

Dr. 6061

SOLAR/2011-78/14

# **SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION**

**TERRELL D. MOSELEY OFFICE BUILDING  
LYNCHBURG, VIRGINIA  
FEBRUARY 1978 THROUGH MAY 1978**

July 1978

Contract EG-77-C-01-4049

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**United States Department of Energy**

**National Solar Heating and  
Cooling Demonstration Program**

**National Solar Data Program**

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IBM Corporation  
Huntsville, AL 35805



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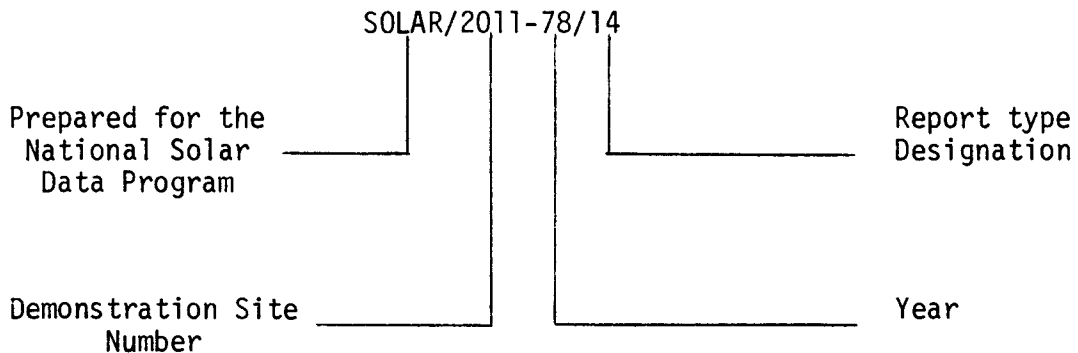
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## NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the T. D. Moseley project site is designated as SOLAR/2011-78/14. The elements of this designation are explained in the following illustration:



o Demonstration Site Number:

Each project site has its own discrete number - 1000 through 1999 for residential sites and 2000 through 2999 for commercial sites.

o Report Type Designation:

This number identifies the type of report, e.g.,

- Monthly Performance Reports are designated by the numbers 01 (for January) through 12 (for December)
- Solar Energy System Performance Evaluations are designated by the number 14.
- Solar Project Descriptions are designated by the number 50
- Solar Project Cost Reports are designated by the number 60

These reports are disseminated through the U. S. Department of Energy, Technical Information Center, P. O. Box 62, Oak Ridge, Tennessee 37830.

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## 1. FOREWORD

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy in accordance with the Solar Heating and Cooling Demonstration Act of 1974. The overall goal of this activity is to assist in establishment of a viable solar energy industry and to stimulate its growth so as to achieve a substantial reduction in fossil fuel consumption through widespread use of solar heating and cooling applications. The International Business Machines Corporation is contributing to this overall goal by monitoring, analyzing, and reporting system performance of solar energy systems through the National Solar Data Program. Information gathered through the Demonstration Program is disseminated in a series of site-specific reports. These reports are issued as appropriate and may include topics such as:

- o Solar Project Description
- o Design/Construction Report
- o Project Costs
- o Maintenance and Reliability
- o Operational Experience
- o System Performance Evaluation

All reports issued during this report period by the National Solar Data Program for the Terrell D. Mosely solar energy system are listed in Section 5, References. Also presented is information on how to order these reports.

This System Performance Evaluation report is a product of the National Solar Data Program. Evaluation reports are periodically issued to document results from analysis of a specific solar energy system's operational performance during the period covered by the report. Information presented has been extracted and/or generated from data specific to the system being evaluated and includes system description, operational characteristics and capabilities, as well as evaluation of results from actual versus expected performance comparison. Each parametric value presented as characteristic of this system's performance represents over eight thousand discrete measurements obtained monthly through the National Solar Data Network.

Acknowledgments are extended to the personnel of Terrell E. Moseley, Inc. for their assistance in answering questions related to configuration and operation of the Terrell D. Mosely solar energy system.

## 2. SUMMARY AND CONCLUSIONS

This System Performance Evaluation report presents a summary of the February 1978 to May 1978 operation of the Terrell D. Moseley solar energy system. This system is designed to provide space heating and domestic hot water pre-heating for approximately 1780 square feet of office area in a Lynchburg, Virginia office building. Presented are results of an evaluation of measured system performance and a comparison of measured micrometeorological data with long term average conditions. Performance evaluations of each major subsystem are also presented.

Measurement data used [1-4] \* were collected through the National Solar Network [5] for the period September 1977 through May 1978. As measurement data were not available for November 1977, November climatic conditions have been estimated and are so indicated where used in this study. System performance data are provided through the National Solar Data Network via the IBM developed Central Data Processing System [6]. The Central Data Processing System supports the daily collection and analysis of data from instrumented solar energy systems located throughout the country. These data are summarized into monthly performance reports which form the common basis used for system evaluation.

This report includes: a brief system description, review of actual system performance during the report period, analysis of performance based on evaluation of climatic, load and operational conditions, and an overall discussion of the results of analysis. Also presented are results of a special study of actual versus expected performance of the Terrell D. Moseley solar energy system.

Measured monthly values of AMBIENT TEMPERATURE\*\* during the four month report period were slightly cooler than normal with the measured average AMBIENT TEMPERATURE 49°F vs. the long term average for the same period of 52°F. This resulted in a greater number of measured Heating Degree Days\*\*\* (1962 vs. 1706) than the long term average. The average monthly incident solar energy per unit area measured during the report period (at a 50° tilt) was 39910 Btu/Sq. Ft. This was less than the estimated normal for the same four month period of 45111 Btu/ Sq. Ft. and the estimated yearly average of 44081 Btu/Sq.Ft. These estimates are for a south facing surface tilted at 50° to horizontal.

During the report period the Terrell D. Moseley solar energy system provided 13.6 million Btu of the 18.3 million Btu demand for space heating. The 74 percent solar utilization was greater than the 70 percent expected. Solar energy for space heating was available 100 percent of the time.

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\* Numbers in brackets designate References listed in Section 5.

\*\* Terms in all capitals are formal names of specific performance factors used in the National Solar Data Program and as defined in References 9 and 10.

\*\*\* Terms with first letter capitals are other than the specific performance factors defined.

In conclusion, the Terrell D. Moseley solar energy system met the demand even though weather conditions were more severe than long term average conditions for the locality. Expected performance parameters, with the exception of system savings, were matched or exceeded by the actual performance of the system. Total energy savings are equivalent to 3866 cubic feet of natural gas. The system savings were far below expectations.

### 3. SYSTEM DESCRIPTION SUMMARY

The following is a brief summary of the Terrell D. Mosely Solar Energy System. For detailed system description see Reference 13. Highlights of this site include:

- o COLLECTOR TYPE: Liquid, Flat plate
- o FREEZE PROTECTION: Drain down
- o APPLICATION: Heating, Hot water
- o STORAGE: Interior tank
- o NEW/RETROFIT: Retrofit
- o PERFORMANCE EVALUATION INSTRUMENTATION: Yes
- o SITE-SPECIFIC FEATURES: Water source heat pump, Site fabricated collectors

The solar energy system for a one story office building in Lynchburg, Virginia, preheats domestic hot water and heats 1780 square feet of occupied space. The building owner, Terrell E. Mosely, Inc., designed and installed the solar system as a retrofit.

The 400 square foot collector array was fabricated by the owner in a single bank on the roof of the adjoining warehouse to the solar conditioned offices. The aluminum absorber plate, painted flat black, is mechanically fastened to a manifolded copper tubing. A thermal mastic is used to improve heat transfer properties between the absorber plate and the tubing. A single glazing of tempered glass covers the absorber plate. The collector back is insulated with a 4 inch thick fiberglass batt. The collector array is mounted on a wooden framing. A steel angle and pipe structure supports the collector array at a 50° tilt to the horizontal.

The collectors are piped in parallel in reverse return and are drained down for freeze protection.

A 2000 gallon steel storage tank, covered with fiberglass insulation, is located in the warehouse adjoining the solar-conditioned offices. The tank is kept partially full so that water may expand without the need for a separate expansion tank. Service hot water is preheated by an immersed coil in the storage tank and is passed through an electric water heater.

Space heating is provided by pumping water from the storage tank through a duct heating coil and/or a water source heat pump. Valves direct the flow through the coil and heat pump and are dependent on the storage water temperature. To maintain a minimum temperature of 57°F in the storage tank, hot water from an auxiliary gas-fired boiler is circulated through an immersed coil in the storage tank.

Space cooling is provided by the water source heat pump, which is located in a closed in the solar condition space. A closed-circuit, dry cooling tower on the warehouse roof is used for heat rejection.

The solar energy space heating system has been fully instrumented for performance evaluation since September 1977, and integrated into the National Solar Data Network.

The collector to storage system is shown schematically in Figure III-1. Figure III-2 presents the storage to loads schematic. The three modes of solar operation for space heating are described below.

Mode 1 - Collector-to-Storage: This mode is initiated when there is a 20°F difference in temperature between the collector and the storage tank. The transfer fluid is circulated from the tank through the collectors and back to the tank until the temperature differential drops to less than 3°F; then the fluid drains into the tank.

Mode 2 - Storage-to-Space Heating: This mode is initiated when there is a demand for space heating, and the temperature of the storage tank water is greater than 85°F. Water is circulated from the storage tank through a liquid-to-air heat exchanger in the air handling unit distribution duct and back to the storage tank.

Mode 3 - Storage-to-Heat Pump: This mode is initiated when there is a demand for space heating by the second stage of the thermostat, and the temperature of the storage tank is less than 85°F. Water is drawn from storage and circulated through a liquid-to-air heat exchanger in the heat pump as long as the storage tank temperature is above 50°F.



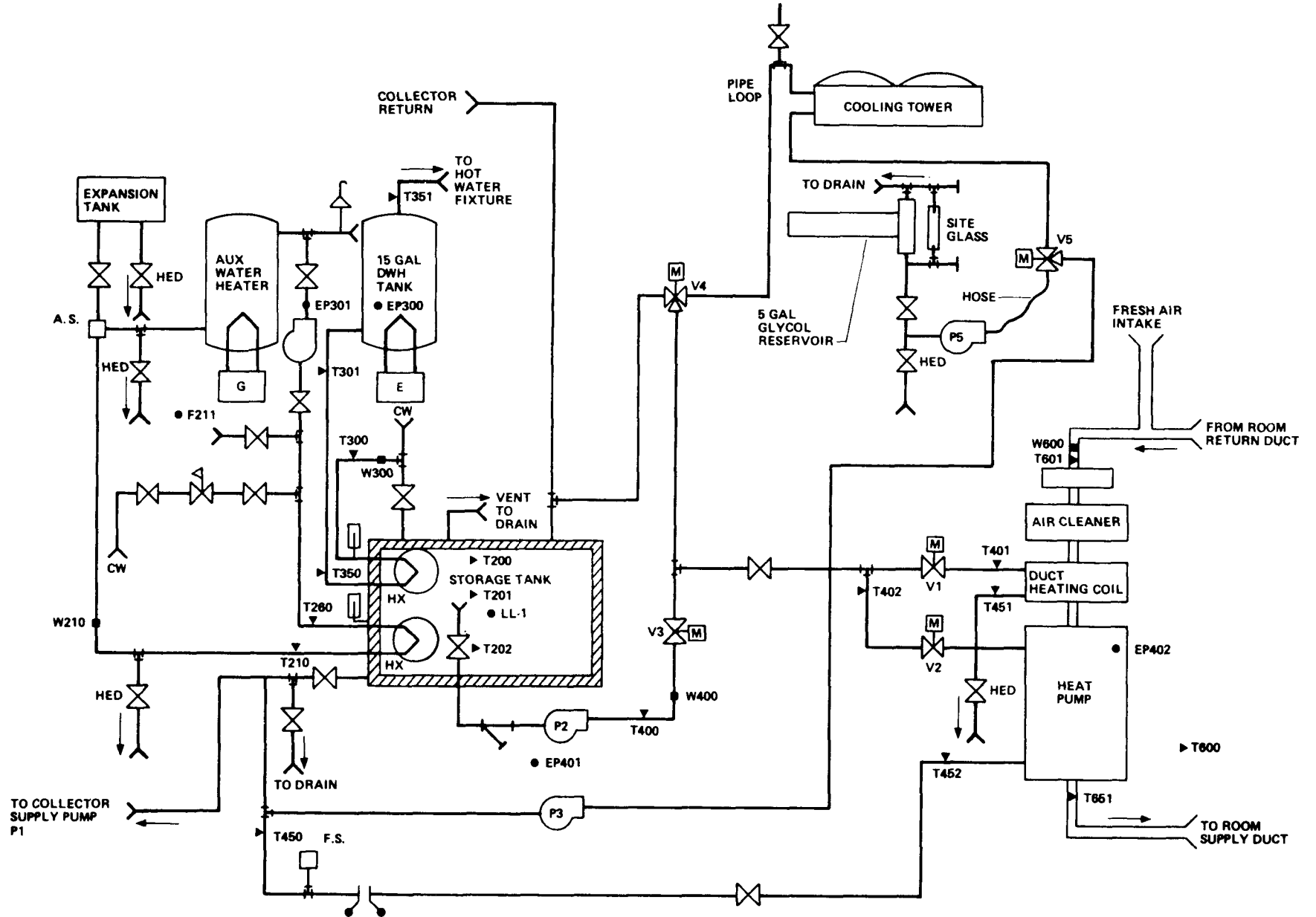


Figure III-2. Terrell D. Moseley System Schematic Storage to Loads

#### 4. PERFORMANCE ANALYSIS

Evaluation of the performance of solar energy systems is accomplished by calculating a set of primary performance factors designed to provide evaluation on the thermal effectiveness of the component subsystems. These computations are based upon a set of performance factors proposed in the intergovernmental agency report "Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program [9]. Data from instrumentation, personalized to the unique features of the site's solar energy system, are collected via the National Solar Data Network. These data are first formed into performance factors indicative of the hourly performance of the system by summation or averaging techniques as appropriate. These hourly factors then serve as a basis for the calculation of daily and monthly values.

The general definitions of the evaluation parameters are provided in Appendix A. The hourly equations used for the T. D. Moseley solar energy system are presented in Appendix B.

Each month a summary of overall performance of the site and a detailed subsystem by subsystem report is available. Monthly reports for the period covered by this report, February 1978 through May 1978 are available for the T. D. Moseley solar energy system [1-4]. These monthly reports establish the baseline for actual system performance used in the comparisons presented in this report.

#### 4.1 Meteorological and Load Conditions

Monthly values of INCIDENT SOLAR ENERGY PER UNIT AREA (total solar energy incident as measured in the plane of the collector array), AMBIENT TEMPERATURE (average outdoor temperature at the site), Heating Degree Days and Cooling Degree Days measured at the T. D. Moseley site during the report period are presented in Table IV-1.

Monthly values of Heating Degree Days are derived from daily values of AMBIENT TEMPERATURE as they are useful indications of the system's heating load. Heating Degree Days are computed as the daily average temperature falls below or rises above 65°F. If the daily average temperature is 60°F, then 5 Heating Degree Days have accumulated. Daily values of Heating Degree Days are summed monthly.

Also presented in Table IV-1 are long term average (normal) monthly values for the climatic parameters described above. Data for long term INCIDENT SOLAR ENERGY PER UNIT AREA are estimates based on the Climatic Atlas of the United States [7]. These estimates use the horizontal data given in the reference to provide average values for the 50° tilt angle of the T. D. Moseley collector array. The estimation procedure is detailed in Reference 14. All other long term average climatic data were taken from the National Oceanic and Atmospheric Administration summary [8] for Lynchburg, Virginia. Long term averages are presented for the entire year to facilitate comparative reference.

INCIDENT SOLAR ENERGY for the T. D. Moseley site was less than average three the four months reported. The exception was February 1978. The average amount measured was 84% of normal for this period. May 1978 had the lowest percentage with 81% of the normal May INCIDENT SOLAR ENERGY.

AMBIENT TEMPERATURE was slightly below normal for February, March and May 1978. It was higher than normal for April 1978. The average for the entire report period was 49°F versus the 52°F normal average for the same period.

SPACE HEATING LOAD would be expected to have been slightly less than average for April 1978 and greater than average for February, March and May 1978. This evaluation is based on the measured Heating Degree Days which is 13% above normal for the report period.

TABLE IV-1  
Meteorological Conditions

Month (Year)(1)	INCIDENT SOLAR ENERGY PER UNIT AREA (50°TILT),Btu/Ft <sup>2</sup>		AMBIENT TEMPERATURE,°F		Heating Degree Days		Cooling Degree Days	
	Measured(2)	Long Term Average(3)	Measured(2)	Long Term Average(4)	Measured(1)	Long Term Average(4)	Measured(1)	Long Term Average(4)
Jan 78	-	32694	-	37	-	880	-	0
Feb 78	39250	36861	30	39	967	753	0	0
Mar 78	40198	46111	43	46	646	607	0	0
Apr 78	40800	48833	57	55	236	261	11	8
May 78	39392	48639	64	66	113	85	98	91
Jun -	-	47028	-	73	-	0	-	232
Jul -	-	47667	-	77	-	0	-	335
Aug -	-	49083	-	75	-	0	-	291
Sep	-	46444	-	70	-	33	-	126
Oct	-	46722	-	59	-	234	-	17
Nov	-	42556	-	48	-	540	-	0
Dec	-	36333	-	39	-	848	-	0
Avg. for Report Period	39910	45111	49	52	481	353	55	49.5
Total for Report Period	159640	180444	-	-	1962	1706	109	99

NOTE:

1. Measured data covers the period February 1978 through May 1978
2. Values for this parameter obtained through National Solar Data Network
3. Values for this parameter estimated from data presented in Reference 7
4. Values for this parameter obtained from Reference 8

## 4.2 System Thermal Performance

The system performance of a solar energy system may be characterized by its thermal performance and its availability. Thermal performance is represented by a single performance factor, TOTAL SOLAR ENERGY USED (the sum of solar energy supplied to each of the subsystems). System availability must be obtained by evaluating the availability of each component subsystem. A general discussion of system availability with the specifics for the T. D. Moseley system is presented in Section 4.7.

The T. D. Moseley solar energy system thermal performance is presented in Table IV-2. The TOTAL SOLAR ENERGY USED to satisfy the space heating subsystem demand during the four month period is 13.6 million Btu. Reference to Table IV-5 shows that this is approximately 74 percent of that subsystem's demand. Utilizing long term average daily temperatures, the measured space heating demand is 107 percent of that expected for the period. In general, the T. D. Moseley solar energy system thermal performance exceeded its design goals for the period.

TABLE IV-2  
System Thermal Performance

Month	ENERGY TO LOADS Btu (1, 2)	SOLAR ENERGY USED-HEATING Btu (1, 2)	SOLAR ENERGY USED-TOTAL Btu (1, 2)
Feb 78	$8.56 \times 10^6$	$5.82 \times 10^6$	$5.82 \times 10^6$
Mar 78	$6.44 \times 10^6$	$4.49 \times 10^6$	$4.49 \times 10^6$
Apr 78	$2.01 \times 10^6$	$1.97 \times 10^6$	$1.97 \times 10^6$
May 78	$1.35 \times 10^6$	$1.35 \times 10^6$	$1.35 \times 10^6$

NOTE:

1. Values for this parameter obtained through National Solar Data Network
2. Values for February and March do not correspond to values reported for those months in References 1 and 2 due to an error in measuring SOLAR ENERGY USED-HEATING. Corrected reports are being re-issued for these months.

### 4.3 Collector Array Subsystem

Collector array performance is described by comparison of INCIDENT SOLAR ENERGY (total solar energy incident on the gross collector array) with COLLECTED SOLAR ENERGY (thermal energy removed from the collector array by the energy transport medium). The ratio of these represents the COLLECTOR ARRAY EFFICIENCY (ratio of energy collected to total solar energy incident on the collector array) where the gross collector array area is 400 square feet. Measured monthly values of INCIDENT SOLAR ENERGY, COLLECTED SOLAR ENERGY, and COLLECTOR ARRAY EFFICIENCY are presented in Table IV-3.

Evaluation of collector efficiency using OPERATIONAL INCIDENT ENERGY (amount of solar energy incident on the gross collector array during the time the collector loop is active) and compensating for the difference between gross collector array area and the gross collector area yields Operational Collector Efficiency. Operational Collector Efficiency is computed as:

$$\text{Operational Collector Efficiency} = \frac{\text{COLLECTED SOLAR ENERGY}}{\text{OPERATIONAL SOLAR ENERGY} \times \left( \frac{\text{gross collector area}}{\text{gross collector array area}} \right)}$$

where gross collector area is the product of the number of collectors and the total area of the aperture of one unit

and gross collector array area is the total area perpendicular to the solar flux vector including all mounting, connecting and transport hardware.

This latter efficiency term is not precisely the same as collector efficiency as represented by the ASHRAE Standard 93-77 [12]. Both Operational Collector Efficiency and the ASHRAE collector efficiency are defined as the ratio of actual useful energy collected to solar energy incident upon the collector and both use the same definition of collector area. However, the ASHRAE efficiency is determined from instantaneous evaluation under tightly controlled, steady state test conditions, while the Operational Collector Efficiency is determined from the actual conditions of all-day solar energy system operation. Measured monthly values of OPERATIONAL INCIDENT ENERGY and computed values of Operational Collector Efficiency are also presented in Table IV-3.

The average Operational Collector Efficiency of the collector array during the report period was .31. The collector operational efficiency fell below 0.31 during April and May as a result of much higher average storage tank temperatures. Also, during May, the collector was manually turned off whenever the storage temperature reached 148°F. This action was taken to save electrical pumping power.

TABLE IV-3  
Collector Array Performance

Month	INCIDENT SOLAR ENERGY, Btu (1, 3)	COLLECTED SOLAR ENERGY, Btu (1, 3)	COLLECTOR ARRAY EFFICIENCY, Btu/Btu (1, 3)	OPERATIONAL INCIDENT ENERGY, Btu (1, 3)	Operational Collector Efficiency, Btu/Btu (?, 4)
Feb 78	15.70 x 10 <sup>6</sup>	6.44 x 10 <sup>6</sup>	0.41	14.54 x 10 <sup>6</sup>	0.44
Mar 78	16.08 x 10 <sup>6</sup>	5.73 x 10 <sup>6</sup>	0.36	14.53 x 10 <sup>6</sup>	0.39
Apr 78	16.32 x 10 <sup>6</sup>	3.27 x 10 <sup>6</sup>	0.20	13.53 x 10 <sup>6</sup>	0.24
May 78	15.76 x 10 <sup>6</sup>	2.03 x 10 <sup>6</sup>	0.13	11.97 x 10 <sup>6</sup>	0.17

NOTE:

1. Values for this parameter obtained through National Solar Date Network
2. Values for this parameter computed from data obtained through National Solar Data Network
3. This parameter is based on gross collector array area
4. This parameter is based on gross collector area

#### 4.4 Storage Subsystem

Storage subsystem performance is described by comparison of ENERGY TO STORAGE (amount of energy delivered to the storage tank), ENERGY FROM STORAGE (amount of energy extracted by the heating subsystem) and CHANGE IN STORED ENERGY (difference in stored energy from beginning to end of the report period). The ratio of the sum of ENERGY FROM STORAGE and CHANGE IN STORED ENERGY to the ENERGY TO STORAGE is defined as STORAGE EFFICIENCY. Measured monthly values of ENERGY TO STORAGE, ENERGY FROM STORAGE, CHANGE IN STORED ENERGY, and STORAGE EFFICIENCY are presented in Table IV-4.

The 2000 gallon storage tank was charged with 19.5 million Btu of auxiliary and solar energy and supplied 15.7 million Btu to the space heating load. The monthly STORAGE AVERAGE TEMPERATURE (mass-weighted average temperature of the primary storage medium) rose from 68°F in February to 124°F in May. Usage of solar energy was high in February and March due to the operation of the solar-assisted heat pump down to storage tank temperatures of approximately 55°F. This caused the storage temperature to remain low, energy losses were correspondingly low and the majority of energy delivered to storage was used for space heating. During April and May the space heating demand was less, allowing storage temperatures to rise.

In effect, the bulk of the available stored solar energy was utilized to satisfy the space heating subsystem requirements, signifying an efficiently designed system.

TABLE IV-4  
Storage Subsystem Performance

Month	ENERGY TO STORAGE, Btu(1)	ENERGY FROM STORAGE, Btu(1)	CHANGE IN STORED ENERGY, Btu(1)	STORAGE EFFICIENCY Btu/Btu(1)	STORAGE AVERAGE TEMPERATURE °F (1)
Feb 78	$7.47 \times 10^6$	$6.85 \times 10^6$	$0.19 \times 10^6$	0.94	68
Mar 78	$6.75 \times 10^6$	$5.50 \times 10^6$	$0.79 \times 10^6$	0.93	86
Apr 78	$3.27 \times 10^6$	$1.97 \times 10^6$	$0.07 \times 10^6$	0.62	122
May 78	$2.03 \times 10^6$	$1.35 \times 10^6$	$0.29 \times 10^6$	0.81	124

NOTE:

1. Values for this parameter obtained through National Solar Data Network

#### 4.5 Space Heating Subsystem

Space heating subsystem performance is described by comparison of SOLAR ENERGY USED (amount of solar energy supplied to the space heating subsystem) and AUXILIARY THERMAL ENERGY USED (amount of energy supplied to the major components of the subsystem in the form of thermal energy) with SPACE HEATING LOAD (sum of energy supplied by solar system plus energy supplied by auxiliary sources). Measured monthly values for these performance factors are presented in Table IV-5.

The T. D. Moseley Space Heating subsystem has two modes of solar operation. The primary solar mode is: the circulation of solar heated water from the storage tank directly to a liquid-to-air heat exchanger located in the buildings air distribution system. The air handler unit then extracts the necessary amount of solar energy from the water to satisfy the space heating demand. The secondary solar mode of operation is the circulation of solar heated water to a wet heat pump's water-to-refrigerant heat exchanger. If solar heated water is unavailable in the storage tank, then auxiliary thermal energy is provided to the storage tank by a natural gas-fired boiler.

During February all space heating demand was provided via the wet heat pump. March was a transition month between heat pump operation and the direct water-to-air heat exchanger operation. The remaining space heating demand was satisfied almost entirely by using the direct water-to-air heat exchanger. Due to the high energy penalty of the electrical compressor when operating in the solar-assisted heat pump mode, the utilization of solar energy would be more efficient in the direct solar-to-load mode. This mode is available when the storage tank temperature is above 85°F. The system operated in this mode 60 percent of the time. Overall performance of the solar space heating system during the report period has been to supply 13.6 million Btu of the required 18.3 million Btu or 74% of the load.

TABLE IV-5

## Heating Subsystem Performance

Month	SOLAR ENERGY USED-HEATING, Btu(1,2)	AUXILIARY THERMAL USED, Btu (1)	SPACE HEATING LOAD, Btu (1, 2)
Feb 78	$5.82 \times 10^6$	$2.75 \times 10^6$	$8.56 \times 10^6$
Mar 78	$4.49 \times 10^6$	$1.94 \times 10^6$	$6.44 \times 10^6$
Apr 78	$1.97 \times 10^6$	$0.037 \times 10^6$	$2.01 \times 10^6$
May 78	$1.35 \times 10^6$	0	$1.35 \times 10^6$

## NOTE:

1. Values for this parameter obtained through National Solar Data Network
2. Values for February and March do not correspond to values officially reported for those months due to an error in measuring the amount of SOLAR ENERGY USED-HEATING. Corrected reports will be re-issued for these months.

#### 4.6 Operating Energy

Operating energy for the solar energy system is described by the Energy Collection and Storage Subsystem (ECSS) OPERATING ENERGY (electrical operating energy required to support heat transfer loops) and the Space Heating OPERATING ENERGY (electrical energy required to support subsystem). Measured monthly values for these performance factors are presented in Table IV-6.

During the report period, the total operating energy consumed in collecting and delivering thermal energy for space heating was 3.69 million Btu or 20 percent of the amount of energy delivered to the load. The ECSS required 1.63 million Btu of operating energy and the space heating subsystem used 2.06 million Btu. The operating energies appear high based on comparisons of solar systems with like load requirements. The collector pump and the space heating circulating pumps are oversized (1/3 H.P.) for system requirements. If possible in this application, usage of smaller pumps would yield higher system savings.

TABLE IV-6

## System Operating Energy

Month	ECSS OPERATING ENERGY, Btu (1)	OPERATING ENERGY -HEATING, Btu (1)	TOTAL SYSTEM OPERATING ENERGY, Btu (1)
Feb 78	$0.43 \times 10^6$	$0.91 \times 10^6$	$1.34 \times 10^6$
Mar 78	$0.44 \times 10^6$	$0.72 \times 10^6$	$1.16 \times 10^6$
Apr 78	$0.37 \times 10^6$	$0.25 \times 10^6$	$0.62 \times 10^6$
May 78	$0.39 \times 10^6$	$0.18 \times 10^6$	$0.57 \times 10^6$

## NOTE:

1. Values for this parameter obtained through National Solar Data Network

#### 4.7 System Availability

The availability of a solar energy system is determined by the ability of its functional subsystems to perform their designed tasks when design operational conditions exist.

This may be expressed as

$$\text{Availability} = \frac{\text{Solar Subsystem Equipment Operating Time}}{\text{Demand for Subsystem Time.}}$$

where Availability = 100 percent if the Demand Time is zero.

A subsystem is considered unavailable if a demand for its function exists, prevailing conditions meet appropriate prescribed criteria, and the subsystem fails to perform its function. A subsystem is then considered available at all times it is not unavailable. Availability also indicates the degree to which a subsystem responds to those demands which it was intended to satisfy. Subsystem availability alone, rather than total system availability, is presented in this report as more than one subsystem could be expected to be operational at the same time and a composite availability factor would confuse the actual conditions of performance. Availability of the Moseley solar energy system as presented in this report is represented by the availability of its energy collection and storage subsystem and the solar portions of the space heating subsystem. The monthly availability of the solar portions of these subsystems is presented in Table IV-7.

The Moseley Energy Collection and Storage subsystem is considered available except for those times when the following conditions exist:

- (1) INCIDENT SOLAR ENERGY (total solar energy incident on the gross collector array) is greater than twenty-five percent of its monthly average,
- (2) STORAGE AVERAGE TEMPERATURE (mass-weighted average temperature of the primary storage minimum is less than its maximum allowable value, and
- (3) OPERATIONAL INCIDENT ENERGY (solar energy incident on the collector array during the time that the collector loop is active) is less than twenty-five percent of the INCIDENT SOLAR ENERGY.

The Moseley Space Heating subsystem is considered available except for those times when the following conditions exist:

- (1) A space heating demand was encountered as indicated by SPACE HEATING LOAD (sum of the energy supplied by the solar energy system plus the energy supplied by auxiliary sources) and
- (2) No solar energy was used to attempt to satisfy the space heating load as indicated by SOLAR ENERGY USED-HEATING (amount of solar energy supplied to the space heating subsystem).

The availability percentages, shown in Table IV-7, of the solar energy subsystems gives a measure of the subsystems' ability to meet their design requirements. The availability of the Energy Collection and Storage subsystem was 96 percent and the Space Heating subsystem availability was 100 percent for the entire report period. The solar Space Heating subsystem availability percentages are enhanced by the back-up solar assisted heat pump mode of operation.

TABLE IV-7  
System Availability by Major Subsystem

Month	Energy Collection and Storage Subsystem (1, 2) Percent	Space Heating Subsystem (1, 2) Percent
Feb 78	100%	100%
Mar 78	100%	100%
Apr 78	90%	100%
May 78	95%	100%
Average	96%	100%

NOTE:

1. Monthly percentages rounded to nearest 5 percent
2. Values for this parameter computed from data obtained through National Solar Data Network.

## 4.8 Energy Savings

Energy savings for the solar energy system is described by FOSSIL ENERGY SAVINGS (estimated difference between conventional fossil energy requirements and actual fossil energy requirements of subsystem) and ELECTRICAL ENERGY SAVINGS (estimated difference between conventional electrical energy required and actual electrical energy required by subsystem). Calculated monthly values for these performance factors are presented in Table IV-8.

Energy savings calculations are based on the projected energy requirements using a natural-gas-fired boiler with an assumed efficiency of 60 percent, supplying heated water to an air-duct heat exchanger. Total system savings for the 4 month report period are 22.72 million Btu of fossil energy at a cost of 5.54 million Btu of electrical energy. Since this comparison is made with different energy sources, a more meaningful way to represent the savings would be to convert metered fuel savings to raw fuel savings at the generating station. Assuming that the electric power was generated at a natural-gas-fired generating station, the electrical savings converted to natural gas savings are 16,788 cubic feet.

The conversion efficiency of .3 was used to convert metered ELECTRICAL ENERGY SAVINGS to generating station savings in Btu. Then the natural gas energy content factor of 1100 Btu per cubic foot was applied to yield ELECTRICAL ENERGY SAVINGS in cubic feet. The total FOSSIL ENERGY SAVINGS are 20,654 cubic feet. There, the net computed savings are 3866 cubic feet of natural gas.

TABLE IV-8  
System Energy Savings

Month	Electrical Savings Btu (1, 2, 3)	Electrical Savings Kilowatt Hours (4)	Fossil Savings Btu (3)	Fossil Savings Cubic Feet (5)
Feb 78	$-2.93 \times 10^6$	-858	$9.70 \times 10^6$	8818
Mar 78	$-1.82 \times 10^6$	-533	$7.49 \times 10^6$	6809
Apr 78	$-0.41 \times 10^6$	-120	$3.28 \times 10^6$	2982
May 78	$-0.38 \times 10^6$	-111	$2.25 \times 10^6$	2045

NOTE:

1. Negative savings indicate expenditures above the conventional operating costs of the system
2. Savings are at the meter, not at the generating station:  
divide savings by 0.3 to obtain total resource cost estimation
3. Values for this parameter obtained through National Solar Data Network and by assuming a fossil combustion efficiency of 0.60
4. Based on 3413 Btu per kilowatt hour
5. Based on the energy content of Natural Gas of 1100 Btu per cubic foot

## 5. REFERENCES

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- 10.\* "User's Guide to the Monthly Performance Report of the National Solar Data Program", Feb. 28, 1978, SOLAR/0004-78/18
11. W. A. Beckman, S. A. Klein, J. A. Duffie, "Solar Heating Design by the F-CHART Method", New York: John Wiley, 1977
12. ASHRAE Standard 93-77, Methods of Testing to Determine the Thermal Performance of Solar Collectors, The American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, N. Y., 1977
- 13.\* U. S. Dept. of Energy, "Solar Project Description for T. D. Moseley Solar Energy System", May 1978, SOLAR/2011-78/50
14. S. A. Klein, "Calculation of Monthly Average Insolation on Tilted Surfaces", Solar Energy, Vol 19, pp 325-329, November 4, 1977

\* Copies of these reports may be obtained from Technical Information Center, P. O. Box 62, Oak Ridge, Tenn. 37830

## APPENDIX A

### DEFINITIONS OF PERFORMANCE FACTORS

#### COLLECTOR ARRAY PERFORMANCE

The collector array performance is characterized by the amount of solar energy collected with respect to the energy available to be collected.

- o INCIDENT SOLAR ENERGY is the total solar energy incident on the gross collector array area. This is the area of the collector array energy-receiving aperture, including the framework which is an integral part of the collector structure.
- o OPERATIONAL INCIDENT ENERGY is the amount of solar energy incident on the collector array during the time that the collector loop is active (attempting to collect energy).
- o COLLECTED SOLAR ENERGY is the thermal energy removed from the collector array by the energy transport medium.
- o COLLECTOR ARRAY EFFICIENCY is the ratio of the energy collected to the total solar energy incident on the collector array. It should be emphasized that this efficiency factor is for the collector array, and available energy includes the energy incident on the array when the collector loop is inactive. This efficiency must not be confused with the more common collector efficiency figures which are determined from instantaneous test data obtained during steady state operation of a single collector unit. These efficiency figures are often provided by collector manufacturers or presented in technical journals to characterize the functional capability of a particular collector design. In general, the collector panel maximum efficiency factor will be significantly higher than the collector array efficiency reported here.

#### STORAGE PERFORMANCE

The storage performance is characterized by the relationships among the energy delivered to storage, removed from storage, and the subsequent change in the amount of stored energy.

- o ENERGY TO STORAGE is the amount of energy, both solar and auxiliary, delivered to the primary storage medium.
- o ENERGY FROM STORAGE is the amount of energy extracted by the load subsystems from the primary storage medium.
- o CHANGE IN STORED ENERGY is the difference in the estimated stored energy during the specified reporting period, as indicated by the relative temperature of the storage medium (either positive or negative value).

- o STORAGE AVERAGE TEMPERATURE is the mass-weighted average temperature of the primary storage medium.
- o STORAGE EFFICIENCY is the ratio of the sum of the energy removed from storage and the change in stored energy to the energy delivered to storage.

#### ENERGY COLLECTION AND STORAGE SUBSYSTEM

The Energy Collection and Storage Subsystem (ECSS) is composed of the collector array, the primary storage medium, the transport loops between these, and other components in the system design which are necessary to mechanize the collector and storage equipment.

- o INCIDENT SOLAR ENERGY is the total solar energy incident on the gross collector array area. This is the area of the collector array energy-removing aperture, including the framework which is an integral part of the collector structure.
- o AMBIENT TEMPERATURE is the average temperature of the outdoor environment at the site.
- o ENERGY TO LOADS is the total thermal energy transported from the ECSS to all load subsystems.
- o ECSS OPERATING ENERGY is the electrical operating energy required to support the ECSS heat transfer loops.

#### SPACE HEATING SUBSYSTEM

The space heating subsystem is characterized by performance factors accounting for the complete energy flow into the subsystem. The average building temperature and the average ambient temperature are tabulated to indicate the relative performance of the subsystem in satisfying the space heating load and in controlling the temperature of the conditioned space.

- o SPACE HEATING LOAD is the sum of the energy supplied by the solar energy system plus the energy supplied by auxiliary sources.
- o SOLAR FRACTION OF LOAD is the percentage of the total demand which is supported by solar energy.
- o SOLAR ENERGY USED is the amount of solar energy supplied to the space heating subsystem.
- o OPERATING ENERGY is the amount of electrical energy required to support the subsystem, (e.g., fans, pumps, etc.) and which is not intended to affect directly the thermal state of the subsystem.
- o AUXILIARY THERMAL USED is the amount of energy supplied to the major components of the subsystem in the form of thermal

energy in a heat transfer fluid or its equivalent. This term also includes the converted electrical and fossil fuel energy supplied to the subsystem.

- o AUXILIARY FOSSIL FUEL is the amount of fossil fuel energy supplied directly to the subsystem.
- o ELECTRICAL ENERGY SAVINGS is the estimated difference between the electrical energy requirements of an alternative conventional system (carrying the full load) and the actual electrical energy required by the subsystem.
- o FOSSIL ENERGY SAVINGS is the estimated difference between the fossil energy requirements of the alternative conventional system (carrying the full load) and the actual fossil energy requirements of the subsystem.
- o BUILDING TEMPERATURE is the average heated space dry bulb temperature.
- o AMBIENT TEMPERATURE is the average ambient dry bulb temperature at the site.

#### ENVIRONMENTAL SUMMARY

The environmental summary is a collection of the weather data which is generally instrumented at each site in the program. It is tabulated in this data report for two purposes--as a measure of the conditions prevalent during the operation of the system at the site, and as an historical record of weather data for the vicinity of the site.

- o TOTAL INSOLATION is accumulated total solar energy incident upon the gross collector array measured at the site.

## APPENDIX B

### SOLAR ENERGY SYSTEM PERFORMANCE EQUATIONS FOR TERRELL D. MOSELEY

#### I. INTRODUCTION

Solar energy system performance is evaluated by performing energy balance calculations on the system and its major subsystems. These calculations are based on physical measurement data taken from each subsystem every 320 seconds. This data is then numerically combined to determine the hourly, daily, and monthly performance of the system. This appendix describes the general computational methods and the specific energy balance equations used for this evaluation.

Data samples from the system measurements are numerically integrated to provide discrete approximations of the continuous functions which characterize the system's dynamic behavior. This numerical integration is performed by summation of the product of the measured rate of the appropriate performance parameters and the sampling interval over the total time period of interest.

There are several general forms of numerical integration equations which are applied to each site. These general forms are exemplified as follows: The total solar energy available to the collector array is given by

$$\text{SOLAR ENERGY AVAILABLE} = (1/60) \sum [I001 \times \text{AREA}] \times \Delta\tau$$

Where I001 is the solar radiation measurement provided by the pyranometer in BTU/ft<sup>2</sup>-hr, AREA is the area of the collector array in square feet,  $\Delta\tau$  is the sampling interval in minutes, and the factor (1/60) is included to correct the solar radiation "rate" to the proper units of time.

Similarly, the solar energy collected by the system is given typically by

$$\text{COLLECTED SOLAR ENERGY} = \sum [M100 \times \text{CP} \times \text{RHO} \times (T150 - T100)] \times \Delta\tau$$

Where W100 is the flow rate of the heat transfer fluid in gal/min, CP and RHO are the specific heat and density, and T100 and T150 are the temperatures of the fluid before and after passing through the heat exchanging component. Frequently this temperature difference is referred to as simply TD100. The symbol M100 is obtained from measurement W100 by multiplying by the fluid density.

For electrical power, a general example is

$$\text{ECSS OPERATING ENERGY} = (3413/60) \sum [EP100] \times \Delta\tau$$

where EP100 is the power required by electrical equipment in kilowatts and the two factors (1/60) and 3413 correct the data to Btu/min.

These equations are comparable to those specified in "Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program". This document, given in the list of references, was prepared by an inter-agency committee of the government, and presents guidelines for thermal performance evaluation.

Performance factors are computed for each hour of operation of systems. Each numerical integration process, therefore, is performed over a period of one hour. Since long-term performance data is desired, it is necessary to build these hourly performance factors to daily values. This is accomplished, for energy parameters, by summing the twenty-four hourly values. For temperatures, the hourly values are averaged. Certain special factors, such as efficiencies, require appropriate handling to properly weight each hourly sample for the daily value computation. Similar procedures are required to convert daily values to monthly values.

The equations presented for the calculation of performance factors for specific sites conform to the general guidelines outlined above. Additional considerations include special handling of calculations to account for various modes of operation of systems. That is, some components and sensors are incorporated into systems so that they are shared by more than one subsystem, and consequently the energy flow associated with them must be accounted to appropriate subsystems based on system mode of operation.

EQUATIONS USED IN MONTHLY PERFORMANCE REPORT

- NOTE:     - ALL UNITS BTU UNLESS OTHERWISE SPECIFIED  
          - MEASUREMENT NUMBERS REFERENCE SYSTEM SCHEMATICS FIGURES III-1 & III-2

SITE SUMMARY REPORT

INCIDENT SOLAR ENERGY

$$= (1/60) \sum [I001 \times \text{AREA}] \times \Delta\tau$$

INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/SQ. FT)

$$= 1/60 \sum I001 \times \Delta\tau$$

COLLECTED SOLAR ENERGY

$$= \sum [M100 \times (T150 - T100 \times \text{CP})] \times \Delta\tau$$

COLLECTED SOLAR ENERGY PER UNIT AREA (BTU/SQ. FT.)

$$= \sum [M100 \times (T150 - T100) \times \text{CP/AREA}] \times \Delta\tau$$

AVERAGE AMBIENT TEMPERATURE (DEGREES F)

$$= (1/60) \sum [T001] \times \Delta\tau$$

AVERAGE BUILDING TEMPERATURE (DEGREES F)

$$= (1/60) \sum [T600] \times \Delta\tau$$

ECSS SOLAR CONVERSION EFFICIENCY

$$= \text{SOLAR ENERGY TO LOAD/INCIDENT SOLAR ENERGY}$$

ECSS OPERATING ENERGY

$$= (56.88) \sum (\text{EP101}) \times \Delta\tau$$

WHENEVER COLLECTORS ARE OPERATING

TOTAL SYSTEM OPERATING ENERGY

$$= \text{ECSS OPERATING ENERGY} + \text{HEATING OPERATING ENERGY}$$

TOTAL ENERGY CONSUMED

$$= \text{AUXILIARY ELECTRIC ENERGY} + \text{AUXILIARY FOSSIL ENERGY} + \text{SYSTEM OPERATING ENERGY} \\ + \text{COLLECTED SOLAR ENERGY}$$

SPACE HEATING LOAD

$$= \text{HEATING SOLAR ENERGY} + \text{HEATING AUXILIARY THERMAL ENERGY}$$

TOTAL LOAD

HEATING SOLAR FRACTION (PERCENT)

$$= 100 \times \text{HEATING SOLAR ENERGY} / \text{HEATING LOAD}$$

HEATING SOLAR ENERGY

$$= \sum [M400 \times (T400 - T450) \times CP] \times \Delta\tau - \text{STORAGE AUXILIARY ENERGY} \\ \text{FOR MODE 2}$$

TOTAL SOLAR ENERGY

$$= \sum [M400 \times (T400 - T450) \times CP] \times \Delta\tau - \text{HEATING AUXILIARY THERMAL ENERGY}$$

HEATING OPERATING ENERGY

$$= (56.88 \sum (EP400 + EP301 + \text{FAN POWER}) \times \Delta\tau \\ \text{FOR MODE 2}$$

TOTAL OPERATING ENERGY

$$= \text{ECSS OPERATING ENERGY} + \text{HEATING OPERATING ENERGY}$$

HEATING AUXILIARY THERMAL ENERGY (BTU)

$$= \text{STORAGE AUXILIARY ENERGY} + 0.7 \times \text{HEATING AUXILIARY ENERGY}$$

TOTAL AUXILIARY THERMAL ENERGY

$$= \text{HEATING AUXILIARY THERMAL ENERGY}$$

HEATING AUXILIARY ELECTRIC FUEL

$$= (56.88) \sum [EP402] \times \Delta\tau$$

TOTAL AUXILIARY ELECTRIC FUEL

$$= \text{HEATING AUXILIARY ELECTRIC FUEL}$$

HEATING AUXILIARY FOSSIL FUEL

$$= CF \times (F211 - F211L)$$

where CF is the heat content of the fossil fuel in Btu/cubic feet

TOTAL AUXILIARY FOSSIL FUEL

$$= \text{HEATING AUXILIARY FOSSIL FUEL}$$

HEATING ELECTRICAL SAVINGS

$$= - (\text{HEATING AUXILIARY ELECTRIC FUEL} + \text{HEATING OPERATING ENERGY}) \\ + \text{HEATING FOSSIL SAVINGS} \times \text{AUXILIARY PUMP SAVING FACTOR} + \text{FAN POWER} \\ \text{FOR MODE 2}$$

TOTAL ELECTRICAL SAVING

$$= \text{HEATING ELECTRICAL SAVINGS}$$

HEATING FOSSIL SAVINGS

$$= \text{HEATING SOLAR ENERGY/CEEH}$$

where CEEH is the auxiliary furnace burner efficiency

TOTAL FOSSIL SAVINGS

$$= \text{HEATING FOSSIL SAVINGS}$$

SYSTEM PERFORMANCE FACTOR

$$= \text{SYSTEM LOAD} / (\text{AUXILIARY FOSSIL FUEL} + 3 \frac{1}{3} \times (\text{AUXILIARY ELECTRIC FUEL} \\ + \text{SYSTEM OPERATING ENERGY}))$$

OPERATIONAL INCIDENT ENERGY

$$= 1/60 \sum [I001 \times \text{AREA}] \times \Delta\tau$$

COLLECTOR ARRAY EFFICIENCY

$$= \text{SOLAR ENERGY COLLECTED/INCIDENT SOLAR ENERGY}$$

ENERGY TO STORAGE

$$= \text{SOLAR ENERGY COLLECTED} + \text{AUXILIARY ENERGY TO STORAGE}$$

ENERGY FROM STORAGE

$$= \sum [M400 \times (T400 - T450) \times CP] \times \Delta\tau$$

CHANGE IN STORED ENERGY

$$= \text{STOCAP} \times (\text{TSTL} \times \text{RHO} \times \text{CP} - \text{TSTLO} \times \text{RHO}_p \times \text{CP}_p)$$

where subscript p indicates values from previous scan

STORAGE AVERAGE TEMP (DEGREE F)

$$= 1/60 \sum [(T200 + T201 + T202) \times 3] \times \Delta\tau$$

STORAGE EFFICIENCY

$$= (\text{CHANGE IN STORED ENERGY} + \text{ENERGY FROM STORAGE})/\text{ENERGY TO STORAGE}$$

AUX. THERMAL TO ECSS

$$= \sum [M210 \times (T210 - T260) \times CP] \times \Delta\tau$$

ECSS SOLAR CONVERSION EFFICIENCY

$$= \text{SOLAR ENERGY TO LOAD/INCIDENT SOLAR ENERGY}$$

DAYTIME AMBIENT TEMP (DEGREE F)

$$= (1/360 \sum [T001] \times \Delta\tau$$

+ 3 HOURS FROM SOLAR NOON

## APPENDIX C

### ACTUAL VERSUS EXPECTED PERFORMANCE COMPARISON

#### T. D. MOSELEY SOLAR ENERGY SYSTEM

##### 1. INTRODUCTION

An interactive computer program, FCHART, developed by the University of Wisconsin, Solar Energy Laboratory [11], was used to calculate the expected performance parameters used in this report. The long term average climatological data were obtained from the National Oceanic and Atmospheric Administration Bulletin [8] on Lynchburg, Virginia. The solar radiation data were obtained from solar radiation maps provided by the Environmental Science Services Administration, Climatic Atlas of the United States [7]. These long term averages along with actual measured climatic data were presented previously in Table IV-1.

FCHART uses the degree-day method for calculating heating load. The degree-day method of estimating the space heating load of a building is based upon the fact that the amount of heat required to maintain a comfortable indoor temperature is primarily dependent upon the difference between the indoor and outdoor temperatures. The monthly space heating load,  $L_s$ , for a building is assumed to be proportional to the number of degree-days during the month.

$$L_s = UA \times DD$$

where

DD is the number of degree-days in a month

UA is the building overall energy loss  
coefficient-area product

In addition to the degree-day method, FCHART provides an option to use actual loads in the computational process. The following discussion addresses both these options in the performance comparison.

## 2. PERFORMANCE COMPARISON

Table C-1 presents a comparison of Incident Solar, Heating Load and Solar Fraction based on long term average and measured climatic conditions. It can be noted that actual weather conditions resulted in higher than normally expected heating loads. This is further indicated by the less than expected solar fractions in February and March. Climatic conditions, ambient temperature and heating degree-days actually recorded verify this result as noted in Table IV-1.

Comparisons of actual measured heating loads and expected heating loads are shown in Table C-2. The months of February and March show the expected heating loads, based on actual measured weather, to be within six percent and three percent, respectively, of the actual measured heating loads. April and May are 11 and 16 percent, respectively. The percentages for April and May can be expected to diverge since the relative significance of the UA factor in heat load computations diminishes in the spring and summer season.

The FCHART software was provided a constant UA of 418.7 Btu/hr-F for heating load computations. The monthly space heating load, L, is assumed to be proportional to the number of degree days during the month.

$$L = UA \times DD$$

Consequently, given the actual measured load, L, and measured degree-days, DD, an effective monthly UA can be calculated.

$$UA_{\text{effective}} = \frac{L}{DD \times 24}$$

Table C-3 presents a comparison of constant UA to effective UA calculated from actual loads and heating degree days. The calculated effective UA for February, March and April shows a close correspondence to the design constant. The calculated UA for May shows the divergence expected for the seasonal change.

An alternate method to the degree-day/UA calculation for heating load is providing actual loads into the FCHART model. This method was utilized to compare solar fractions with results presented in Table C-4. It can be readily seen that the use of actual loads with actual measured weather conditions tracks the actual measured solar fractions much more closely than the long term average conditions. The average solar fraction delineates the performance under climatic conditions which were colder than expected.

### 3. SUMMARY

The T. D. Moseley solar energy system comparison showed the system meeting the expected demand even though climatic conditions were colder than long term average conditions for the locality. Expected performance parameters were matched or exceeded by the actual performance of the system. This performance is indicative of a system designed, built and maintained to meet or surpass its design goals.

TABLE C-1 Performance Comparison - Long Term vs Measured Weather

T. D. Moseley Solar Energy System

Month (Year) (1)	INCIDENT SOLAR 50°Tilt - Btu/ft <sup>2</sup>		HEATING LOAD Million Btu's		SOLAR FRACTION %	
	Measured Weather(2)	Long Term Average(3)	Measured Weather(4)	Long Term Average(5)	Measured Weather(4)	Long Term Average(5)
Feb 78	39250	36861	9.59	7.57	58.4	64.2
Mar 78	40198	46111	6.25	6.09	77.1	85.8
Apr 78	40800	48833	2.37	2.63	100.0	100.0
May 78	39392	48639	1.14	0.85	100.0	100.0

NOTE:

1. Measured data covers the period February 1978 through May 1978
2. Values for this parameter obtained through National Solar Data Network
3. Values for this parameter computed based on data obtained from Reference 7
4. This parameter calculated by FCHART based on data obtained through National Solar Data Network
5. This parameter calculated by FCHART based on data obtained from Reference 7

TABLE C-2 Heating Load Comparison - Actual vs Expected

T. D. Moseley Solar Energy System

HEATING LOAD (MILLION Btus)

Month (Year) (1)	Actual Heating Load (2)	EXPECTED	
		Measured Weather Heating Load (3)	Long Term Avg. Weather Heating Load (4)
Feb 78	8.567	9.59	7.57
Mar 78	6.437	6.25	6.09
Apr 78	2.007	2.37	2.63
May 78	1.352	1.14	0.85

NOTE:

1. Measured data covers period February 1978 through May 1978
2. This parameter computed based on data obtained through National Solar Data Network (NSDN)
3. This parameter calculated by FCHART based on data obtained through NSDN
4. This parameter calculated by FCHART based on data obtained from Reference 8.

TABLE C-3

UA Comparison - Design vs Actual Effective

T. D. Moseley Solar Energy System

ENERGY LOSS COEFFICIENT (UA) - Btu/hr-°F

Month (Year) (1)	Design Constant (2)	Calculated Effective (3)
Feb 78	418.7	394.5
Mar 78	418.7	431.2
Apr 78	418.7	373.8
May 78	418.7	498.5

NOTE:

1. Measured data covers the period February 1978 through May 1978
2. This parameter is design UA obtained from system designer
3. Calculated from measured load and heating degree day parameters

TABLE C-4 Solar Fraction Comparison - Actual vs Expected

T. D. Moseley Solar Energy System

SOLAR FRACTION (%)

Month (Year) (1)	Actual Solar Fraction (2)	Expected - Based on Actual Heating Loads (5)	
		Measured Weather Solar Fraction (3)	Long Term Avg. Weather Solar Fraction (4)
Feb 78	68	60.9	56.9
Mar 78	70	75.9	83.6
Apr 78	98	100.0	100.0
May 78	100	100.0	100.0
Average	84	84.2	85.1

NOTE:

1. Measured data covers the period February 1978 through May 1978
2. This parameter computed by Central Data Processing System (CDPS) from data obtained through National Solar Data Network
3. This parameter calculated by FCHART based on data obtained through National Solar Data Network
4. This parameter calculated by FCHART based on data obtained from Reference 8
5. Actual loads input to replace FCHART computation of heating load.