.7052×10^9
DEC	.053	.0285	1.325	.7129	.5339	9.1169×10^9
					TOTAL	65.0833×10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .719

F-CHART WORKSHEET 3

SOLAR HEATING LOAD FRACTION

E. AREA = 50.0 [M^2]

F. STORAGE SIZE CORRECTION FACTOR (X/X_o) = 1.0

G. LOAD HEAT EXCHANGER CORRECTION FACTOR (Y/Y_o) = 1.0

	C12.	C13.	C14.	C15.	C16.	C17.
MONTH	CORRECTED X/A (C8.)×(F.)	CORRECTED Y/A (C11.)×(G.)	X (C12.)×(E.)	Y (C13.)×(E.)	F	HEATING LOAD SUPPLIED [J/MONTH] (C16.)(C5.)
JAN	.051	.0271	2.55	1.355	.8439	15.1252 x10^9
FEB	.065	.0397	3.25	1.985	1.0	12.266 x10^9
MAR	.110	.0726	5.5	3.63	1.0	7.692 x10^9
APR	.163	.1065	8.15	5.325	1.0	4.8 x10^9
MAY	.298	.1894	14.9	9.47	1.0	2.55 x10^9
JUN	.280	.1788	14.0	8.94	1.0	2.46 x10^9
JUL	.279	.1714	13.95	8.57	1.0	2.55 x10^9
AUG	.283	.1873	14.15	9.365	1.0	2.55 x10^9
SEP	.295	.2091	14.75	10.455	1.0	2.46 x10^9
OCT	.180	.1214	9.0	6.07	1.0	4.446 x10^9
NOV	.071	.0431	3.55	2.155	1.0	11.74 x10^9
DEC	.053	.0285	2.65	1.4258	.8718	14.8868 x10^9
					TOTAL	83.526 x10^9

ANNUAL FRACTION BY SOLAR (TOTAL, C17.)/(TOTAL, C5.) = .9227

TABLE B.94

SESP INPUT DATA

LOCATION: EL PASO, TEXAS

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	685.8	444.6	318.6	104.4	.001	.001	.001	.001	.001	84.6	414.0	648.0
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	1218.61	1591.06	2021.63	2411.69	2632.7	2688.17	2467.16	2352.7	2117.6	1701.13	1351.57	1152.6
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	44.6	48.2	55.4	62.6	71.6	80.6	80.6	78.8	73.4	64.4	51.8	44.6
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	8267.8	538.2	620.4	661.0	46.5	990.75						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	T1	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	31.5	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

TABLE B.95

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	14.56	2.21	6.32	1.17	120.00
FEB	9.44	2.21	0.51	0.63	180.00
MAR	6.76	2.21	0.00	0.06	210.00
APR	2.22	2.21	0.00	0.00	211.00
MAY	0.00	2.21	0.00	0.00	210.00
JUN	0.00	2.21	0.00	0.00	210.00
JUL	0.00	2.21	0.00	0.00	180.00
AUG	0.00	2.21	0.00	0.00	180.00
SEP	0.00	2.21	0.00	0.00	180.00
OCT	1.80	2.21	0.00	0.00	180.00
NOV	8.79	2.21	0.17	0.50	150.00
DEC	13.76	2.21	5.52	1.12	120.00
TOTAL	57.33	26.48	12.52	3.49	2130.99
	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	48.05	7.28	20.84	3.86	3.60
FEB	31.15	7.28	1.68	2.09	5.40
MAR	22.32	7.28	0.00	0.20	6.30
APR	7.32	7.28	0.00	0.00	6.33
MAY	0.00	7.28	0.00	0.00	6.30
JUN	0.00	7.28	0.00	0.00	6.30
JUL	0.00	7.28	0.00	0.00	5.40
AUG	0.00	7.28	0.00	0.00	5.40
SEP	0.00	7.28	0.00	0.00	5.40
OCT	5.93	7.28	0.00	0.00	5.40
NOV	29.01	7.28	0.56	1.66	4.50
DEC	45.40	7.28	18.23	3.69	3.60
TOTAL	189.19	87.37	41.31	11.50	63.93

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	56.62	46.97	55.35	27.21	3.42	27.03
FEB	94.62	71.27	90.19	29.48	5.19	29.26
MAR	100.00	97.29	99.33	22.32	7.08	23.11
APR	100.00	99.96	99.98	7.32	7.28	8.26
MAY	100.00	100.00	100.00	0.00	7.28	0.98
JUN	100.00	100.00	100.00	0.00	7.28	0.98
JUL	100.00	100.00	100.00	0.00	7.28	1.88
AUG	100.00	100.00	100.00	0.00	7.28	1.88
SEP	100.00	100.00	100.00	0.00	7.28	1.88
OCT	100.00	100.00	100.00	5.93	7.28	7.81
NOV	98.08	77.19	93.89	28.45	5.62	29.57
DEC	59.85	49.30	58.39	27.17	3.59	27.16
TOTAL	78.16	86.83	80.90	147.87	75.86	159.81

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.96

SESP INPUT DATA

LOCATION: EL PASO, TEXAS

C	C1	C2	C3	C4	C5							
	1.0	1.0	12.0	1.0	0.0							
DD	1	2	3	4	5	6	7	8	9	10	11	12
	685.8	444.6	318.6	104.4	.001	.001	.001	.001	.001	84.6	414.0	648.0
HBAR	1	2	3	4	5	6	7	8	9	10	11	12
	1218.61	1591.06	2021.63	2411.69	2632.7	2688.17	2467.16	2352.7	2117.6	1701.13	1351.57	1152.6
TAMB	1	2	3	4	5	6	7	8	9	10	11	12
	44.6	48.2	55.4	62.6	71.6	80.6	80.6	78.8	73.4	64.4	51.8	44.6
GAL	1	2	3	4	5	6	7	8	9	10	11	12
	2.0	0.0	0.0	0.0	0.0	0.0	1.4	4.8	7.3	8.4	6.9	4.6
	13	14	15	16	17	18	19	20	21	22	23	24
	3.5	5.3	2.5	2.3	2.0	3.8	6.9	11.8	9.6	6.9	5.4	4.7
	STO	A	CH	CC	TILT	VOL						
	4133.9	269.1	310.2	330.5	46.5	495.4						
	UA	XM	B	AZ	DENH	DENC	SPHTH	SPHTC	THOT	TCOLD	RLOSS	$S
	4262.5	.66	.68	0.0	8.89	8.34	.8	1.0	140.0	51.8	21232.9	3.3
	$W	RLAT	TI	TLIM	$FAN	UATOP	UABOT	UASEG	ETA	GPH	ETA2	GPH2
	3.3	31.5	70.0	68.0	.03	1.41	1.41	.141	.7	480.0	.6	------

SOLAR ENERGY ANALYSIS

	HEAT W/O SOLAR(MEGABTU)		HEAT W/SOLAR(MEGABTU)		SOLAR PUMP ON-TIME(HRS)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	14.56	2.21	0.15	0.25	120.00
FEB	9.44	2.21	0.00	0.00	180.00
MAR	6.76	2.21	0.00	0.00	180.00
APR	2.22	2.21	0.00	0.00	210.00
MAY	0.00	2.21	0.00	0.00	180.86
JUN	0.00	2.21	0.00	0.00	180.00
JUL	0.00	2.21	0.00	0.00	158.14
AUG	0.00	2.21	0.00	0.00	180.00
SEP	0.00	2.21	0.00	0.00	180.00
OCT	1.80	2.21	0.00	0.00	180.00
NOV	8.79	2.21	0.00	0.00	150.00
DEC	13.76	2.21	0.00	0.03	120.00
TOTAL	57.33	26.48	0.15	0.28	2018.99

	COST OF HEAT W/O SOLAR($)		COST OF HEAT W/SOLAR($)		OPERATING COST($)
MONTH	SPACE	WATER	SPACE	WATER	
JAN	48.05	7.28	0.48	0.83	3.60
FEB	31.15	7.28	0.00	0.01	5.40
MAR	22.32	7.28	0.00	0.00	5.40
APR	7.32	7.28	0.00	0.00	6.30
MAY	0.00	7.28	0.00	0.00	5.43
JUN	0.00	7.28	0.00	0.00	5.40
JUL	0.00	7.28	0.00	0.00	4.74
AUG	0.00	7.28	0.00	0.00	5.40
SEP	0.00	7.28	0.00	0.00	5.40
OCT	5.93	7.28	0.00	0.00	5.40
NOV	29.01	7.28	0.00	0.00	4.50
DEC	45.40	7.28	0.00	0.09	3.60
TOTAL	189.19	87.37	0.48	0.92	60.57

	SOLAR FRACTION			GROSS SAVINGS($)		NET SAVINGS($)
MONTH	SPACE	WATER	COMBINED	SPACE	WATER	
JAN	99.00	88.61	97.63	47.57	6.45	50.42
FEB	100.00	99.89	99.98	31.15	7.27	33.03
MAR	100.00	100.00	100.00	22.32	7.28	24.20
APR	100.00	100.00	100.00	7.32	7.28	8.30
MAY	100.00	100.00	100.00	0.00	7.28	1.86
JUN	100.00	100.00	100.00	0.00	7.28	1.88
JUL	100.00	100.00	100.00	0.00	7.28	2.54
AUG	100.00	100.00	100.00	0.00	7.28	1.88
SEP	100.00	100.00	100.00	0.00	7.28	1.88
OCT	100.00	100.00	100.00	5.93	7.28	7.81
NOV	100.00	100.00	100.00	29.01	7.28	31.79
DEC	100.00	98.80	99.83	45.40	7.19	49.00
TOTAL	99.75	98.94	99.49	188.70	86.44	214.58

FUEL RATES($/BTU DELIVERED) SPACE 0.00 WATER 0.00 FAN ON-TIME RATE($/HR) 0.03

TABLE B.98

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[3] Klein, S. A. et al., TRNSYS - A Transient System Simulation Program, User's Manual, Report #38, Engineering Experiment Station, University of Wisconsin - Madison, 1973.

[4] Liu, B.Y.H. and Jordan, R. C., "The Interrelationship and Characteristic Distribution of Direst, Diffuse, and Total Solar Radiation", Solar Energy, 4, No. 3, pp 1-19, 1960.

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[6] Meinel, A. B. and Meinel, M. P., Applied Solar Energy, Addison - Wesley, p. 47, 1976.

[7] Ibid.