



SOLCOST

(VERSION 3.0)

MASTER

USER'S GUIDE

SOLAR ENERGY DESIGN
PROGRAM FOR NON-THERMAL
SPECIALISTS

MARTIN MARIETTA DATA SYSTEMS

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KNOWN BUGS AS OF MAY 30, 1980

- A. IN SOLCOIN, LINE 133 MUST BE ENTERED AS A ZERO, OR SKIPPED WITH A "G".
INPUT OF ANY POSITIVE VALUE WILL CAUSE THE PROGRAM TO STOP AFTER
THE INPUTS AND THE UPDATED COLLECTOR PARAMETERS ARE LISTED.

LINE 133 IS A FLAG TO ALLOW USERS TO COMPUTE AND PRINT UPDATED
COLLECTOR PARAMETERS ONLY AND THEN STOP.

SEE LINES 169-189.

- B. IF LINE 140=0 AND THE STORAGE TEMPERATURES ARE PRINTED, THE AVERAGE
TEMPERATURES ARE NOT CORRECT IN THE TABLE. IF LINE 140=1 (I.E.
THE ITERATIVE PROCEDURE IS ON) THEN THE AVG. TEMPS. ARE OK. THIS
THE IS DEFAULT MODE.

- C. SOLAR TAX INCENTIVES HAVE CHANGED.

THE FED. CREDIT IS NOW 40% OF \$10,000. THE VERSION 3. DEFAULTS FOR
LINE 66 ARE OUT OF DATE, SO USERS MUST ENTER 66, .4, 5000.,
.4, 5000. •

BUSINESS INCENTIVES HAVE ALSO CHANGED. THE INVESTMENT TAX CREDIT
IS NOW 15% FOR BUILDING HVAC SYSTEMS AND 25% FOR PROCESS HEATING
SYSTEMS.

USER GUIDE ERRATA

- A. Page F-5, paragraph F3, should be changed as follows:

xxxx,CM140000,T40,zz.

xxxx = JOBNAME

zz = Priority

USER,user number,password,C.

CHARGE,charge#.

GET,PROFIL/UN=LIBRARY.

BEGIN,SOLCOST,,INPUT.

END OF RECORD

N or T

Input Deck

END

End of File

MAY, 1980

SOLCOST - VERSION 3.0
SOLAR ENERGY DESIGN PROGRAM
FOR
NON-THERMAL SPECIALISTS

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USER'S GUIDE
MARTIN MARIETTA DATA SYSTEMS
DENVER OPERATIONS DIVISION

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FORWARD

This User's Guide documents the data inputs for the SOLCOST Solar Energy Design Program. SOLCOST is intended for use by architects, contractors, engineers, and other members of HVAC industry responsible for making decisions on economically justifiable investments in solar energy heating and cooling systems. The input data requirements have been simplified so non-thermal specialists can easily use the program to generate an estimate of thermal performance and the resulting payback or rate of return from a proposal solar project. SOLCOST was developed by Martin Marietta for DOE's Division of Solar Energy, Research and Development Branch and updated by the Solar Environmental Engineering Company.

MMDS - REMOTE COMPUTING SERVICE

RCS offers the scientific and engineering users a very powerful remote computing capability. Terminal services are provided to many locations throughout the United States and Canada via MMDS Network.

The types of services available:

- IAF - Interactive Facility. A versatile performance-tested interactive capability for editing, compiling, executing and checking out programs, as well as on-line graphical displays.
- RBF - Remote Batch Facility. It offers a choice of service response category for most economical service consistent with usage requirements.

STATUS OF SOLCOST VALIDATION PROCESS

The absorption cooling and solar assisted heat pump system types have not been validated to date.

The Solar Environmental Engineering Company (SEEC) of Fort Collins, Colorado is performing an independent validation of SOLCOST under a separate DOE contract. That effort to date has verified that the SOLCOST liquid space heating and service water heating analysis predicts system performance which compares well with measured solar performance data.

INTERACTIVE PROGRAM

An interactive program now exists which prepares input files for input to the SOLCOST program. Two modes of input are available: 1) short form where the user specifies the line number and then the new values; or 2) long form where the program interrogates the user for the necessary inputs. The program also displays general information and default values for the inputs, when desired. The input read portion of the SOLCOST program is free formatted, so the user may edit the input file manually before resubmission.

NOTICE

SEEC or Martin Marietta, in providing SOLCOST, accepts no responsibility or liability for the accuracy, completeness, utility or availability of this program or this document. Martin Marietta warrants only that this program will perform in accordance with the user documentation as amended from time to time. SEEC OR MARTIN MARIETTA MAKES NO WARRANTY, EXPRESSED OR IMPLIED, WITH RESPECT TO THE SOLCOST PROGRAM INCLUDING BUT NOT LIMITED TO IMPLIED, WARRANTIES OR MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE. IN NO EVENT SHALL SEEC OR MARTIN MARIETTA BE LIABLE FOR ANY DIRECT, INDIRECT INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

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I. INTRODUCTION

The SOLCOST solar energy design program is a public domain computerized design tool intended for use by non-thermal specialists to size solar systems with a methodology based on a life cycle cost analysis. The intended user group includes architects, housing developers, lenders, solar equipment manufacturers, HVAC engineers and contractors. Although most of these users are not computer oriented, it is expected that engineering users of SOLCOST will provide the above users with access to SOLCOST on a design service basis.

Section II of this guide contains an overview of SOLCOST capabilities and options. For more detail, the user is referred to a technical paper written by the SOLCOST authors*. Section III is a detailed guide to the SOLCOST input parameters. Section IV contains sample problems showing typical input decks and resulting SOLCOST output sheets. Appendices B, C, D and E have details of different parts of the analysis.

*D. Hull and R. Giellis, "SOLCOST: A Solar Energy Design Program," Proceedings of the Systems Simulation and Economic Analysis Conference, Document No. SERI/TP-351-431, San Diego, California, January, 1980.

II. OVERVIEW OF SOLCOST SOLAR ENERGY DESIGN PROGRAM

The SOLCOST program computes an optimum solar collector area from an analysis of life cycle cost differences for a solar system versus a reference (conventional) HVAC system. The basic approach used is to perform one day long computation for each month of the year. This computation utilizes historical weather data including minimum temperatures, maximum temperature, average degree days, horizontal insolation, and percent sunshine values. This approach provides an accurate solution while keeping computer costs to a reasonable value.

Figure II-1 shows the flow chart for the SOLCOST analysis which computes the cost optimized solar collector size. Two analyses are coupled together in SOLCOST to evaluate active solar collection systems. They are a) the solar collector/system performance analysis, and b) life cycle cost analysis.

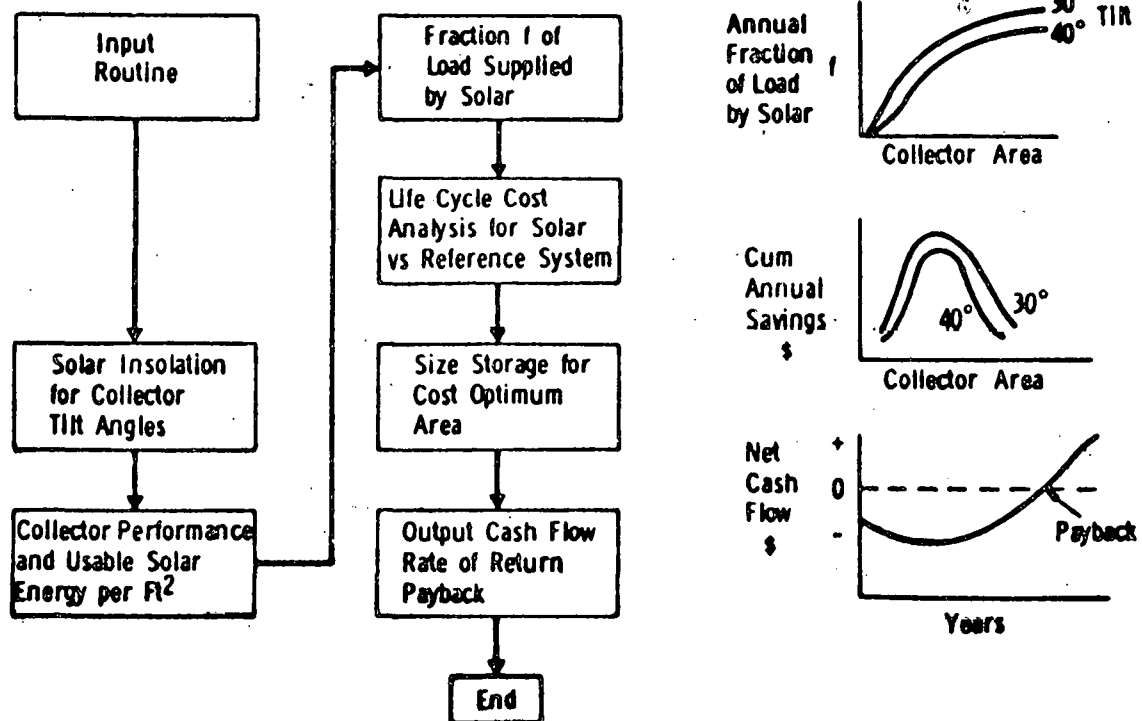


Figure II-1. SOLCOST Flow Chart

Major outputs from the program consist of a) prediction of annual fraction of heating or cooling load provided by the solar system, b) the optimum collector area and tilt angle for the installation, and c) a detailed cash flow summary including payback and rate of return for the optimum collector area.

Several types of solar systems can be evaluated with SOLCOST, including service hot water and space heating systems using liquid or air collectors. Other systems incorporating heat pumps and absorption cooling are available, but should be used with reservation for they have not been validated against actual measured data.

Solar radiation and weather data for 336 cities is stored in SOLCOST. The user accesses this data simply by entering a numeric code for the city nearest the design location.

Collector Sizing Methodology - SOLCOST computes the cost savings realized by a solar system (when compared with a conventional system) and uses the net present worth of the solar savings to compute the optimum collector area. Figure II-2 outlines the SOLCOST collector sizing methodology.

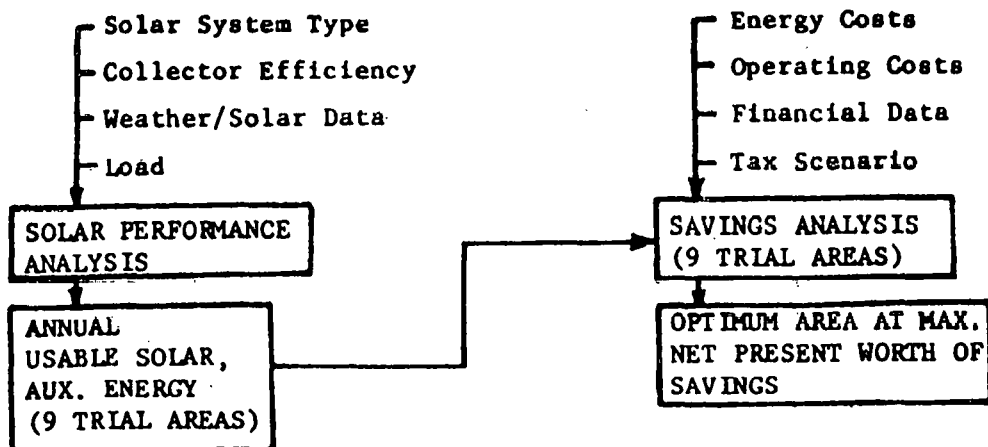


Figure II-2. SOLCOST Collector Sizing Methodology

The solar performance routine computes the maximum collector area, A_{\max} , for a 100% solar system (i.e., A_{\max} will supply 100% of the load in the highest load month). Then the annual auxiliary energy requirement is computed for collector areas sized at fractions of 0.1 through 0.9 of A_{\max} . The fractions are adjusted to be multiples of the collector module size. The annual auxiliary energy usage is computed for each of the nine or fewer trial collector sizes from the input definition of the auxiliary energy system (fuel type and efficiency).

The capital costs for the solar system are input to SOLCOST with two values:

- 1) Fixed system costs which are not dependent on collector size, and
- 2) Installed collector costs per square foot of collector.

These fixed and unit area cost inputs allow SOLCOST to compute the capital costs for the nine system sizes being considered. The capital cost for solar storage is accounted for with input estimates of storage size per unit collector area and installed cost per gallon (or per ton of rock bed storage).

The conventional (reference) system capital cost can also be input to the SOLCOST analysis. Figure II-3 illustrates some possible choices open to an owner considering solar for new construction. (Obviously, not all the fuels will be available at his location.) Usually the individual will be considering one or two fuels for the conventional and solar auxiliary system.

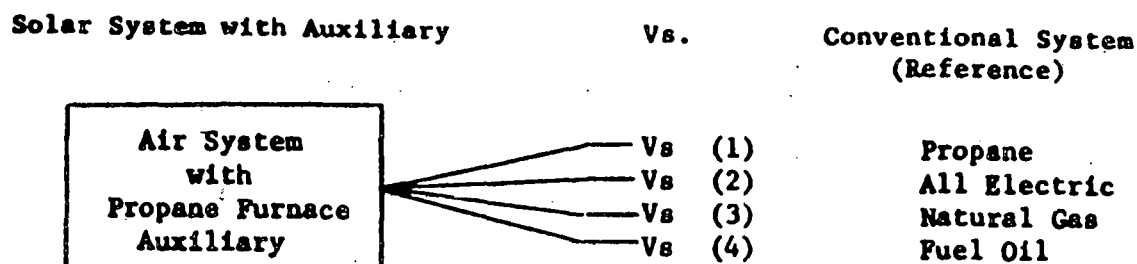


Figure II-3. Example of Heating System Options in SOLCOST

If the owner is considering Option 1, solar augmented with propane versus 100% propane heating, he need only enter the costs for the solar system, since the capital costs for the propane furnace are the same in both systems. If he is considering Option 2, solar/propane versus all electric, he must enter the estimated capital cost for the all electric system. Also, he must include the capital cost for the propane auxiliary system in the fixed cost for the solar system. Fuel costs are escalated with a compounding escalation factor which is input with the fuel price schedule.

The major inputs to the savings analysis consist of a) parameters which describe the initial and operating costs for the solar and conventional systems, and b) tax related data which depends on the solar user's tax situation. The scenario flag tells the program which tax case is being considered, including 1) residential users who deduct interest charges only and who may have different property tax considerations for their solar investment, 2) business users who have the full range of business related tax deductions, and 3) non-profit organizations which do not pay any taxes.

When there is a down payment, the rate of return on the net cash flow is computed for each of the trial collector areas. A cash flow summary sheet and monthly energy summary are printed for only the optimum collector area. For each of the trial collector areas, the following data is also output: annual fraction of load provided by solar, rate of return on net cash flow, present worth of net cash flow computed with a user input discount rate. For users who wish to generate the cash flow and monthly energy summaries for suboptimum areas, an option exists to force SOLCOST to evaluate an input solar collector area. (See line 21)

The SOLCOST collector performance analysis determines the usable solar energy which can be collected on a per square foot basis by a collector with given efficiency characteristics. For users who are uncertain about the definition or specification of efficiency parameters, SOLCOST contains built in values for typical collector types which the user can easily access.

Loads Calculation Options - The user has a choice of entering his own estimate of heating and/or cooling loads, or using one of the following three methods available in SOLCOST.

- a) Entry of monthly fuel usage records and existing HVAC system description by the retrofit user. SOLCOST will estimate space heating loads using reasonable assumptions on equipment.
- b) Specification that the building will meet ASHRAE Std 90-75 Energy Conservation in New Building Design. The user inputs the building dimensions and SOLCOST computes the overall thermal conductance which meets the ASHRAE standard.
- c) User input of the building UA in Btu/hr-°F. This approach assumes that the user (or his engineer) has analyzed his building with a conventional loads calculation procedure such as the method described in the ASHRAE Handbook of Fundamentals.

Summary of SOLCOST Methodology (Systems Performance)

There are two parts to the SOLCOST analysis. These consist of 1) a solar system performance analysis, and 2) a life cycle cost analysis. The following sections are intended to give the user an overview of the key elements in the SOLCOST solar system analysis.

Solar Insolation Model

SOLCOST computes hourly solar fluxes incident on the tilted collector at mid-month points for average clear day and average cloudy day conditions for each month of the year. The insolation model is based on the method contained in Chapter 59 of the ASHRAE Applications Handbook. A full description is given in Appendix A.

Solar Collector Performance

The hourly insolation values are passed to the solar collector performance segment where they are used with time varying ambient temperatures

and varying inlet temperatures to predict instantaneous solar energy collection rates. The collector's performance is modeled with an efficiency curve. The user has the option of entering his collector efficiency data or he can use default efficiency data contained in SOLCOST.

Collector performance is computed for the 15th of each month using the following procedure:

- a) On one hour steps through the day, the parameter $(T_{in} - T_{amb})/q_i$ is computed, where

T_{in} = inlet fluid temperature

T_{amb} = ambient air temperature

q_i = incident solar energy rate

Beginning at dawn, the inlet temperature is set equal to the minimum storage temperature for the particular solar system being analyzed. Initial inlet temperatures are program defaulted, keyed by system type. They can also be specified by the user. The SOLCOST program will also solve for these initial tank temperatures for liquid systems. See Appendix B for more details. These temperatures change from month to month if both heating and cooling is provided.

- b) Collector efficiency (η) is calculated for the value of $(T_{in} - T_{amb})/q_i$ and the rate of solar energy collection (q_{coll}) is computed from:

$$q_{coll} = \eta q_i$$

The energy collection rate versus time is then stored for later processing.

- c) A heat balance on the storage tank is performed after each time step and the resulting inlet temperature rise is computed from:

$$\Delta T_s = \eta_c (q_{coll} - q_{load}) / m_s C_{p_s}$$

where: ΔT_s = the change in storage temperature during the time step which is one hour

q_{coll} = rate of energy collected by the collector

q_{load} = building energy use rate

η_c = efficiency of the collection system

m_s = storage mass

C_{p_s} = specific heat of storage material

- d) The above steps are repeated for each hour of the day for both the clear day and cloudy day insolation profiles. Then the solar collection rates are integrated over the day and weighted with the percent of possible sunshine value in the following manner:

$$Q_{\text{ave. day collection, Btus/ft}^2} = PP \times Q_{\text{clear day collection, Btus/ft}^2} + (1.0-PP) \times Q_{\text{cloudy day collection Btus/ft}^2}$$

where: PP = (percent of possible sunshine)/100. This is the monthly average value taken from the U.S. Climatic Atlas for 336 stations in the SOLCOST data bank. The SOLCOST program can also use recorded insolation values.

This weighting of the clear and cloudy day collector performance with the percent of possible sunshine accounts for the variability of the incoming solar energy due to random cloudiness conditions. Confidence in this approach is based on the correlations obtained between SOLCOST and other sizing methods which have recently been developed, specifically the FCHART method of Beckman, Duffie, and Klein. Their method is based on hundreds of yearly hour by hour simulations which have been empirically condensed into the FCHARTS.

Usable Solar Energy

Usable solar energy is estimated by applying a system transport efficiency to the collected energy values. For well engineered systems this factor will be on the order of 0.95. These values depend on system configuration and component specifications, i.e., heat exchanger losses between collector and storage, cooling equipment coefficient of performance, piping insulation losses, storage tank heat losses, etc.

Having the usable solar energy defined on a per square foot basis, SOLCOST next computes the annual fraction of the load supplied by collector areas sized to provide from 10% to 100% of the total load. See the examples in section IV. The user may also specify the collector module size and the maximum allowable collector area. This calculation is repeated for all specified tilt angles, then the results are passed to the life cycle cost routine where the fuel requirements are estimated for the solar system (as a function of collector area) and the reference heating, ventilating and air conditioning (HVAC) system.

III. GUIDE TO SOLCOST INPUT DATA

This section presents explanatory information for the SOLCOST inputs, which are listed on pages III-21 through III-70. Sample problems for several input decks are explained in Section IV; the user should examine those examples to get acquainted with the SOLCOST parameters and data formats.

The SOLCOST inputs consist of constants and arrays of data values. Each input is described in this guide under a Line Number which ranges from Line 1 to Line 303. An input may be one of the following:

Floating Point Constant

56, 25. is the solar system installed cost per sq. ft.

68, .10 is a 10% loan interest rate

71, 20. is a 20-year term for the life cycle cost analysis

Integer Constant

10, 2 is a flag to use collector Type 2

21, 3 is a flag to run a single collector area case

Floating Point Array

29, 32., 38., 45., 50., 60., 65., 68., 70., 62., 50., 40., 31.,*

is an array of monthly minimum average temperatures

Integer Array

4, 3, 3, 3, 3, 2, 2, 2, 2, 3, 3, 3, 3, * is an array of integer fuel type flags by month

Remember, the SOLCOST input parameters are listed by line numbers in this User's Guide. These line numbers agree with the SOLCOST Line numbers in the data input file.

SOLCOST CONTAINS "built in" values for several of the inputs. If the user accepts these default values, he makes no input and SOLCOST automatically

uses the defaulted value. Therefore, it is critical that the user check each defaulted value to verify that it applies to his analysis. Values of the defaulted parameters are given on Pages III-3 through III-20.

Several parameters have no defaulted value. These must be input to run SOLCOST. These mandatory inputs contain an * or an entry of NONE in the DEFAULT column. As a check, the line numbers of the mandatory inputs are listed here for an analysis which uses a simplified loads calculation method:

<u>Line No.</u>	<u>Parameter</u>
1	Solar System Type
4	Fuel Type for Reference System
6	Fuel Type for Solar Auxiliary System
10	Collector Type
25	Site Location Flag
56	Collector Installed Cost
74	Income Tax Rate
90-94	Fuel Cost Schedule and Escalation Rate

Some parameters are supplied with default values depending on the specification of a different parameter, for example the Solar System Type Flag, Line 1, keys in values for the overall system Efficiency, Line 2, and the Collector Inlet Temperature, Line 3. If the user takes exception to any of these defaults, he should enter his own values. Other keyed defaults include:

Line 4 - Ref. Sys. Fuel ... keys ... Line 5 - Ref. Furnace Effic.
 Line 6 - Solar Aux. Fuel ... keys ... Line 7 -Aux. Furnace Effic.
 Line 10 - Collector Type ... keys ... Lines 14, 15 - Collector Effic.
 Line 25 - Site Location ... keys ... Lines 26 - 33 - Weather and Solar Data

If an input parameter does not apply to the analysis, omit the input all together. For example, if the SOLCOST weather data bank is used by input of Line 25, then Lines 26 through 31 need not be input since this data is supplied internally from the data bank. Another example, if Line 65 is input as a 1 (residence) then lines which refer to business only (Lines 75 through 81) can be ignored.

SOLAR AND REFERENCE (CONVENTIONAL) SYSTEM DEFINITION

<u>LINE NO.</u>		<u>DEFAULT VALUES[†]</u>	<u>COMMENTS</u>
1	Solar System Type Flag, Integer Array	*	See Table III-1
2	Solar System Transport Efficiency, Real Array	See Table III-1	See Appendix G
3	Collector Inlet Temperature, °F, Real Array	See Table III-1	See Appendix B
4	Fuel Type Flag for Reference System, Integer Array	*	See Table III-2
5	Efficiency/COP for Reference System, Real Array	See Table III-2	
6	Fuel Type for Solar Auxiliary Heat Source	*	See Table III-2
7	Efficiency/COP for Solar Auxiliary Heat Source	See Table III-2	
<u>SOLAR COLLECTOR DATA</u>			
10	Collector Type Flag (Integer)	*	See Table III-3
11	Collector Fixed or Tracking Type Flag (Integer)	Fixed	
12	Collector Azimuth Angle, Degrees	South	West = -, East = +
13	Collector Tilt Angles, Degrees, Real Array	Latitude Lat + 7.5°; +15°	Up to 3 tilt angles allowed
14 ^{††}	Collector Efficiency at $(T_{in} - T_{amb})/q_i = 0.0$	0.0	Input only if line 10 = 21 or 23 See Appendix C
15 ^{††}	Collector Efficiency at $(T_{in} - T_{amb})/q_i = 0.5^\circ\text{F}/(\text{Btu/hr-ft}^2)$	0.0	

NOTES:

[†] A * in this column implies no default value, data must be supplied by user to run SOLCOST.

^{††} Appendix C gives directions for modifying these inputs for varying installations. If a heat exchanger is present, it is critical that the efficiency values be de-rated to account for the heat exchanger effect.

SOLAR COLLECTOR DATA - Continued

<u>LINE NO.</u>		<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
16	Storage Maximum Allowable Temperature, °F	200.	
17	Liquid Storage per Unit Collector Area, Gallons/sq ft	1.5	
18	Rock Bed Storage per Unit Collector Area, Pounds/sq ft	50.	
19	Air Collector Efficiency (See Appendix G for Inputs), Real Array	0.0	Input only if Line 10 = 24
20	Evacuated Tubular Collector Efficiency (see Appendix G), Real Array	None	Input only if Line 10 = 22
21	Flag for Non-Standard Analysis on Input Collector Area (Integer)	0	Options are 0, 1, 2, 3
22	User Input Collector Area (Non Standard Analysis), sq ft	0.0	Input if Line 21 = 1,2,3
23	Modular Collector Panel Area, sq ft	20.	
<u>WEATHER AND SOLAR DATA</u>			
24	Print Flag for City List (Integer)	0	Enter a 1 to get a list of cities in the data bank. SOLCOST will do no further processing.
25	Site Location Number (Integer)	None	See Table III-4
26	Site Latitude, Degrees	*	See Figure A1 Input REQUIRED if SOLCOST Site Location (Line 25) Not Specified
27	Site Clearness Factor	*	
28	Fraction of Possible Sunshine, Real Array	*	
29	Min. Daily Ave. Temperature, °F, Real Array	*	
30	Max. Daily Ave. Temperature, °F, Real Array	*	
31	Heating Degree Days, °F - Day, Real Array	*	

III-4

WEATHER AND SOLAR DATA - Continued

LINE NO.		DEFAULT VALUES	COMMENTS
34	Ground Reflectivity, Real Array	0.2	Default=0.2 for all months
35	Daily Horizontal Insolation, Btu/day - sq ft, Real Array	NONE	Most sites in data bank have radiation data.
36	Clearness Numbers, Real Array	Table A2	See Appendix A
<u>SIMPLIFIED HEATING AND COOLING LOADS DATA</u>			
40	Space Heating/Cooling Loads Input or Compute Flag (Integer)	2	Compute with deg-days
41	Service Hot Water Load Input or Compute Flag (Integer)	3	User must input Line 49
42	Building Heat Loss Coefficient, Btu/day-°F-sq ft	0.0	Required if Line 40=2
43	Building Gross Floor Area, sq ft	0.0	Required if Line 40=2
44	ASHRAE STD 90-75 Building Description Array, Real Array	NONE	Required if Line 40=3 See Table III-6
45	Utility Usage Method for Space Heating 45, <u>Fuel Type</u> , <u>Fuel Heat Content</u> , <u>Seasonal Fuel Usage</u> , <u>Seasonal Degree Days</u> , <u>Gross Floor Area</u> *	NONE	Required if Line 40=4 See Table III-7
46	User Input Loads Array, Millions of Btus/Day 46, <u>Jan Load</u> , <u>Feb Load</u> , <u>Dec Load</u> *	NONE	Required if Line 40=5
47	Typical Residential Hot Water Use Pattern 47, <u>Fuel Type</u> , <u>Fuel Heat Content</u> , <u>No. of Occupants</u> , <u>HW Use Schedule</u> , <u>HW Delivery Temperature</u> *	NONE	Required if Line 41=1 See Table III-8
48	Utility Usage Records for Hot Water Loads 48, <u>Fuel Type</u> , <u>Fuel Heat Content</u> , <u>Fuel Usage</u> *	NONE	Required if Line 41=2 See Table III-8
49	User Input Daily Service HW Load, Millions of Btus/day	0.0	Required if Line 41=3

<u>LINE NO.</u>	<u>SYSTEM COST DATA</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
55 ____	Solar System --- Fixed Initial Cost	0:00	\$, does not include collector or storage
56 ____	Solar Collector --- Installed Cost per sq ft	*	\$/sq ft
57 ____	Solar Storage --- Liq. Storage Installed Cost	1.00	\$/gallon
58 ____	Solar Storage --- Rock Bed Storage Instal. Cost	50.00	\$/ton
59 ____	Solar System --- Maintenance Cost	.005	Fraction of initial cost
60 ____	Reference System --- Initial Installed Cost	0.00	\$
61 ____	Reference System --- Maintenance Cost	.005	Fraction of initial cost .005 is 0.5 per year

FINANCE AND TAX DATA

9-III

65 ____	Financial Scenario Flag (Integer)	1	Options are 1 = Residential 2 = Business 3 = Institutional
66 ____	Solar Tax Incentive Table, Real Array (Residential Only)	.30,2000.,.20,8000.	Res. scenario defaults to 1978 NEA incentives
67 ____	Discount Rate for Net Present Worth Analysis	.09	.09 means 9%
68 ____	Loan Interest Rate	.09	.09 means 9%
69 ____	Loan Term	20.	Years
70 ____	Loan Down Payment	.10	Enter 1.0 if cash basis
71 ____	Term of Life Cycle Cost Analysis (Life of Solar System)	20.	Years
72 ____	Insurance Rate	.005	.005 means .5% per year
73 ____	Property Tax Rate (See Line 83 for Prop. Tax Incentive)	0.0	.025 means 2.5% per year

LINE NO. FUEL AND ELECTRICITY COST DATA[†] (CONTINUED)

- 91 _____ Electricity Cost Schedule, Real Array
Line 91=Same format as natural gas, default heat content = 3413. Btus/Kwh. This is a single step schedule where the owner pays 3.9 cents per kw-hr. Escalation rate is 9% per year.
Example: 91,.039,100000.,.09*
- 92 _____ Fuel Oil Cost Schedule, Real Array.
Line 92=Same format as natural gas. Default heat content = 139,600 Btus/gallon (No. 2 Fuel Oil) This is a two step schedule for fuel oil. The -1.0 for escalation flags the input of a time varying escalation table, see Line 102.
Example: 92,.94,1000.,.87,100000.,-1.0*
- 93 _____ Liquified Petroleum (LP) Gas Cost Schedule, Real Array
Line 93=Same format as natural gas. Default heat content = 91,500 Btus/gallon (propane) This schedule flags propane at \$1.10 gallon, 15% escalation rate, and a heat content of 93000. Btus/gallon.
Example: 93,1.10,100000.,.15,93000.*
- 94 _____ Coal Cost Schedule, Real Array
Line 94=Same format as natural gas, default heat content = 30×10^6 Btu/ton
- 95 _____ Electricity Demand Cost Schedule (Input if demand charges apply), Real Array
Line 95, \$/Kw, No. of Kw, (Schedule Step 1)
\$/Kw, No. of Kw, (Schedule Step 2, price for next y units)
\$/Kw, No. of Kw, (Schedule, Step n, up to 9 allowed, minimum of 1 required)
Escalation*
- 96 _____ Electrical Demand Level for Reference System, Kw
- 97 _____ Electrical Demand Level for Solar Auxiliary, Kw
- 98 _____ Electrical Demand Level for Solar Assisted Heat Pump, Kw
- (Input required if demand charges apply. Default Values = 0.0)

[†] THERE ARE NO DEFAULT VALUES FOR FUEL COSTS. A COST SCHEDULE MUST BE ENTERED FOR EACH FUEL SPECIFIED ON LINES 4 AND 6.

LINE NO. FUEL ESCALATION TABLES AND SEASONAL FUEL COST SCHEDULES

100 Escalation Table for Natural Gas, Real Array

100,	<u>Escalation Rate,</u>	<u>Years,</u>	(Rate for First N years)
	<u>Escalation Rate,</u>	<u>Years,</u>	(Rate for next X years)
	<u>Escalation Rate,</u>	<u>Years,</u>	(Rate for next Y years)
	<u>Escalation Rate,</u>	<u>Years,*</u>	(Rate for next Z years)

NOTE: One to four steps may be entered. A -1.0 must be entered for the escalation rate in Line 90 in order to use the array 100 table.

101 Escalation Table for Electricity, Real Array (Same format as Line 100)

102 Escalation Table for Fuel Oil, Real Array (Same format as Line 100)

103 Escalation Table for LP Gas, Real Array (Same format as Line 100)

104 Escalation Table for Coal, Real Array (Same format as Line 100)

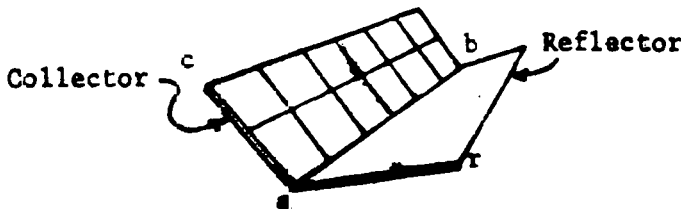
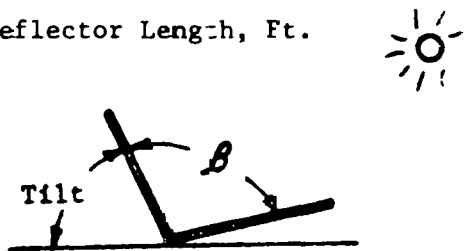
NOTE Lines 106 through 109 can be ignored if fuel prices are constant through the year, i.e., there are no seasonal changes in fuel prices.

106 Summer Fuel Cost Schedule for Reference System, Real Array (Same format as Lines 90-94. Fuel heating value must be entered. Line 104 can be entered to escalate this schedule with multiple escalations. Line 108 must be entered to flag months during which this schedule is to be used.)

107 Summer Fuel Cost Schedule for Auxiliary System, Real Array (Same format as Lines 90-94. Fuel heating value must be entered. Line 103 can be entered to escalate this schedule with multiple escalations. Line 109 must be entered to flag months during which this schedule is to be used.)

108 Month Flags for Summer Fuel, Reference System, Integer Array (Array of 12 flags, enter an integer 1 for the months in which fuel schedule on Line 106 is to be used.)

109 Month Flags for Summer Fuel, Auxiliary System, Integer Array (Array of 12 flags, enter an integer 1 for the months in which fuel schedule on Line 107 is to be used.)

LINE NO.	REFLECTOR ANALYSIS DATA	DEFAULT VALUES	COMMENTS
120	Reflector Analysis Flag (Integer)	0	Enter a 1 and Lines 121-126 to access SOLCOST reflector analysis. Set Line 130 to print hourly fluxes incident on collector.
			
121	Reflector/Collector Common Edge Length, Ft.	0.	Enter length of line ab.
122	Collector Length, Ft.	0.	Enter length of line ac.
123	Reflector Length, Ft.	0.	Enter length of line ar.
			
124	Reflector/Collector Angle, Deg.	0.	Enter angle β in degrees
125	Reflector Diffuse Solar Reflectivity	0.	
126	Reflector Specular Solar Reflectivity	0.	
130	Extended Print Flag for Hourly Solar Fluxes (Integer)	0	Enter an integer 1 to print clear and cloudy day hourly vs. time
131	Extended Print Flag for Printer Plots (Integer)	0	Enter an integer 1 to generate printer plots.
132	Extended Print Flag for Insolation Summary (Integer)	0	Enter an integer 1 to print insolation summary.
134	Print Suppression Flag	0	if 1, 2 or 3 output is reduced

<u>PARAMETER</u>	<u>DAWN STORAGE TEMPERATURE ITERATIVE PROCEDURE⁺</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
140_____	Flag to Skip Inlet Temperature Iterative Procedure (Integer)	1	Enter a 0 to skip iterative procedure.
141_____	Convergence ΔT on Dawn Storage Temperature, $^{\circ}F$	1.	Default ΔT provides reasonable speed and accuracy.
142_____	Maximum Allowable Number of Iterations (Integer)	30	
143_____	Minimum Allowable Storage Tank Temperature, $^{\circ}F$ (For Hot Water Systems see line 153)	100.	Lower Set point below which useful energy cannot be supplied to the load.
145_____	Flag to Print Monthly Max, Min, Avg Storage Temperatures (Integer)	0 (no output)	Enter a 1 to print optimum or specified collector area. Enter a 2 to print all candidate collector areas.
<u>DETAILED SERVICE (DOMESTIC) HOT WATER SYSTEM INPUTS⁺⁺</u>			
150_____	Hourly Hot Water Load Fractions Versus Hour of Day (Array of 24 Elements)	Default is 150, 0.021, 0.0, 0.0, 0.0, 0.0, 0.0, 0.021, 0.5, .071, .085, .071, .043, .035, .05, .028, .021, .021, .035, .071, .113, .092, .071, .05, .05, * (See page III-40)	

⁺See Appendix B for discussion

⁺⁺ The use of mixing (tempering) valves in two-tank service water heating systems is often required by building codes. Version 1.0 of SOLCOST could not evaluate the effect of this component on system performance, however, Versions 2.0 and later can account for mixing valve effects. See Lines 151 and 152.

<u>PARAMETER</u>	<u>COLLECTOR PARAMETER MODIFICATION</u> ^{*†}	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
169_____	Flag to Designate that the Collector Parameters are to be Updated (Integer)	0	Input a 1 to execute.
170_____	Flag to Designate that the Input Collector Parameters have been Defined to be a Function of Average Collector Temperature not Inlet Temperature (Integer Array) [†]	0	Input a 1 to execute for each parallel path.
171_____	\dot{m}_{cp} Per Square Foot of Collector as Tested (Array)	10. (2. for air systems)	$\frac{\text{Btu}}{\text{Hr-}^{\circ}\text{F-Ft}^2}$
172_____	\dot{m}_{cp} Per Square Foot of Collector as Used (Array)	10. (2. for air systems)	$\frac{\text{Btu}}{\text{Hr-}^{\circ}\text{F-Ft}^2}$
173_____	$F_{R\tau}$ Input for each Collector Path (Array)	0.7	
174_____	F_{RU} Input for each Collector Path (Array)	1.0	$\left(\frac{\text{Btu}}{\text{Hr-}^{\circ}\text{F-Ft}^2}\right)^{-1}$
175_____	Number of Series Collectors in each Parallel Path (Integer)	2	
176_____	Number of Parallel Paths with Different Parameters or Flow Rates (Integer)	1	If $\neq 1$ line 21 must be set equal to 3.
177_____	Individual Collector Panel Area for each Parallel Path (Array)	20.	ft^2
180_____	Flag to Indicate that the Collectors in Air Systems are Leaky (Integer)	0	Input a 1 to execute.

* See Appendix C for details and examples.

[†] All arrays are 10 units long.

<u>PARAMETER</u>	<u>COLLECTOR PARAMETER MODIFICATION*</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
181_____	Air Collector Pressure Flag (Integer)	1	1 = Negative Pressure 2 = Positive Pressure
182,183,184	Leak Parameters, σ , β and θ , See Appendix C		
185_____	Heat Exchanger Flag (Integer)	0	Set equal to 1 to execute.
186_____	Heat Exchanger Effectiveness	0.6	
187_____	Manifold Conduction Flag (Integer)	0	Set to a 1 to execute. Also, line 21 must be 3.
188_____	Inlet UA of Piping/Ducting	100.	$\frac{\text{Btu}}{\text{Hr-}^{\circ}\text{F}}$
189_____	Outlet UA of Piping/Ducting	100.	$\frac{\text{Btu}}{\text{Hr-}^{\circ}\text{F}}$

*See Appendix C for details and examples.

<u>PARAMETER</u>	<u>DETAILED SERVICE (DOMESTIC) HCT WATER SYSTEM INPUTS (cont.)</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
151_____	Auxiliary Water Heater Set Temperature, °F	120.	
152_____	Water Delivery (Mixing Valve) Temperature, °F	120.	
153_____	Monthly Supply (or Ground) Water Temperatures, °F (Array)	50.	
154_____	Hot Water Usage, Gal./Day	0.	
155_____	Auxiliary Tank UA, Btu/Hr-°F	5.41	
156_____	Preheat (or Storage) Tank Insulation U Value Btu/Hr-Ft ² - °F	.28	See Appendix B for details. Also applies to space heating sys- tems.
157_____	Ambient Temperature at Auxiliary and Preheat Tanks, °F	75.	
	<u>SUBSYSTEM COMPONENT SELECTION OPTIONS</u>		
190_____	Flag to Execute Subsystem Selection/Sizing Routines (Integer)	0	0 = No Sizing 1 = Perform Sizing
191_____	Flag for Counterflow Liq-Liq HX in Collection Loop, (Integer)	0	0 = No HX 1 = HX Present
192_____	Flag for Crossflow Air-Liq (or Liq-Air) HX in Collection Loop (or in Load Distribution Loop) (Integer)	0	0 = No HX 1 = HX Present
193_____	Flag to Include Components in System Costs for Life Cycle Cost Analysis (LCCA) (Integer)	0	0 = Do not include 1 = Include in LCCA

<u>PARAMETER</u>	<u>LIQUID COLLECTION SUBSYSTEM DESIGN/COST DATA</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
201_____	Collector Flow Rate	.025	GPM/Ft ² _c
202_____	Collector Pressure Drop	.60	Ft. of Water
203_____	Heat Exchanger Pressure Drop (Collection Side)	.50	Ft. of Water
204_____	Total Pipe or Duct Length in Collection Loop	50.	Ft.
205_____	Installed Duct/Pipe Cost per Foot	4.	\$/Ft.
207_____	Additional Velocity Head Above Pipe, Valve and Tee Velocity Losses	.1	Ft.
208_____	Pressure Loss Head (Collection Loop)	.5	Ft.
209_____	Elevation Head (Collection Loop)	.5	Ft.
210_____	Design Pipe Velocity	5.	Ft./Sec.
211_____	Number of Valves (Integer) in Collection Loop	2	--
212_____	Number of Elbows (Integer) in Collection Loop	10	--
213_____	Number of Tees (Integer) in Collection Loop	0	--
214_____	Specific Heat of Collector Fluid	.85	Btu/Lb-°F
215_____	Specific Heat of Storage Fluid	1.0	Btu/LB-°F
217_____	Cost Per Elbow	1.	\$
218_____	Cost Per Valve	3.	\$
219_____	Cost Per Tee	1.	\$

PARAMETER	LIQUID COLLECTION SUBSYSTEM DESIGN/COST DATA (CONT)	DEFAULT VALUES	COMMENTS
221	Friction Factor for Velocity Head Loss Calculation	.012	--
222	Equivalent Pipe Length Per Valve at Ref. Dia. = 12 In.	50.	Ft.
223	Equivalent Pipe Length Per Elbow at Ref. Dia. = 12 In.	30.	Ft.
224	Equivalent Number of Feet Per Tee at Ref. Dia. = 12 Inches	60.	Ft.
<u>HEAT EXCHANGERS (AIR OR LIQUID)</u>			
225	Storage Side of Heat Exchanger Multiplier	3.	--
227	F'/F_R Ratio for Collector Heat Exchanger	.95	--
230	Design Point for Crossflow Load HX-Liq. Space Heating (Ratio of $\frac{UA_{min}}{UA_{load}}$)	2.	--
231	Load HX Air Flow Rate	1000.	SCFM
232	Load HX (Liq-to-Air) Water Flow Rate (Also Service Water Coil in Air Systems)	15.	GPM
<u>AIR SYSTEM COMPONENTS - DESIGN/COST DATA</u>			
233	Duct Design Air Velocity	700.	Ft/Min
234	Air Collector Design Flow Rate	2.	SCFM/Ft ² _c
235	Air Collector Pressure Drop	.5	Inches of Water
236	Air System Service Water Coil Pressure Drop	.2	Inches of Water
237	Insulation Friction Factor for Ducts	1.15	--
238	Solar System Site Elevation	3000.	Ft.
240	Service Hot Water Coil Effectiveness for Air Systems. (Array of 9 elements)	.30	Input an effectiveness for each collector area.

<u>PARAMETER</u>	<u>AIR SYSTEM COMPONENTS - DESIGN/COST DATA</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
241_____	Maximum Duct Pressure Drop Per 100 ft of Duct	.08	Inches of Water
242_____	Flag to Indicate that SOLCOST is to Calculate Rock Box Pressure Drop (Integer)	0	Input a 1 to execute.
243_____	Rock Bed Pressure Drop	.15	Inches of Water
244_____	Rock Bed Inside Height	5.	Feet
245_____	Rock Bed Density	100.	lb/ft ³
246_____	Maximum Number of Branches for Collector Manifold (Integer)	10	

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<u>PARAMETER</u>	<u>AIR SYSTEM COMPONENTS - DESIGN/COST DATA (CONT)</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
250 _____	No. of Turns in Air System Collection Ducting (Integer)	6	--
251 _____	No. of Normally Open Dampers in Air System Collection Ducting (Integer)	4	--
252 _____	Installed Cost Per Turn in Air Systems	25.	\$
253 _____	Installed Cost Per Normally Open Damper in Air Systems	25.	\$
254 _____	Equivalent Length of Duct for Each Turn at Ref. Dia. = 1.0 Ft.	.5	Ft.
255 _____	Equivalent Length of Duct for Each Damper at Ref. Dia. = 1.0 Ft.	.75	Ft.

<u>PARAMETER</u>	<u>TOTAL SYSTEMS OPTIMIZATION*</u>	<u>DEFAULT VALUES</u>	<u>COMMENTS</u>
260_____	Flag to Execute Methodology (Integer)	0	0 = Not execute 1 = Executed and short output 2 = Executed and long output
261_____	Property Tax Rate for the Structure	.025	May be different than property tax for solar system.
271_____	Input Pairs (New Load, Cost) for Wall Insulation. Input up to 10 Pairs (Array)	all 0's	Input pairs in form (Btu/Deg-Day-ft ² , \$)
272_____	Same as 271 but for Ceiling Insulation		
273_____	Same as 271 but for Windows		
274_____	Same as 271 but for Doors		
275_____	Same as 271 but for Infiltration Reducing Features		

* See Appendix E for details and an example.

PARAMETER	PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS ⁺	DEFAULT VALUES	COMMENTS
280 _____	No. of Points in Candidate Pump (Head, Flow) Subset, (Integer Array, 12 elements)		Sum cannot exceed 24
281 _____	Pump Head Values for Candidate Pumps (Array, 24 elements)		Ft.
282 _____	Pump Flow Values Corresponding to Heads in Line 281 (Array, 24 elements)		GPM
283 _____	Costs for Candidate Pumps (Array, 12 elements)		\$
290 _____	No. of Points in Crossflow HX Cost and UA Arrays (Integer)		Cannot exceed 13
291 _____	Crossflow HX Costs (Array, 13 elements)		\$
292 _____	Crossflow HX UA (Array, 13 elements)		Btu/Hr-°F
295 _____	No. of Points in Counterflow HX Cost and UA Arrays (Integer)		Cannot exceed 20
296 _____	Counterflow HX Costs (Array, 20 elements)		\$
297 _____	Counterflow HX UA (Array, 20 elements)		Btu/Hr-°F
300 _____	No. of Points in Candidate Fan Subsets (Array, 10 elements)		Sum cannot exceed 47
301 _____	Fan Head Values for Candidate Fans (Array, 47 elements)		Inches of Water
302 _____	Fan Flow Values Corresponding to Heads in Line 301 (Array, 47 elements)		SCFM
303 _____	Costs for Candidate Fans (Array, 10 elements)		\$

See pages III-62 to III-70

⁺ See Appendix E for a discussion.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
1	Solar System Type Flag	Array of system type flags by month. Available systems are listed in Table III-1. Can change by month, depending on system design and loads.
2	Solar System Transport Efficiency	Accounts for losses from pipes or ducts. [†] Table III-1 for defaults. See Appendix G.
3	Collector Inlet Temperature	Minimum daily collector inlet temperature in morning. SOLCOST computes inlet temperature rise through the day. See Table III-1 for defaults. Check Line 16 for allowable outlet temperature.

TABLE III-1. SOLAR SYSTEM TYPES AND DEFAULT VALUES

<u>Type Flat (line 1)</u>	<u>Solar System Type</u>	<u>Transport Effi- ciency[†] (Line 2)</u>	<u>Collector Inlet Temperature (Line 3)</u>
1	Space heating with liquid collectors, collector/storage HX, fan coils, or air duct HX	.95	115.
2	Type 1, no collector/storage HX	.95	105.
5 ^{††}	Space cooling with liquid collectors, absorption cooling	.60	190.
6 ^{††}	Type 5, no collector/storage HX	.60	180.
7	Space heating with air collectors, rock bed storage	.95	70.
8	Service water heating only, collector/storage HX, two tank method	.90	120.
9 ^{††}	Series heat pump system, water-to-water heat pump between storage and the load.	.95	60.
10 ^{††}	Parallel heat pump system, type 1 system with parallel air-to-air heat pump for auxiliary	.95	50.

[†]Transport efficiency is the fraction: 1. - Pipe Losses/Collected Solar. It does not include the efficiency of solar collection. Appendix G contains a methodology for estimating this factor. Storage tank insulation losses are accounted for separately with line 156.

^{††} Not validated, attempts to input these systems will result in termination of the run.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
4	Reference System Fuel Type (see Table III-2)	Reference System is main conventional heating or cooling system.
5	Reference System Efficiency/COP (see Table III-2)	Heating system efficiency or cooling system coefficient of performance.
6	Solar System-Fuel Type for Auxiliary Heating/Cooling.	See Table III-2
7	Solar System-Efficiency/COP for Auxiliary Equipment	Assumed constant through year. See Table III-2 for defaults keyed by Line 6.

TABLE III-2 COMBUSTION/USAGE EFFICIENCY FOR FUEL TYPES FOR REFERENCE OR AUXILIARY SYSTEMS

<u>Lines 4 & 6</u>	<u>Fuel/ Utility</u>	<u>Space Heating Efficiency</u>	<u>Service Water Heating Efficiency[†]</u>	<u>Space Cooling COP^{††}</u>
1	Natural gas	.7	.63	.45
2	Electricity	1.0	.90	2.50
3	Fuel Oil	.65	.59	.45
4	LP Gas	.70	.63	.45
5	Coal	.65	.59	.45

[†]For Line 1 = 8

^{††}For Line 1 = 5 or 6

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
10	Collector Type Flag (see Table III-3)	Entry of 1 through 10 causes SOLCOST to internally supply the defaulted efficiencies listed in Table III-3. If the user enters a 21 through 24 he must enter his own efficiency data as explained in Table III-3. (See note 1, next page)
11	Collector Fixed or Tracking Type Flag	<p>The SOLCOST insolation routine checks this flag to determine which components of the incoming solar radiation can be included in the analysis. Some collectors cannot accept diffuse solar energy, so types 5 through 8 must be specified. Altitude tracking collectors follow the solar altitude angle by month. Allowable options include:</p> <p>1 = Fixed, beam & diffuse (default) 2 = Azimuth tracking, beam & diffuse 3 = Altitude tracking, beam & diffuse 4 = Full tracking, beam & diffuse 5 = Fixed, beam only</p> <p>(See Note 2 ... next page)</p>


<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
		6 = Azimuth tracking, beam only 7 = Altitude tracking, beam only 8 = Full tracking, beam only
12	Collector Azimuth	Defaults to due South = 0.0 degrees, SE = +, SW = -
13	Collector Tilt 	Defaults to latitude, lat. + 7.5 degrees, & lat. + 15 degrees. Opti- mum collector size and cash flow sheet will be computed for each tilt angle.
14	Collector Efficiency	Input only if Line 10 = 21 or 23 See Appendix C, especially if a heat exchanger is present.
15	Collector Efficiency at $\Delta T/q = 0.5^{\circ}\text{F}/(\text{Btu/hr-ft}^2)$	Input only if line 10 = 21 or 23 See Appendix C.
16	Storage Maximum Allowable Temperature	Defaults to 200. $^{\circ}\text{F}$. The collector is shut off when this temperature exceeded.

TABLE III-3. COLLECTOR TYPES AND EFFICIENCY DATA

Type Flag			Intercept	$\Delta T/q_t = .5$
1	Liquid, flat plate, 1 cover, paint	Defaulted	.82	.24
2	Liquid, flat plate, 2 covers, paint	Defaulted	.67	.30
3	Liquid, flat plate, 1 cover, selective	Defaulted	.70	.30
4	Liquid, flat plate, 2 covers, selective	Defaulted	.67	.50
5	Liquid concentrating	Defaulted	.71	.65
6	Liquid, evacuated tube type	Defaulted	.62	.49
7	Air, flat plate, 1 cover, paint	Defaulted	.60	.17
8	Air, flat plate, 2 covers, paint	Defaulted	.52	.21
10	Liquid, trickle type, 1 cover	Defaulted	.72	.01
21	----User Defined, Liquid Type	User input Lines 14 & 15		
22	----User Defined, Evacuated Tube Type	User input, Line 20		
23	----User Defined, Air Type	User input, Line 14 & 15		
24	----User Defined, Air Type	User input, Line 19		

*****NOTES*****

1. A flat plate reflector can be evaluated by SOLCOST. See Lines 120-126 for input details.
1. The "azimuth" tracking algorithm assumes rotation about axis located in the plane of the collector at a fixed tilt angle.
3. If HX present, derate with methodology of Appendix C. Collector Parameters.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
17	Liquid Storage per Unit Collector Area	SOLCOST computes storage size for each candidate collector area by multiplying the area by this parameter. System performance and installation costs (see Line 57) are affected by this input. Units are gallon/sq. ft. Default is 1.5 gal/sq. ft.
18	Rock Bed Storage per Unit Collector Area	Similar to Line 17. Units are pounds/sq. ft. Default is 50 pounds/sq. ft.
19	Air Collector Efficiency	See Appendix G for input of this efficiency vs. ambient temperature and insolation is known. When efficiency data is known vs. inlet temperature, set Collector Type Flag = 23 and input lines 14 & 15.
20	Evacuated Tubular Collector Efficiency	See Appendix G for input of this efficiency array. Performance of these devices changes with the hour angle of the sun.
21	Flag for Non-Standard Analysis on Input Collector Area	<p>= 0 Causes SOLCOST to determine cost optimum collector area. (Default)</p> <p>= 1 Solar system performance and life cycle cost analysis is computed for candidate collector areas. Monthly performance and cash flow tables are printed for the collector area input on Line 22.</p> <p>= 2 Solar system performance only is computed for candidate collector areas. A monthly performance table is printed for collector area specified on Line 22.</p> <p>= 3 Solar system performance and life cycle cost analysis is computed for the collector area specified on Line 22. (Minimum run time option.)</p>
22	User Input Collector Area	See Line 21. In the optimization mode, this area is the upper limit on collector size for Line 21 = 0. Default value is 1×10^6 sq. ft. SOLCOST internally rounds to the nearest integer multiple of the module size input on Line 23.
23	Modular Collector Area	Area of one collector panel. The candidate system sizes will be multiples of this input. Default value is 20 sq. ft.
24	Print Flag for Data Bank City List	Input a 1 to get a table of cities and location codes for all of the cities in the data bank. <u>SOLCOST will do no further processing.</u>
25	Site Location Number	See Table III-4, (pg. III-23) for listing of cities. Data bank supplies weather and solar data for each site, lines 26 through 33. Use city nearest to installation. See Note 1 next page.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
26	Site Latitude	Dégrees
27	Site Clearness Factor	Each monthly clearness number in solar insolation calculation is multiplied by this parameter. See Appendix A for defaults.
28	Fraction of Possible Sunshine	Fraction of time that solar insolation is greater than a threshold. insolation value which corresponds to distinct shadows. Enter as fractions, i.e., .70 is 70%. See Note 2. Ignore this input if line 25 is input.
29	Minimum Daily Average Temperature	Used in collector performance analysis.
30	Maximum Daily Average Temperature	Same as Line 29 explanation.
31	Heating Degree Days (65°F base)	Used in simplified heating loads analysis.
34	Ground Reflectivity	Default is 0.2 corresponding to no-snow conditions. Use 0.7 for snow conditions.
35	Daily Horizontal Insolation	Input Monthly values of average global horizontal insolation, Btu/day-sq. ft. See Note 3.
36	Clearness Number Array	Input monthly values of clearness numbers. See Appendix A for details and listing of default values.

NOTES:

1. If a data bank site location is not used (Line 25 not input) then the following data must be input: Lines 26, 27, 28, 29, 30, 31.
2. Lines 28 (Fraction of Possible Sunshine) is the decimal equivalent of the percent of possible sunshine. Historical records for this measurement are available for approximately 300 cities in the United States.
3. Input of Line 35 (Daily Horizontal Insolation) will cause SOLCOST to ignore the Fraction of Possible Sunshine values input (or defaulted from data bank) on Line 28.

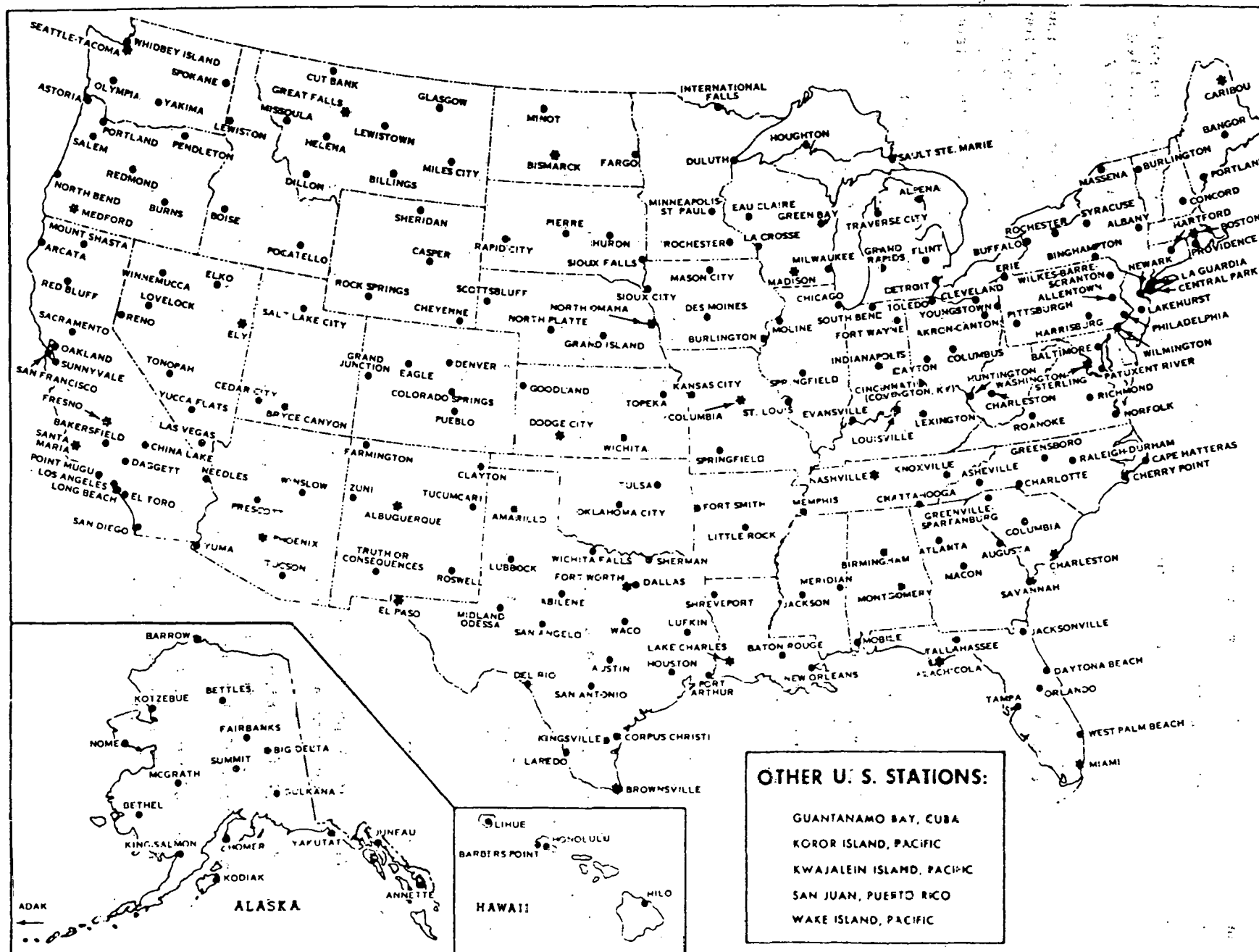


Figure III-1. Cities in SOLCOSI Data Bank With Radiation Data

TABLE III - 4 CITIES IN SOLCOST DATA BANK

SITE CODE	CITY NAME, STATE	LATITUDE			
1	BIRMINGHAM, AL	33.6	48	SAN DIEGO, CA	32.7
2	MOBILE, AL	30.7	49	SAN FRANCISCO, CA	37.6
3	MONTGOMERY, AL	32.3	50	SAN JOSE, CA	37.3
4	ANNETTE, AK	55.0	51	SANTA MARIA, CA	34.9
5	BARROW, AK	71.3	52	SUNNYVALE, CA	37.4
6	BETHEL, AK	60.8	53	BOULDER, CO	40.0
7	BETTLES, AK	66.9	54	COLORADO SPRGS, CO	38.8
8	BIG DELTA, AK	64.0	55	DENVER, CO	39.8
9	FAIRBANKS, AK	64.8	56	EAGLE, CO	39.7
10	GULKANA, AK	62.2	57	GRAND JUNCTION, CO	39.1
11	HOMER, AK	59.6	58	GRAND LAKE, CO	40.3
12	JUNEAU, AK	58.4	59	PUEBLO, CO	38.3
13	KING SALMON, AK	58.7	60	HARTFORD, CT	41.9
14	KODIAK, AK	57.8	61	WILMINGTON, DE	39.7
15	KOTZEBUE, AK	66.9	62	WASHINGTON, DC	39.0
16	MATANUSKA, AK	61.6	63	APALACHICOLA, FL	29.7
17	MCGRATH, AK	63.0	64	DAYTONA BEACH, FL	29.2
18	NOME, AK	64.5	65	GAINESVILLE, FL	29.7
19	SUMMIT, AK	63.3	66	JACKSONVILLE, FL	30.5
20	YAKUTAT, AK	59.5	67	KEY WEST, FL	24.6
21	PAGE, AZ	36.6	68	MIAMI, FL	25.8
22	PHOENIX, AZ	33.4	69	ORLANDO, FL	28.6
23	PRESCOTT, AZ	34.7	70	PENSACOLA, FL	30.5
24	TUCSON, AZ	32.1	71	TALLAHASSEE, FL	30.4
25	WINSLOW, AZ	35.0	72	TAMPA, FL	28.0
26	YUMA, AZ	32.7	73	W. PALM BEACH, FL	26.7
27	FORT SMITH, AR	35.3	74	ATLANTA, GA	33.7
28	LITTLE ROCK, AR	34.7	75	AUGUSTA, GA	33.4
29	ARCATA, CA	41.0	76	GRIFFIN, GA	33.3
30	BAKERSFIELD, CA	35.4	77	MACON, GA	32.7
31	CHINA LAKE, CA	35.7	78	SAVANNAH, GA	32.1
32	DAGGETT, CA	34.9	79	BARBERS PT, HI	21.3
33	DAVIS, CA	38.6	80	HILO, HI	19.7
34	EL TORO, CA	33.7	81	HONOLULU, HI	21.3
35	EUREKA, CA	40.8	82	LIHUE, HI	22.0
36	FRESNO, CA	36.8	83	ROISE, ID	43.6
37	INYOKERN, CA	35.7	84	LEWISTON, ID	46.4
38	LONG BEACH, CA	33.8	85	POCATELLO, ID	42.9
39	LOS ANGELES, CA	33.9	86	TWIN FALLS, ID	40.6
40	MT SHASTA, CA	41.3	87	CAIRO, IL	37.1
41	NEEDLES, CA	34.8	88	CHICAGO, IL	41.8
42	OAKLAND, CA	37.7	89	LEMONT, IL	41.7
43	PASADENA, CA	34.2	90	MOLINE, IL	41.5
44	POINT MUGU, CA	34.1	91	PEORIA, IL	40.7
45	RED BLUFF, CA	40.2	92	SPRINGFIELD, IL	39.8
46	RIVERSIDE, CA	34.0	93	EVANSVILLE, IN	38.1
47	SACRAMENTO, CA	38.5	94	FORT WAYNE, IN	41.0
			95	INDIANAPOLIS, IN	39.7

TABLE III-4 (cont.)

96	SOUTH BEND, IN	41.7	144	JACKSON, MS	32.3
97	AMES, IA	42.0	145	MERIDIAN, MS	32.3
98	BURLINGTON, IA	40.8	146	VICKSBURG, MS	32.2
99	DES MOINES, IA	41.5	147	COLUMBIA, MO	38.8
100	DUBUQUE, IA	42.5	148	KANSAS CITY, MO	39.3
101	MASON CITY, IA	43.2	149	ST LOUIS, MO	38.8
102	SIOUX CITY, IA	42.4	150	SPRINGFIELD, MO	37.2
103	CONCORDIA, KS	39.6	151	BILLINGS, MT	45.8
104	DODGE CITY, KS	37.8	152	CUT BANK, MT	48.6
105	GOODLAND, KS	39.4	153	DILLON, MT	45.3
106	MANHATTAN, KS	39.2	154	GLASGOW, MT	48.2
107	TOPEKA, KS	39.1	155	GREAT FALLS, MT	47.5
108	WICHITA, KS	37.7	156	HAVRE CITY, MT	48.5
109	COVINGTON, KY	39.1	157	HELENA, MT	46.6
110	LEXINGTON, KY	38.0	158	KALISPELL, MT	48.2
111	LOUISVILLE, KY	38.2	159	LEWISTOWN, MT	47.1
112	BATON ROUGE, LA	30.5	160	MILESCITY, MT	46.4
113	LAKE CHARLES, LA	30.1	161	MISSOULA, MT	46.9
114	NEW ORLEANS, LA	30.0	162	SUMMIT, MT	48.3
115	SHREVEPORT, LA	32.5	163	GRAND ISLAND, NE	41.0
116	BANGOR, ME	44.8	164	LINCOLN, NE	40.9
117	CARIBOU, ME	46.9	165	NORTH OMAHA, NE	41.4
118	EASTPORT, ME	44.9	166	NORTH PLATTE, NE	41.1
119	PORTLAND, ME	43.7	167	SCOTTS BLUFF, NE	41.9
120	ANNAPOLIS, MD	39.0	168	ELKO, NV	40.8
121	BALTIMORE, MD	39.2	169	ELY, NV	39.3
122	PATUXENT RIVER, MD	38.3	170	LAS VEGAS, NV	36.1
123	SILVER HILL, MD	38.8	171	LOVE LOCK, NV	40.1
124	AMHERST, MA	42.3	172	RENO, NV	39.5
125	BLUE HILL, MA	42.2	173	TONOPAH, NV	38.1
126	BOSTON, MA	42.4	174	WINNEMUCCA, NV	40.9
127	LYNN, MA	42.5	175	YUCCA FLATS, NV	37.0
128	NATICK, MA	42.3	176	CONCORD, NH	43.2
129	ALPENA, MI	45.1	177	ATLANTIC CITY, NJ	39.5
130	DETROIT, MI	42.4	178	LAKEHURST, NJ	40.0
131	EAST LANSING, MI	42.7	179	NEWARK, NJ	40.7
132	FLINT, MI	43.0	180	TRENTON, NJ	40.2
133	GRAND RAPIDS, MI	42.9	181	ALBUQUERQUE, NM	35.1
134	HOUGHTON, MI	47.2	182	CLAYTON, NM	36.5
135	LANSING, MI	42.8	183	FARMINGTON, NM	36.8
136	MARQUETTE, MI	46.6	184	ROSWELL, NM	33.4
137	SAULT STE MARIE, MI	46.5	185	TRUTH OR CONSEQUENCE, NM	33.2
138	TRAVERSE CITY, MI	44.7	186	TUCUMCARI, NM	35.2
139	DULUTH, MN	46.8	187	ZUNI, NM	35.1
140	INTRNTAL FALLS, MN	48.6	188	ALBANY, NY	42.8
141	MINNEAPOLIS, MN	44.9	189	BINGHAMPTON, NY	42.2
142	ROCHESTER, MN	43.9	190	BUFFALO, NY	42.9
143	ST CLOUD, MN	45.6	191	CANTON, NY	44.7

TABLE III-4 (cont.)

192	ITHACA, NY	42.5	240	BLOCK ISLAND, RI	41.1
193	MASSENA, NY	44.9	241	NEWPORT, RI	41.5
194	NEW YORK, NY	40.8	242	PROVIDENCE, RI	41.7
195	NY, NY (LAGUARDIA)	40.8	243	CHARLESTON, SC	32.9
196	ROCHESTER, NY	43.1	244	COLUMBIA, SC	34.0
197	SCHENECTADY, NY	42.8	245	GREENVILLE, SC	34.9
198	SYRACUSE, NY	43.1	246	HURON, SD	44.4
199	ASHEVILLE, NC	35.4	247	PIERRE, SD	44.4
200	CAPE HATTERAS, NC	35.3	248	RAPID CITY, SD	44.1
201	CHARLOTTE, NC	35.2	249	SIOUX FALLS, SD	43.6
202	CHERRY POINT, NC	34.9	250	CHATTANOOGA, TN	35.0
203	GREENSBORO, NC	36.1	251	KNOXVILLE, TN	35.8
204	RALEIGH, NC	35.9	252	MEMPHIS, TN	35.1
205	BISMARCK, ND	46.8	253	NASHVILLE, TN	36.1
206	DEVILS LAKE, ND	48.2	254	OAK RIDGE, TN	36.0
207	FARGO, ND	46.9	255	ABILENE, TX	32.4
208	MINOT, ND	48.3	256	AMARILLO, TX	35.2
209	WILLISTON, ND	48.3	257	AUSTIN, TX	30.3
210	AKRON, OH	40.9	258	BIG SPRINGS, TX	32.3
211	CINCINNATI, OH	39.1	259	BROWNSVILLE, TX	25.9
212	CLEVELAND, OH	41.4	260	CORPUSCHRISTI, TX	27.8
213	COLUMBUS, OH	40.0	261	DALLAS, TX	32.9
214	DAYTON, OH	39.9	262	DEL RIO, TX	29.4
215	PUT-IN-BAY, OH	41.7	263	EL PASO, TX	31.8
216	TOLEDO, OH	41.6	264	FORT WORTH, TX	32.8
217	YOUNGSTOWN, OH	41.3	265	GALVESTON, TX	29.2
218	OKLAHOMA CITY, OK	35.4	266	HOUSTON, TX	30.0
219	STILLWATER, OK	36.2	267	KINGSVILLE, TX	27.5
220	TULSA, OK	36.2	268	LAREDO, TX	27.5
221	ASTORIA, OR	46.2	269	LUBBOCK, TX	33.7
222	BAKER, OR	44.8	270	LUFKIN, TX	31.2
223	BURNS, OR	43.6	271	MIDLAND, TX	31.9
224	CORVALLIS, OR	44.6	272	FORT ARTHUR, TX	30.0
225	MEDFORD, OR	42.4	273	SAN ANGELO, TX	31.4
226	NORTH BEND, OR	43.4	274	SAN ANTONIO, TX	29.5
227	PENDLETON, OR	45.7	275	SHERMAN, TX	33.7
228	PORTLAND, OR	45.6	276	WACO, TX	31.6
229	REDMOND, OR	44.3	277	WICHITA FALLS, TX	34.0
230	ROSEBURG, OR	43.2	278	BRYCE CANYON, UT	37.7
231	SALEM, OR	44.9	279	CEDER CITY, UT	37.7
232	ALLENTOWN, PA	40.7	280	SALT LAKE CITY, UT	40.8
233	AVOCA, PA	41.3	281	BURLINGTON, VT	44.5
234	ERIE, PA	42.1	282	MT WEATHER, VA	39.1
235	HARRISBURG, PA	40.2	283	NORFOLK, VA	36.9
236	PHILADELPHIA, PA	39.9	284	RICHMOND, VA	37.5
237	PITTSBURGH, PA	40.5	285	ROANOKE, VA	37.3
238	SCRANTON, PA	41.3	286	OLYMPIA, WA	47.0
239	STATE COLLEGE, PA	40.8	287	PROSSER, WA	46.3

TABLE III-4 (cont.)

288	PULLMAN, WA	46.7	313	CALGARY, ALBERTA	51.0
289	RICHLAND, WA	46.3	314	EDMONTON, ALBERTA	53.6
290	SEATTLE, WA	47.5	315	LETHBRIDGE, ALBRT	49.6
291	SPOKANE, WA	47.6	316	VANCOUVER, BC	49.0
292	TACOMA, WA	47.3	317	VICTORIA, BC	48.0
293	WALLA WALLA, WA	46.1	318	CHURCHILL, MANITBA	58.8
294	WHIDBEY ISLAND, WA	48.4	319	WINNIPEG, MANITBA	49.9
295	YAKIMA, WA	46.6	320	MONCTON, NEW BRUN	46.1
296	CHARLESTON, WV	38.4	321	ST JOHN, NEW BRUN	45.0
297	ELKINS, WV	38.9	322	ST JOHN, NEWFNDLD	47.5
298	HUNTINGTON, WV	38.4	323	AKLAVIK, NW TERR	68.2
299	PARKERSBURG, WV	39.3	324	HALIFAX, NOV SCOT	45.0
300	EAU CLAIRE, WI	44.9	325	HAMILTON, ONT	43.0
301	GREEN BAY, WI	44.5	326	KAPUSKASING, ONT	49.4
302	LA CROSSE, WI	43.9	327	LONDON, ONT	43.0
303	MADISON, WI	43.1	328	OTTAWA, ONT	45.5
304	MILWAUKEE, WI	43.0	329	TORONTO, ONT	43.7
305	CASPER, WY	42.9	330	WINDSOR, ONT	42.0
306	CHEYENNE, WY	41.2	331	MONTREAL, QUEBEC	45.5
307	LANDER, WY	42.8	332	QUEBEC CITY, QUEB	47.0
308	LARAMIE, WY	41.3	333	SASKATOON, SASK	52.0
309	ROCK SPRINGS, WY	41.6	334	KOROR ISLAND	7.3
310	SHERIDAN, WY	44.8	335	KWAJALEIN ISLAND	8.7
311	YELLOWSTNPARK, WY	44.7	336	WAKE ISLAND	19.3
312	SAN JUAN, PR	18.4			

Data for 248 U.S. locations (see map) were taken from the NOAA Report, "Input data for Solar Systems".* In constructing the weather data base, NOAA used monthly normals (30-year mean values) of maximum, minimum, and average temperatures, and heating degree days extracted from Climatology of the United States No. 81 (By State) and Local Climatological Data Annual Summaries for 1977.

Average daily values of total hemispheric (global) solar radiation on a horizontal surface were based on corrected measurements for the remaining 222 stations. The 26 rehabilitated data stations are indicated by asterisks on the locator map. Most of the average values are based on a 24-25 year period. SOLMET Volume 1 - User's Manual lists the exact period, as well as provides information on the rehabilitation of hourly solar radiation data.

Additional U.S. cities for which no radiation data was available are still in the SOLCOST data bank. The percent of possible sunshine is used to estimate radiation for these locations. Users are cautioned to check these estimates against interpolated radiation for neighboring cities in the data base.

Several Canadian cities are also included in the SOLCOST data bank. The source for this data is not well documented and Canadian users are cautioned to check this data with possibly more recent literature sources.

*V. Cinquemani, et al, Input Data for Solar Systems, Nov. 1978, prepared by NOAA for U.S. Department of Energy, Division of Solar Technology, under Interagency Agreement No. E(49-26)-1041.

SOLCOST may not execute for cities north of the Arctic Circle.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
40	Space heating/cooling Loads Input or Compute Flag	See Table III-5 and Appendix H. Ignore this input if there is no space heating load.
41	Service Hot water Load Input or Compute Flag	See Table and Appendix H.

TABLE III-5. SPACE HEATING/COOLING AND SERVICE HOT WATER LOADS INPUT OR COMPUTATION METHOD

<u>Line 40</u>		
<u>Type Flag</u>	<u>Loads Computed or Input From:</u>	<u>Input Required</u>
2	Input Building Heat Loss Coefficient, H	Lines 42 and 43 (Default)
3	ASHRAE STD 90-75, H	Line 44
4	Utility Usage Records, H	Line 45
5	User Input or Loads by Month H, C, HW	Line 46
<u>Line 41</u>		
<u>Type Flag</u>	<u>Service HW Load From:</u>	
1	Typical Residential HW Use Pattern, HW	Line 47
2	Utility Usage Records (Summer Only), HW	Line 48
3	User Input HW Load, HW	Line 49 (Default)
4	Daily Water Use, Gallons	Line 154
5	See Appendix H for further information on loads.	

42	Building Heat Loss	$BHLC = \frac{\text{Design Heat Loss} \times 24}{(T_{in} - T_{out}) \times A_{floor} \text{ design}}, \frac{\text{Btu}}{^{\circ}\text{F-Day-Ft}^2}$
43	Building Gross Floor Area	Above ground floor area, used with Line 42.
44	ASHRAE STD 90-75 Building Description	Input of this data will cause SOLCOST to compute a space heat loss coefficient assuming the building satisfies ASHRAE Standard 90-75. See Table III-6.
45	Utility Usage Records	For retro-fit installations where building energy consumption is known. See Table III-7.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanation/Options</u>
46	User Input Loads by Month	Net daily energy delivered to heating or cooling load. Service and domestic water heating loads <u>can</u> be included in this input; if so, do not enter Lines 41 and 49.
47	Typical Residential HW Use Pattern	SOLCOST estimates hot water load from typical residential use patterns. See Table III-8.
48	Utility Usage Records (Summer Only)	Users can input their summer fuel usage to determine their HW load. See Table III-8.
49	User Input HW Load	Input constant net daily service water load here, millions of Btus/day. Default value is 0.0, ignore Line 41 and 49 if HW load has been combined with space heat load on Line 46.

TABLE III-6. INPUTS FOR ASHRAE STD 90-75 METHOD FOR SPACE HEATING LOAD ARRAY 44

= 1. for a detached one or two-family dwelling.
 TYPE..... = 2. for all other residential buildings, 3 stories or less
 = 3. for all buildings other than Type 1 or Type 2.
 WALL AREA..... = Gross exterior wall area, above grade, sq. ft. (includes windows and doors.)
 CEILING AREA..... = Ceiling area, sq. ft.
 WINDOW..... = Perimeter (sash crack length) of all windows, ft.
 PERIMETER
 SLIDING GLASS.... = Area of residential sliding glass doors, sq. ft. (Enter
 DOOR AREA 0.0 if Type 3 building.)
 RESIDENTIAL..... = Area of residential swinging doors, sq. ft. (Enter 0.0 if
 DOOR AREA Type 3 building.)
 NON RESIDENTIAL.. = Perimeter of non-residential swinging, revolving, or slid-
 DOOR PERIMETER ing doors, ft. (Enter 0.0 for Type 1 and 2 building.)
 FLOOR AREA..... = Area of floors over unheated spaces, i.e. crawl spaces,
 unheated basements, etc., sq. ft. (Enter 0.0 if none.)
 SLAB PERIMETER... = Perimeter of slab-on-grade floors, ft. (Enter 0.0 if
 none.)
 RESIDENTIAL..... = 44 , 1., 1420., 1200., 140., 42., 63., 0.0, 120., 0.0, *
 EXAMPLE

TABLE III-7. HEATING LOAD FROM UTILITY RECORDS (RETRO-FIT BUILDING)

Input Array 45 where:

Fuel Type..... From Table III-2, decimal.

Fuel Heat Content..... Btus/unit of fuel (unburned)
(Enter 1.0 to use default values listed on lines 90-94)

Seasonal Fuel Usage..... Quantity of fuel consumed over heating season.
(Space Heating Only) Units must be consistent with fuel heat content units. Deduct estimated fuel used for hot water heating.

Seasonal Degree Days..... Number of degree days (°F-Day) in heating season.
Available from local weather stations or fuel suppliers.

Gross Floor Area..... Above ground floor area in building.

Examples: 45, 3., 1.0, 1084., 7640., 1500., * \$ User default heat content
45, 3., 141800., 1084., 7640., 1500., * \$ User input heat content

TABLE III-8. DOMESTIC HOT WATER LOAD CALCULATION METHODS

Array 47 - Typical Use Pattern Method

Fuel Type..... From Table III-2, decimal

Fuel Heat Content..... Btus/unit of fuel (unburned) Enter 1.0 to use default values listed on Lines 90-94.

No. of Occupants..... Average number of occupants in residence, decimal.

Hot Water Use Schedule..... = 1. for light use, integer, (15. gal./person/day)
= 2. for average use, (20. gal./person/day)
= 3. for heavy use, (30. gal./person/day)

Water Delivery Temperature.. = Typically 140°F for houses with dishwashers.

Example: 47, 1., 1.0, 5., 2., 135., * \$ Typical Use Method

Array 48 - Summer Fuel Consumption Method

Fuel Type..... From Table III-2, decimal.

Fuel Heat Content.. Btus/unit of fuel (unburned). Enter 1.0 to use default values listed on Lines 90-94.

Fuel Usage..... = Average monthly fuel consumption for water heating.
Units must be consistent with fuel heat content input.

Example: 48, 1., 1.0, 65., * \$ Summer Fuel Method

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
55	Solar System Fixed Initial Cost	Input total system fixed costs or increment above reference system costs. Does not include collector costs or storage costs.
56	Solar System Installed Cost per Unit Collector area.	Installed cost per square foot of collector area.
57	Solar System Installed Cost of Liquid Storage.	Installed cost per gallon of water storage for liquid systems.
58	Solar System Installed Cost of Rock Bed Storage.	Installed cost per ton of rock bed storage.
59	Solar System Maintenance Cost	Fraction of initial cost for maintenance each year.
60	Ref. System Initial Installed Cost	Input total cost of reference system that would be installed instead of the solar system.
61	Ref. System Maintenance Cost	See Line 59.
65	Financial Scenario Indicator	Three tax considerations are available: 1 ... Homeowner solar system (Residential) 2 ... Business owned system 3 ... Non-profit organization owned system, i.e., schools, public buildings.
66	Solar Tax Incentives (Applies to Residential Scenario Only, Business Owner see Line 77)	If applicable, enter Array 66 as follows: 66, <u>Fraction</u> , <u>\$</u> , <u>Fraction</u> , <u>\$</u> + i.e., 66,.30,2000.,.20,8000.,* (Default) means: 30% of first \$2000 +20% of next \$8000 will be credited against net tax due. Two steps must be input.
67	Discount Rate of Present Worth Analysis	A discount rate is the minimum rate of return which a person (or company) usually realizes from their investments. For homeowners a reasonable discount rate is the interest rate at which they can borrow money for a solar investment.
68	Loan Interest Rate	If there is no loan, i.e., 100% down payment, input a 1.0 down payment fraction and omit Lines 68 and 69.
69	Loan Term	Years
70	Loan Down Payment	For 10% down, enter .10, etc.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
71	Term of Life Cycle Cost Analysis	Usually this is the expected life of the solar system. It can be different from the loan term. Max. of 30 years allowed.
72	Insurance Rate	Fraction of initial cost each year. Same rate applies to both solar and reference system.
73	Property Tax Rate	Fraction of initial cost each year. If a state or local property tax incentive applies, enter a -1.0 for Line 73, and Enter Line 83.
74	Income Tax Rate	Owner's income tax rate (fraction).
75	Depreciation Method	Applies to BUS scenario only. Options are: 1=SL ... straight line 2=DB ... declining balance
76	DB Multiplier	Multiplier used in declining balance depreciation method. Limited to 1.5 for commercial and industrial buildings and 2.0 for new residential rental property.
77	Investment Tax Credit Rate	Solar tax credit is 10% (Default) Enter 20% for process heating equipment.
78	Additional First Year Depreciation	Allowed for solar systems which are considered business related equipment, i.e., to heat hot water for a manufacturing process, a car wash heater, etc. Usually 20% (enter .20) is allowed, up to a \$2000 limit.
79	System Useful Life	The allowable useful life for depreciation purposes. Currently ten years is allowed for building HVAC systems.
80	Storage Tank Useful Life	Same as Line 79, only 22 years is allowable minimum for storage components.
81	Salvage Value Fraction	Salvage value at the end of useful life.
82	Inflation Factor for Maintenance, Insurance, and Property Taxes	Annual escalation of these costs due to inflation. A value of 6% (enter .06) is considered reasonable.
83	Property Tax Rate vs. Time	If your state or county has eliminated (or reduced) property tax rates on solar systems, enter:

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
		83, Rate, First I Years, Rate, Next J Years, *
		83, 0., 10., .025 30., *
		means zero property taxes will be levied for the first ten years, and normal rate of 2.5% will apply for the next 30 years. If Line 83 is input, a -1.0 must be entered in Line 73.
84	Collector Optimization Method Flag	SOLCOST defaults to the net present worth method to compute the cost optimum system size. Enter Line 84=2 to optimize with internal rate of return. Enter Line 84=3 to optimize with undiscounted lifetime savings
90	Natural Gas Cost Schedule (See Note 1 and pages III-7,8 for examples)	Check with local supplier for heat content of delivered natural gas. Default is 100000 Btus/100 cubic feet. In Denver this value is 84000. Escalation rate is on a percent per year basis, entered as a fraction. Escalation should include inflation effect, i.e., if a real price rise of 5% is expected, and inflation is 4%, enter .09 as the escalation.
91	Electricity Cost Schedule (See Note 1)	Enter as dollars/Kw-hr.
92	Fuel Oil Cost Schedule	Enter as dollars/gallon.
93	LP Gas Cost Schedule	Enter as dollars/gallon.
94	Coal Cost Schedule	Enter as dollars/ton.
95	Electricity Demand Cost	If the utility applies demand charges, this schedule must be input and expected demand levels estimated on lines 96, 97, and 98. In Denver, the local utility is charging \$6.55 per month for the first Kw and \$2.70 per Kw of demand above one Kw. Last entry on Line 95 must be the escalation factor for demand costs.
96	Electrical Demand Level Ref. System	Required if demand charges apply.
97	Electrical Demand Level Solar Auxiliary Furnace	Required if demand charges apply.
98	Electrical Demand Level Solar Assisted Heat Pump	Required if demand charges apply.

Note:

1. Utilities will usually quote their electric and gas rate schedules without including fuel cost and gas cost adjustment factors. The input electric and gas cost schedules must be adjusted to account for these parameters.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
100	Escalation Table for Natural Gas	<p>Escalation rate vs. time for natural gas. Enter a -1.0 for the escalation factor in Array 90. Entry of Array 90 and Array 100 as in the example:</p> <p>90, .15,800.,-1.*</p> <p>100, .08,5.,.06,10.,.09,15.,*</p> <p>will cause the natural gas price to be escalated:</p> <p>8 %/yr for the first 5 years 6 %/yr for the next 10 years 9 %/yr for the next 15 years</p> <p>A maximum of four escalations may be entered in Array 100.</p>
101	Escalation Table for Electricity	See Line 100
102	Escalation Table for Fuel Oil	See Line 100
103	Escalation Table for LP Gas	See Line 100
104	Escalation Table for Coal	See Line 100
106	Summer Fuel Cost Schedule for Reference System	<p>Lines 106 and/or 107 may be entered when fuel or electricity prices vary by season or month. Lines 108 and/or 109 must be entered with integer 1's or 0's to flag the months during which the prices in Lines 106 and 107 apply. For example, a proposed system uses electricity for the solar auxiliary and also for the reference energy source. During the months of April through September, the electric rate is increased by 20%. The following arrays should be entered:</p> <p>91,.034,100000.,.10,*</p> <p>106,.0408,100000.,.10,3413.,*</p> <p>107,.0408,100000.,.10,3413.,*</p> <p>108,0,0,0,1,1,1,1,1,1,0,0,0,*</p> <p>109,0,0,0,1,1,1,1,1,1,0,0,0,*</p> <p>Array 91 will be used for the months October through March. Array 106 will be used during the months flagged by 1's in array 108. Array 107 will be used during the months flagged by 1's in array 109. Note that</p>
107	Summer Fuel Cost Schedule for System Solar Auxiliary	
108	Month Flags for Summer Fuel Reference System	
109	Month Flags for Summer Fuel Auxiliary	

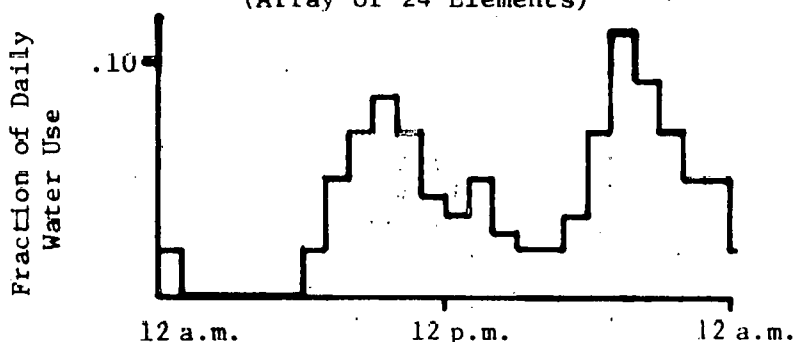
<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>																					
		the fuel heat content <u>must</u> be entered in arrays 106 and 107. If the user wishes to escalate the summer price schedule with multiple escalation factors, he must enter a -1.0 for the escalation in Line 106 or 107, and also enter: Line 104 to escalate Line 106, Line 108 to escalate Line 107.																					
120	Reflector Analysis Flag	Enter an integer 1 to access the reflector/collector analysis. Flat plate reflectors with a common edge at the collector base are assumed. The analysis accounts for shadowing of the collector by the reflector at low sun angles. Diffuse and specular reflections are considered in the analysis.																					
121	Reflector/Collector Common Edge Length	Length in feet of common edge between collector and reflector.																					
122	Collector Length	Collector length, ft.																					
123	Reflector Length	Reflector length, ft.																					
		****NOTE: The above dimensions need not be actual, but should indicate the relative sizes of collector and reflector.																					
124	Reflector/Collector Angle	Angle between the reflector and collector, degrees.																					
125	Reflector Diffuse	Dimensionless, enter as decimal fraction, i.e. enter .70 as 70% Reflectivity.																					
126	Reflector Specular Solar Reflectivity	Typical values for common reflector materials																					
		<table> <tr> <th></th><th><u>Diffuse Reflectivity</u></th><th><u>Specular Reflectivity</u></th></tr> <tr> <td>Silvered glass</td><td>0.</td><td>.70-.84</td></tr> <tr> <td>Aluminized acrylic on .025" aluminum</td><td>0.</td><td>.85</td></tr> <tr> <td>Aluminized teflon on .025" aluminum</td><td>0.</td><td>.87</td></tr> <tr> <td>Alzak aluminum</td><td>0.</td><td>.78</td></tr> <tr> <td>White marble, ground</td><td>.53</td><td>0.</td></tr> <tr> <td>White sand, fine</td><td>.59</td><td>0.</td></tr> </table>		<u>Diffuse Reflectivity</u>	<u>Specular Reflectivity</u>	Silvered glass	0.	.70-.84	Aluminized acrylic on .025" aluminum	0.	.85	Aluminized teflon on .025" aluminum	0.	.87	Alzak aluminum	0.	.78	White marble, ground	.53	0.	White sand, fine	.59	0.
	<u>Diffuse Reflectivity</u>	<u>Specular Reflectivity</u>																					
Silvered glass	0.	.70-.84																					
Aluminized acrylic on .025" aluminum	0.	.85																					
Aluminized teflon on .025" aluminum	0.	.87																					
Alzak aluminum	0.	.78																					
White marble, ground	.53	0.																					
White sand, fine	.59	0.																					

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>	
		<u>Diffuse Reflectivity</u>	<u>Specular Reflectivity</u>
		White sand, course	.50 0.
		Roofing, bituminous felt, aluminized	.60 0.
		Aluminum, as received	0. .40-.70
		Aluminum, cleaned	0. .45-.75
		Aluminized Mylar	0. .75-.85
		****NOTE: The sum of the diffuse and specular reflectivities is the total solar reflectivity for the surface.	
130	Extended Print Flag Hourly Solar Fluxes	Enter an integer 1 to print hourly solar fluxes incident on the collector for each day in the analysis.	
131	Extended Print Flag Printer Plots	Enter an integer 1 to get printer plots for load fraction versus collector area, savings versus collector area and cash flow versus life of system.	
132	Extended Print Flag Insolation Summary	Enter an integer 1 to get a solar insolation summary.	
134	Print Suppression Flag	Value 0 = Print everything (Default) 1 = Print only thermal results 2 = Print only cash flow table 3 = Print only bottom line results, i.e., payback, net present worth, ROR, solar fraction, annual energy savings.	

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
<u>ITERATIVE DAWN STORAGE TEMPERATURE PROCEDURE</u>		
140	Flag to Skip Inlet Temperature Iterative Procedure (Integer)	Enter a 0 to skip iterative procedure.
141	Convergence ΔT on Dawn Storage Temperature, $^{\circ}F$	Default ΔT provides reasonable speed/accuracy. See Appendix B.
142	Maximum Allowable Number of Iterations (Integer)	If convergence is not achieved before this number of iterations, a warning message is printed.
143	Minimum Allowable Storage Tank Temperature, $^{\circ}F$ (For Service Hot Water Systems, see line 153)	Lower Set Point below which useful energy can be supplied to the load. The storage temperature is not allowed to go below this temperature. Ignore for service hot water systems.
145	Flag to Print Monthly Max, Min, Avg Storage Temperatures (Integer)	Enter a 0 (zero) (default) for no output. Enter a 1 to print for optimum or specified collector area only. Enter a 2 to print all candidate

DETAILED SERVICE (DOMESTIC) WATER SYSTEM INPUTS*

- 150 Hourly Hot Water Load Fractions versus Hour of Day
(Array of 24 Elements)



Default Daily Hot Water Load Schedule

Array of 24 fractions which determine the hourly load for that hour from midnight. Default values yield the profile shown in the following figure.

$$\dot{Q}_1 = \text{FRACT}_i * Q_{\text{Daily Load}} \quad i = 1, \dots, 24$$

$$\text{and } \sum_{i=1}^{24} \text{FRACT}_i = 1.0$$

+ The use of mixing (tempering) valves in two-tank service water heating systems is often required by building codes. Version 1.0 of SOLCOST could not evaluate the effect of this component on system performance. Versions 2.0 and later do account for mixing valve effects. See Lines 15 and 152.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
151	Auxiliary Water Heater Set Temperature, °F	Auxiliary water heater set temperature. Usually this is the delivery temperature, however, when a mixing valve is present, this temperature may be higher than the set point on the mixing valve.
152	Water Delivery (Mixing Valve) Temperature, °F	Delivery (or mixing valve) temperature.
153	Monthly Supply (or Ground) Water Temperatures, °F (Array) See Table III-9 for suggested average soil temperatures.	Array of monthly supply (or ground water) temperatures. The minimum allowable storage tank temperature is internally defaulted to the input monthly supply temperature (Line 153) and Line 143 is ignored. For combined space and service water systems, SOLCOST assumes that the service water is pre-heated in the space heating storage tank.
154	Hot Water Usage, Gal/Day	Hot water usage in gallons per day. Input will cause the hot water load to be computed from: $Q_{\text{Daily}} = 8.33 \text{ NGal}(T_{\text{Del}} - T_{\text{Supply}})$ Load If this load method is used, Line 41 must be input as an Integer 4. For combined space heating and service water systems, SOLCOST will internally add the hot water load to the space heating load or to the load input in Line 46.
155	Auxiliary Tank UA, Btu/lir-°F	Auxiliary tank UA. This parameter will not affect the SOLCOST results, since a similar loss is assumed for the alternative conventional system. The magnitude of this loss is printed in the storage temperature summary (Line 145=1).
156	Pre-Heat (or Storage) Tank Insulation U Value, Btu-Hr/ft ² -°F	Pre-heat tank insulation U value. Experience has shown that tank insulation losses are often double their expected analytical values. For this reason, users are cautioned to be liberal in their estimate of the insulation U-value. Since the size of this tank is not known beforehand, and because the insulated surface area varies with volume, SOLCOST

TABLE III-9

AVERAGE EARTH TEMPERATURES

Location	Month	Winter 12,1,2	Spring 3,4,5	Summer 6,7,8	Autumn 9,10,11	Annual
Alabama						
Anniston AP ^a		55.	58.	70.	67.	63.
Birmingham AP		54.	58.	71.	68.	63.
Mobile AP		61.	63.	74.	71.	67.
Mobile CO ^b		61.	64.	75.	72.	68.
Montgomery AP		58.	61.	73.	70.	65.
Montgomery CO		59.	62.	74.	71.	66.
Arizona						
Bisbee COOP ^c		55.	58.	70.	67.	62.
Flagstaff AP		35.	39.	54.	50.	45.
Ft Huachuca (proving ground)		55.	58.	71.	68.	63.
Phoenix AP		60.	64.	79.	75.	69.
Phoenix CO		61.	65.	80.	76.	70.
Prescott AP		46.	49.	65.	61.	55.
Tucson AP		59.	62.	76.	73.	68.
Winslow AP		45.	49.	65.	61.	55.
Yuma AP		65.	69.	84.	80.	75.
Arkansas						
Fort Smith AP		52.	56.	72.	68.	62.
Little Rock AP		53.	57.	72.	68.	62.
Texarkana AP		56.	60.	74.	71.	65.
California						
Bakersfield AP		56.	60.	74.	70.	65.
Beaumont CO		53.	56.	67.	64.	60.
Bishop AP		47.	51.	65.	61.	56.
Blue Canyon AP		43.	46.	58.	55.	50.
Burbank AP		58.	60.	68.	66.	63.
Eureka CO		50.	51.	54.	54.	52.
Fresno AP		54.	58.	72.	68.	63.
Los Angeles AP		58.	59.	64.	63.	61.
Los Angeles CO		60.	61.	68.	66.	64.
Mount Shasta CO		41.	44.	57.	54.	49.
Oakland AP		53.	54.	60.	59.	56.
Red Bluff AP		54.	58.	72.	69.	63.
Sacramento AP		53.	56.	67.	64.	60.
Sacramento CO		54.	57.	68.	65.	61.

The list presents the average earth temperature from 0 to 10 feet below the surface for the four seasons of the year and for the whole year for the indicated locals. The temperatures were computed on the basis of the method described in the 1965 ASHRAE technical paper entitled "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States" by T. Kusuda and P. R. Achenback (in ASHRAE Transactions, Volume 71, Part I, p. 61, 1965) using the monthly average air temperatures published by the U.S. Weather Bureau for listed localities in the United States. Earth temperatures are expressed in fahrenheit degrees.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
California					
Sandberg CO	47.	50.	63.	60.	55.
San Diego AP	59.	60.	66.	65.	62.
San Francisco AP	53.	54.	59.	57.	56.
San Francisco CO	55.	55.	59.	58.	57.
San Jose COOP	55.	57.	64.	62.	59.
Santa Catalina AP	57.	58.	64.	62.	60.
Santa Maria AP	54.	55.	60.	59.	57.
Colorado					
Alamosa AP	30.	35.	52.	48.	41.
Colorado Springs AP	39.	43.	59.	55.	49.
Denver AP	39.	43.	60.	56.	50.
Denver CO	41.	45.	61.	58.	51.
Grand Junction AP	39.	44.	65.	60.	52.
Pueblo AP	41.	45.	62.	58.	51.
Connecticut					
Bridgeport AP	40.	44.	61.	57.	50.
Hartford AP	39.	43.	61.	57.	50.
Hartford AP (Brainer)	39.	43.	60.	56.	50.
New Haven AP	40.	44.	60.	56.	50.
Delaware					
Wilmington AP	44.	48.	64.	60.	54.
Washington, D.C.					
Washington AP	47.	51.	66.	63.	56.
Washington CO	47.	51.	66.	63.	57.
Silver Hill OBS ^d	46.	50.	65.	61.	55.
Florida					
Apalachicola CO	63.	65.	75.	73.	69.
Daytona Beach AP	65.	67.	75.	74.	70.
Fort Myers AP	70.	71.	78.	76.	74.
Jacksonville AP	63.	66.	75.	73.	69.
Jacksonville CO	64.	66.	76.	73.	70.
Key West AP	74.	75.	80.	79.	77.
Key West CO	75.	76.	81.	79.	78.
Lakeland CO	68.	69.	77.	75.	72.
Melbourne AP	68.	70.	77.	75.	72.
Miami AP	72.	74.	79.	78.	76.
Miami CO	72.	73.	78.	77.	75.
Miami Beach COOP	74.	75.	80.	78.	77.
Orlando AP	68.	70.	77.	75.	72.
Pensacola CO	62.	64.	74.	72.	68.
Tallahassee AP	61.	64.	74.	72.	68.
Tampa AP	68.	69.	77.	75.	72.
West Palm Beach	71.	73.	79.	77.	75.
Georgia					
Albany AP	60.	63.	75.	72.	67.
Athens AP	54.	58.	71.	68.	63.
Atlanta AP	54.	57.	70.	67.	62.
Atlanta CO	54.	57.	70.	67.	62.
Augusta AP	56.	59.	72.	69.	64.
Columbus AP	56.	59.	72.	69.	64.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Georgia					
Macon AP	58.	61.	74.	71.	66.
Rome AP	53.	56.	70.	67.	61.
Savannah AP	60.	63.	74.	71.	67.
Thomasville CO	62.	64.	74.	72.	68.
Valdosta AP	61.	64.	74.	72.	68.
Idaho					
Boise AP	40.	44.	62.	58.	51.
Idaho Falls 46 W	30.	35.	55.	50.	42.
Idaho Falls 42 N W	28.	33.	54.	49.	41.
Lewiston AP	42.	46.	63.	59.	52.
Pocatello AP	35.	40.	59.	55.	47.
Salmon CO	32.	37.	56.	52.	44.
Illinois					
Cairo CO	49.	53.	70.	66.	60.
Chicago AP	38.	43.	62.	57.	50.
Joliet AP	37.	42.	61.	56.	49.
Moline AP	38.	43.	62.	58.	50.
Peoria AP	39.	44.	63.	58.	51.
Springfield AP	41.	45.	64.	60.	52.
Springfield CO	43.	47.	66.	62.	54.
Indiana					
Evansville AP	47.	51.	67.	63.	57.
Fort Wayne AP	39.	43.	61.	57.	50.
Indianapolis AP	41.	46.	64.	59.	52.
Indianapolis CO	43.	48.	65.	61.	54.
South Bend AP	38.	42.	61.	56.	49.
Terre Haute AP	42.	47.	65.	60.	53.
Iowa					
Burlington AP	39.	44.	64.	59.	51.
Charles City CO	33.	38.	60.	55.	46.
Davenport CO	39.	44.	64.	59.	51.
Des Moines AP	37.	42.	63.	58.	50.
Des Moines CO	38.	43.	64.	59.	51.
Dubuque AP	34.	39.	60.	55.	47.
Sioux City AP	35.	40.	62.	57.	49.
Waterloo AP	35.	40.	61.	56.	48.
Kansas					
Concordia CO	42.	47.	67.	62.	54.
Dodge City AP	43.	48.	67.	62.	55.
Goodland AP	38.	43.	62.	57.	50.
Topeka AP	43.	47.	66.	62.	55.
Topeka CO	44.	49.	68.	63.	56.
Wichita AP	45.	50.	68.	64.	57.
Kentucky					
Bowling Green AP	47.	51.	67.	63.	57.
Lexington AP	44.	48.	65.	61.	54.
Louisville AP	46.	50.	67.	63.	56.
Louisville CO	47.	51.	67.	64.	57.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Louisiana					
Baton Rouge AP	61.	63.	74.	72.	67.
Burrwood CO	65.	67.	77.	74.	71.
Lake Uharles AP	61.	64.	75.	73.	68.
New Orleans AP	63.	65.	75.	73.	69.
New Orleans CO	64.	66.	77.	74.	70.
Shreveport AP	58.	51.	75.	72.	66.
Maine					
Caribou AP	24.	29.	50.	45.	37.
Eastport CO	33.	37.	51.	48.	42.
Portland AP	33.	38.	56.	51.	44.
Maryland					
Baltimore AP	45.	59.	65.	61.	55.
Baltimore CO	47.	51.	67.	63.	57.
Frederick AP	44.	48.	65.	61.	55.
Massachusetts					
Boston AP	41.	44.	61.	57.	51.
Nantucket AP	41.	44.	57.	54.	49.
Pittsfield AP	34.	38.	55.	51.	44.
Worcester AP	36.	40.	58.	54.	47.
Michigan					
Alpena CO	33.	37.	54.	50.	43.
Detroit Willow Run AP	38.	42.	60.	56.	49.
Detroit City AP	38.	43.	60.	56.	49.
Escanaba CO	30.	35.	53.	49.	42.
Flint AP	36.	40.	58.	54.	47.
Grand Rapids AP	36.	40.	58.	54.	47.
Grand Rapids CO	38.	42.	60.	56.	49.
East Lansing CO	36.	40.	58.	54.	47.
Marquette CO	31.	35.	53.	49.	42.
Muskegon AP	36.	40.	57.	53.	47.
Sault Ste Marie AP	28.	32.	51.	47.	39.
Minnesota					
Crookston COOP	25.	31.	55.	49.	40.
Duluth AP	25.	30.	52.	47.	38.
Duluth CO	26.	21.	52.	47.	39.
International Falls	22.	27.	51.	45.	36.
Minneapolis AP	32.	37.	60.	54.	46.
Rochester AP	31.	36.	58.	53.	44.
Saint Cloud AP	28.	33.	56.	51.	42.
Saint Paul AP	32.	37.	60.	54.	46.
Mississippi					
Jackson AP	57.	61.	73.	70.	65.
Meridian AP	57.	60.	72.	69.	64.
Vicksburg CO	58.	61.	74.	71.	66.
Missouri					
Columbia AP	43.	48.	66.	62.	55.
Kansas City AP	44.	49.	68.	64.	56.
Saint Joseph AP	42.	47.	67.	62.	54.
Saint Louis AP	45.	49.	67.	63.	56.
Saint Louis CO	46.	50.	68.	64.	57.
Springfield AP	45.	49.	66.	62.	56.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Montana					
Billings AP	35.	40.	59.	55.	47.
Butte AP	27.	31.	50.	45.	38.
Glasgow AP	27.	33.	56.	51.	42.
Glasgow CO	28.	34.	57.	52.	43.
Great Falls AP	34.	38.	56.	52.	45.
Harve CO	31.	36.	57.	52.	44.
Helena AP	31.	36.	55.	50.	43.
Helena CO	32.	36.	55.	50.	43.
Kalispell AP	32.	37.	54.	50.	43.
Miles City AP	32.	37.	59.	54.	45.
Missoula AP	33.	37.	56.	51.	44.
Nebraska					
Grand Island AP	38.	43.	64.	59.	51.
Lincoln AP	39.	44.	64.	60.	52.
Lincoln CO University	40.	45.	65.	61.	53.
Norfolk AP	35.	40.	62.	57.	48.
North Platte AP	37.	42.	62.	57.	49.
Omaha AP	39.	44.	65.	60.	52.
Scottsbluff AP	36.	41.	60.	56.	48.
Valentine CO	35.	40.	61.	56.	48.
Nevada					
Elko AP	34.	39.	57.	53.	46.
Ely AP	35.	39.	56.	52.	45.
Las Vegas AP	56.	60.	78.	74.	67.
Reno AP	40.	44.	58.	55.	49.
Tonopah	41.	45.	61.	57.	51.
Winnemucca AP	38.	42.	60.	56.	49.
New Hampshire					
Concord AP	33.	38.	56.	52.	45.
Mt Washington COOP	17.	21.	37.	33.	27.
New Jersey					
Atlantic City CO	45.	49.	63.	60.	54.
Newark AP	43.	47.	63.	59.	53.
Trenton CO	43.	47.	64.	60.	53.
New Mexico					
Albuquerque AP	46.	50.	67.	63.	57.
Clayton AP	43.	47.	63.	59.	53.
Raton AP	38.	42.	58.	54.	48.
Roswell AP	51.	54.	69.	66.	60.
New York					
Albany AP	36.	40.	59.	54.	47.
Albany CO	38.	43.	61.	56.	49.
Bear Mountain CO	38.	42.	59.	55.	48.
Binghamton AP	34.	38.	56.	52.	45.
Binghamton CO	38.	42.	59.	55.	48.
Buffalo AP	37.	41.	58.	54.	47.
New York AP (La Guardia)	44.	48.	64.	60.	54.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
New York					
New York CO	44.	47.	63.	59.	53.
New York Central Park	44.	48.	64.	60.	54.
Oswego CO	36.	40.	58.	54.	47.
Rochester AP	37.	41.	58.	54.	47.
Schenectady COOP	35.	40.	59.	55.	47.
Syracuse AP	38.	42.	60.	56.	49.
North Carolina					
Asheville CO	48.	51.	64.	61.	56.
Charlotte AP	52.	55.	69.	66.	60.
Greensboro AP	49.	53.	67.	64.	58.
Hatteras CO	56.	59.	70.	68.	63.
Raleigh AP	51.	55.	69.	65.	50.
Raleigh CO	52.	56.	70.	66.	61.
Wilmington AP	56.	59.	71.	69.	64.
Winston Salem AP	50.	53.	67.	64.	58.
North Dakota					
Bismarck AP	27.	33.	56.	51.	42.
Devils Lake CO	24.	29.	54.	48.	39.
Fargo AP	26.	32.	56.	50.	41.
Minot AP	25.	31.	54.	49.	39.
Williston CO	27.	33.	56.	50.	41.
Ohio					
Akron-Canton AP	39.	43.	60.	56.	50.
Cincinnati AP	43.	47.	64.	50.	54.
Cincinnati CO	46.	50.	66.	63.	56.
Cincinnati ABBE OBS	45.	49.	65.	61.	55.
Cleveland AP	40.	44.	61.	57.	51.
Cleveland CO	41.	45.	62.	58.	51.
Columbus AP	41.	46.	62.	59.	52.
Columbus CO	43.	47.	64.	60.	53.
Dayton AP	42.	46.	63.	59.	52.
Sandusky CO	41.	45.	62.	58.	51.
Toledo AP	38.	43.	60.	56.	49.
Youngstown AP	39.	43.	60.	56.	50.
Oklahoma					
Oklahoma City AP	50.	54.	71.	67.	60.
Oklahoma City CO	50.	55.	71.	68.	61.
Tulsa AP	50.	54.	71.	67.	61.
Oregon					
Astoria AP	47.	48.	56.	54.	51.
Baker CO	36.	40.	56.	52.	46.
Burns CO	36.	40.	58.	54.	47.
Eugene AP	46.	48.	59.	57.	52.
Meacham AP	34.	38.	52.	49.	43.
Medford AP	46.	49.	62.	59.	54.
Pendelton AP	42.	46.	63.	59.	53.
Portland AP	46.	49.	60.	57.	53.
Portland CO	48.	50.	61.	59.	55.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Oregon					
Roseburg AP	47.	49.	60.	57.	53.
Roseburg CO	48.	51.	61.	59.	55.
Salem AP	46.	49.	60.	57.	53.
Sexton Summit	42.	44.	55.	52.	48.
Troutdale AP	45.	58.	59.	57.	52.
Pennsylvania					
Allentown AP	40.	44.	62.	58.	51.
Erie AP	38.	42.	58.	55.	48.
Erie CO	40.	44.	60.	56.	50.
Harrisburg AP	43.	47.	63.	59.	53.
Park Place CO	36.	40.	57.	53.	46.
Philadelphia AP	44.	48.	64.	61.	54.
Philadelphia CO	46.	50.	66.	62.	56.
Pittsburgh Allegheny	42.	46.	62.	58.	52.
Pittsburgh GRTR PITT	40.	44.	61.	57.	51.
Pittsburgh CO	44.	48.	64.	60.	54.
Reading CO	43.	47.	64.	60.	54.
Scranton CO	40.	44.	61.	57.	50.
Wilkes Barre-Scranton	39.	43.	60.	56.	49.
Williamsport AP	40.	44.	61.	57.	51.
Rhode Island					
Block Island AP	41.	45.	59.	55.	50.
Providence AP	39.	43.	59.	56.	49.
Providence CO	41.	45.	62.	58.	51.
South Carolina					
Charleston AP	58.	61.	72.	70.	65.
Charleston CO	60.	62.	74.	71.	67.
Columbia AP	56.	59.	72.	69.	64.
Columbia CO	57.	60.	72.	69.	64.
Florence AP	55.	59.	72.	69.	64.
Greenville AP	53.	56.	69.	66.	61.
Spartanburg AP	53.	56.	70.	66.	61.
South Dakota					
Huron AP	31.	37.	60.	55.	46.
Rapid City AP	34.	39.	58.	54.	46.
Sioux Falls AP	32.	37.	60.	55.	46.
Tennessee					
Bristol AP	48.	51.	65.	62.	56.
Chattanooga AP	51.	55.	69.	65.	60.
Knoxville AP	50.	54.	68.	65.	59.
Memphis AP	52.	56.	71.	68.	62.
Memphis CO	53.	57.	72.	68.	62.
Nashville AP	51.	54.	69.	66.	60.
Oak Ridge CO	49.	52.	67.	64.	58.
Oak Ridge	49.	52.	67.	64.	58.
Texas					
Abilene AP	55.	58.	73.	70.	64.
Amarillo AP	47.	50.	67.	63.	57.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Texas					
Austin AP	60.	63.	76.	73.	68.
Big Springs AP	56.	59.	74.	70.	65.
Brownsville AP	68.	70.	79.	77.	74.
Corpus Christi AP	65.	68.	78.	76.	72.
Dallas AP	57.	61.	76.	72.	66.
Del Rio AP	62.	65.	77.	75.	70.
El Paso AP	54.	58.	72.	69.	63.
Fort Worth AP (Amon Carter)	57.	60.	75.	72.	66.
Galveston AP	63.	66.	77.	74.	70.
Galveston CO	63.	66.	77.	74.	70.
Houston AP	62.	65.	76.	73.	69.
Houston CO	63.	66.	77.	74.	70.
Laredo AP	67.	70.	81.	79.	74.
Lubbock AP	50.	54.	69.	65.	59.
Midland AP	55.	59.	73.	70.	64.
Palestine CO	58.	62.	74.	71.	66.
Port Arthur AP	61.	64.	75.	72.	68.
Port Arthur CO	63.	65.	76.	74.	69.
San Angelo AP	58.	61.	74.	71.	66.
San Antonio AP	61.	64.	77.	74.	69.
Victoria AP	64.	67.	78.	76.	71.
Waco AP	58.	62.	76.	73.	67.
Wichita Falls AP	53.	57.	73.	69.	63.
Utah					
Blanding CO	39.	43.	60.	56.	50.
Milford AP	37.	42.	61.	56.	49.
Salt Lake City AP	40.	44.	63.	59.	51.
Salt Lake City CO	41.	46.	65.	60.	53.
Vermont					
Burlington AP	32.	37.	57.	52.	44.
Virginia					
Cape Henry CO	51.	55.	68.	65.	60.
Lynchburg AP	48.	51.	66.	62.	57.
Norfolk AP	51.	54.	68.	64.	59.
Norfolk CO	52.	56.	69.	66.	61.
Richmond AP	48.	52.	67.	63.	58.
Richmond CO	50.	53.	68.	64.	59.
Roanoke AP	48.	51.	66.	62.	57.
Washington					
Ellensburg AP	37.	41.	59.	55.	48.
Kelso AP	45.	47.	57.	54.	51.
North Head L H RESVN	47.	49.	54.	53.	51.
Olympia AP	44.	46.	56.	54.	50.
Omak 2 mi N W	36.	40.	59.	55.	47.
Port Angeles AP	45.	46.	53.	52.	49.
Seattle AP (Boeing Field)	46.	48.	58.	56.	52.
Seattle CO	47.	50.	59.	57.	53.
Seattle-Tacoma AP	44.	47.	57.	55.	51.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
Washington					
Spokane AP	37.	41.	58.	54.	47.
Stampede Pass	32.	35.	48.	45.	40.
Tacoma CO	46.	48.	58.	55.	52.
Tattosh Island CO	46.	47.	52.	51.	49.
Walla Walla CO	44.	48.	65.	61.	54.
Yakima AP	40.	44.	61.	57.	50.
West Virginia					
Charleston AP	47.	50.	65.	61.	56.
Elkins AP	41.	45.	59.	56.	50.
Huntington CO	48.	52.	67.	63.	57.
Parkersburg CO	45.	49.	65.	61.	55.
Petersburg CO	44.	48.	63.	60.	54.
Wisconsin					
Green Bay AP	31.	36.	56.	51.	44.
La Crosse AP	32.	38.	60.	55.	46.
Madison AP	34.	39.	59.	54.	47.
Madison CO	34.	39.	60.	55.	47.
Milwaukee AP	35.	40.	58.	54.	47.
Milwaukee CO	36.	41.	59.	55.	48.
Wyoming					
Casper AP	34.	38.	57.	52.	45.
Cheyenne AP	35.	39.	55.	51.	45.
Lander AP	31.	35.	56.	51.	43.
Rock Springs AP	31.	35.	54.	50.	42.
Sheridan AP	33.	37.	56.	52.	44.
Hawaii					
Hilo AP	72.	72.	74.	74.	73.
Honolulu AP	74.	75.	77.	77.	76.
Honolulu CO	74.	74.	77.	76.	75.
Lihue AP	72.	73.	75.	75.	74.
Alaska					
Anchorage AP	25.	29.	46.	42.	35.
Annette AP	40.	42.	51.	49.	46.
Barrow AP	4.	7.	16.	14.	10.
Bethel AP	18.	23.	41.	37.	30.
Gold Bay AP	33.	35.	43.	41.	38.
Cordova AP	32.	35.	45.	43.	39.
Fairbanks AP	14.	19.	38.	34.	26.
Galena AP	13.	18.	37.	33.	25.
Gambell AP	15.	19.	34.	30.	24.
Juneau AP	34.	36.	47.	45.	41.
Juneau CO	36.	39.	49.	46.	42.
King Salmon AP	25.	28.	44.	40.	34.
Kotzebue AP	10.	14.	31.	27.	21.
McGrath AP	14.	18.	37.	33.	25.
Nome AP	16.	20.	37.	33.	26.
Northway AP	12.	16.	32.	29.	22.
Saint Paul Island AP	31.	32.	40.	38.	35.
Yakutat AP	33.	36.	45.	43.	39.

TABLE III-9 (cont.)

Location	Winter	Spring	Summer	Autumn	Annual
West Indies					
Ponce Santa Isabel AP	75.	76.	78.	78.	77.
San Juan AP	77.	77.	79.	79.	78.
San Juan CO	77.	77.	79.	79.	78.
Swan Island	80.	80.	82.	81.	81.
Virgin Islands					
St. Croix, V.I. AP	78.	78.	81.	80.	79.
Pacific Islands					
Canton Island AP	83.	84.	84.	84.	84.
Koror	81.	81.	81.	81.	81.
Ponape Island AP	81.	81.	81.	81.	81.
Truk Moen Island	81.	81.	81.	81.	81.
Wake Island AP	79.	79.	81.	81.	80.
Yap	81.	81.	82.	82.	82.

^aAP = Airport data.

^bCO = City office data.

^cCOOP = Cooperative weather station.

^dOBS = Observation station

Line No.

Input Parameter

Explanations/Options

156 (cont.)

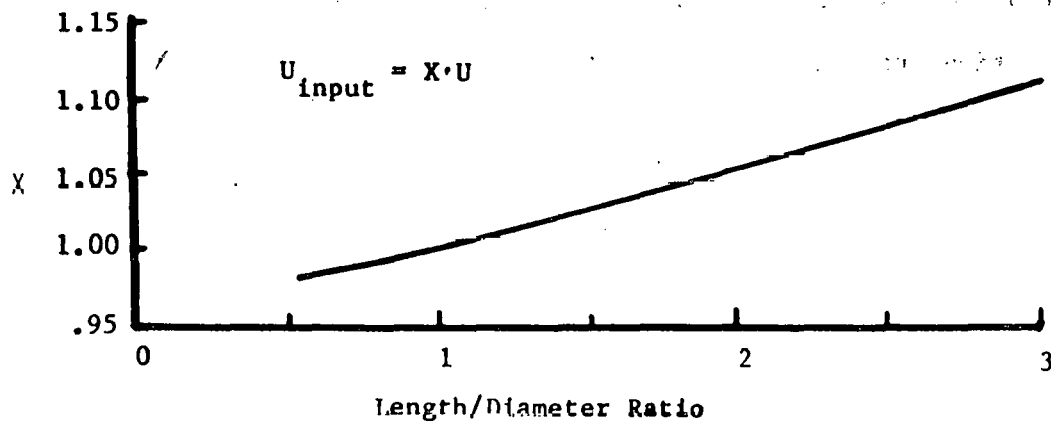
assumes a cylindrical tank with length/diameter ratio equal to one. Hence, the tank area can be expressed as:

$$A_{\text{tank}} = 6\pi \left(\frac{K}{2\pi}\right)^{2/3} (A_{\text{col}})^{2/3}$$

where K = Storage volume/collector area ratio, Ft^3/Ft^2

A_{col} = Collector area, Ft^2

If a given storage tank has an L/D ratio significantly different than one, the user should adjust the input U-value by the factor X given in the following figure.



U-Value Multiplier X for L/D Correction

157

Ambient Temperature at Auxiliary
and Preheat Tanks, $^{\circ}\text{F}$

Ambient temperature at auxiliary
and preheat tank location.
Losses from these tanks are
computed from:

$$Q_{\text{loss}} = U A (T_{\text{tank}} - T_{\text{amb}})$$

<u>Line No.</u>	<u>Input Parameter*</u>	<u>Explanations/Options</u>
169	Flag to Indicate that the Collector Parameters are to be Updated	Input a "1" to execute this option. The SOLCOST program will update the collector parameters which are input with additional information in lines 170 through 189. The resultant efficiencies at 0 and efficiencies at .5 will be included in lines 14 and 15.
170	Flag to Designate that the Input Collector Parameters have been Defined to be a Function of Average Collector Temperature and not Inlet Temperature	Input a "1" to indicate that the collector parameters are to be updated to be a function of inlet temperature not average temperature as input.
171	Mass Capacitance Flow Rate (\dot{m}_c) per ft ² of Collector as Tested	Input the mass capacitance flow rate as per square foot of collector area as the collector was tested. Input as Btu/hr-°F-ft ² .
172	Mass Capacitance Flow Rate (\dot{m}_c) per ft ² of Collector as Used	Input a mass capacitance flow rate per square foot of collector area as panels are to be used. The SOLCOST program assumes a default for liquid (10) and a separate default for air systems (2).
173	$F_{R\alpha}$ Input for each Collector Path	Input the $F_{R\alpha}$ for each panel in each path, however, if more than one path is assumed, the user must input line 21 equal to a 3 and input the collector area in line 22.
174	$F_{R,L}$ Input for each Collector Path	Input the $F_{R,L}$ per panel per path for up to 10 parallel paths. (See line 173)
175	Number of Series Collectors in Each Parallel Path.	SOLCOST assumes that the number of series collector in each path are the same. <u>Remember, that if there is more than one path assumed, line 21 must be equal to a 3 and the collector area must be input on line 22.</u>
176	Number of parallel paths with different parameters or flow rates.	See Line 175.

* See Appendix E for the Methodology Development.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
177	Individual Collector Panel Area for each Parallel Path.	This is the collector area of each panel in each parallel path in ft ² . It is the individual panel area.
180	Flag to Indicate that the Collector in Air Systems are Leaky.*	This methodology is accurate only in the neighborhood of where the parameters were derived for the collector area. If the leakage is in excess of 20% this methodology may not work too well.
181	Air Collector Pressure Drop Flag	1 = negative and 2 = positive pressure
182	Leaky Parameters, σ	
183	Leaky Parameters, β	
184	Leaky Parameters, θ	
185	Heat Exchanger Flag	Input a "1" to cause SOLCOST to calculate an F'_R/F_R number to update the collector parameter to reflect the inclusion of a heat exchanger between the collector and storage. Input the effectiveness in line 186.
186	Heat Exchanger Effectiveness	Input between 0 and 1
187	Manifold Conduction Flag	The user may update the collector manifold heat loss conduction by inputting line 187 equal to a "1" and then the inlet and outlet UA's of the inlet and outlet manifolds. The user must input line 21 equal to a "3" to execute this option.
188	UA Inlet Piping/Ducting	
189	Outlet UA of Piping/Ducting	

* Lines 180-184 are used for situations when the air collector array leaks somewhat. The reader is referred to Appendix C for details of what exactly the individual parameters are. Also, the reader should update the input collector flow rates to reflect what the collectors may actually experience.

SUBSYSTEM COMPONENT SELECTION OPTIONS[†]

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
190	Flag to Execute Subsystem Selection/Sizing Routines (Integer)	Control flag to exercise sizing routines. A liquid system is assumed, unless Line 1 = 7. The default value is 0. Enter a 1 if this feature is desired.
191	Flag for Counterflow Liq-Liq HX in Collection Loop, (Integer)	Flag to size a counterflow liquid-to-liquid heat exchanger in the collection loop. The default value is 0. Enter a 1 if this feature is desired.
192	Flag for Crossflow Air-Liq (or Liq-Air) HX in Collection Loop (or in Load Distribution Loop) (Integer)	Flag to size a crossflow air-to-liquid or a liquid-to-air heat exchanger in the collection loop (or in the load distribution loop). The default value is 0. Enter a 1 if this feature is desired.
193	Flag to Include Components in System Costs for Life Cycle Cost Analysis (Integer)	Flag to include component costs in in life cycle cost analysis. The default value is 0. Enter a 1 if this feature is desired.

LIQUID COLLECTION SUBSYSTEM DESIGN/COST DATA[†]

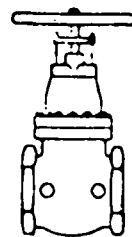
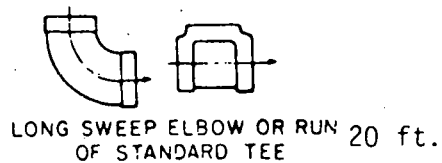
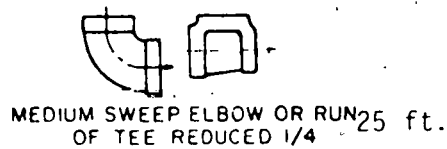
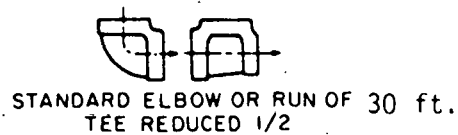
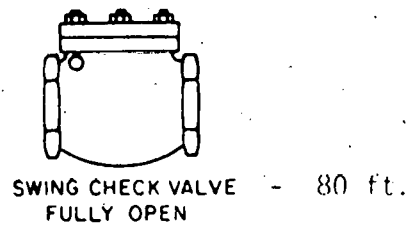
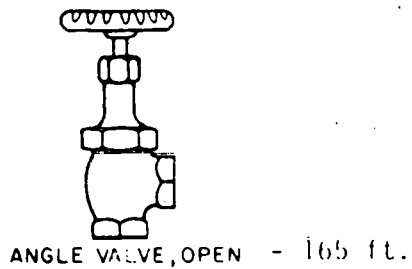
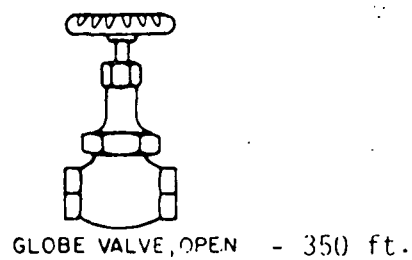
201	Collector Flow Rate	Collector area dependent volumetric flow rate. Enter as gallons per minute (GPM) per square foot of collector area; usually magnitudes are 0.01 - 0.03.
202	Collector Pressure Drop	The collector pressure drop is usually independent of collector area but very dependent on the collector area dependent flow rate described above. Enter in feet of head loss.
203	Heat Exchanger Pressure Drop (Collection Side)	If a heat exchanger is present in the collection loop enter its expected head loss in feet.
204	Total Pipe or Duct Length in Collection Loop	Enter the total pipe/duct length in the collection loop. SOLCOST uses this length to estimate pipe/duct costs and pumping/blower requirements.

[†]See Appendix D for more details.

LIQUID COLLECTION SUBSYSTEM DESIGN/COST DATA (CONT.)

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
205	Installed Duct/Pipe Cost per Foot	Enter cost in dollars per foot to purchase and install the collector loop piping or ducting.
207	Additional Velocity Head Above Pipe, Valve and Tee Velocity Losses	If any additional velocity head loss exists that is not included in the piping, valve, tee or elbow losses, input this line number.
208	Pressure Head Loss, (Collection Loop)	If any head losses in the collection loop exist due to unaccounted pressure changes, input this line.
209	Elevation Head, (Collection Loop)	If any elevation head losses exist in the collector loop such as those encountered in by pipe openings in a drain down system, input this line.
210	Design Pipe Velocity	The pipe bulk velocity is not allowed to exceed this amount by selecting the pipe diameter. See Appendix D for details.
211	Number of Valves (Integer) in Collection Loop	Total number of valves in the collection loop. This number is used to calculate total head loss and subcomponent costs.
212	Number of Elbows (Integer) in Collection Loop	Total number of elbows in the flow loop. This number is used to calculate total head loss and subcomponent costs.
213	Number of Tees (Integer) in Collection Loop	Total number of tees in the collection loop (flow in one side only). This number is used to calculate total head loss and subcomponent costs.
214	Specific Heat of Collector Fluid	Enter the specific heat of the collector fluid in Btu/lbm-°F. This input is used for heat exchanger selection and calculating the collector outlet temperature.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
215	Specific Heat of Storage Fluid	This is the specific heat of the storage fluid used for liquid systems. This input parameter is used exclusively for sizing heat exchangers.
217	Cost Per Elbow	Enter the cost per elbow including materials and installation.
218	Cost Per Valve	Enter the cost per valve including materials and installation.
219	Cost Per Tee	Enter the cost per tee including materials and installation.
221	Friction Factor for Velocity Head Loss Calculation	This is the friction factor as obtained from a Moody diagram which may be seen in most texts dealing with fluid mechanics. For example, Streeter, V.L. The default friction factor is for relatively smooth pipes such as extruded copper with a Reynolds number in excess of 10 million. This factor is a function of roughness, bulk pipe velocity and the viscosity of the fluid used in the collection loop.
222	Equivalent Pipe Length Per Valve at Ref. Dia. = 12 In.	This is the equivalent length of pipe valve at a reference diameter equal to 12 inches. SOLCOST internally scales this equivalent length for diameters other than 12 inches. See Figure III-2 for suggested input values other than those defaulted.
223	Equivalent Pipe Length Per Elbow at Ref. Dia. = 12 In.	Equivalent pipe length per elbow at a reference diameter of 12 inches. SOLCOST internally compensates for diameters other than 12 inches by scaling. See Figure III-2 for suggested values other than those defaulted.
224	Equivalent Number of Feet Per Tee at Ref. Dia. = 12 In.	Equivalent number of feet per tee at a reference diameter of 12 inches. SOLCOST compensates internally for diameters other than 12 inches. It also assumes that flow is through one side of the tee only. See Figure III-2 for suggested equivalent lengths other than those defaulted.



GATE VALVE
3/4 CLOSED - 850 ft.
1/2 CLOSED - 200 ft.
1/4 CLOSED - 40 ft.
FULLY OPEN - 7 ft.

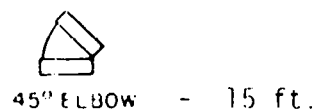
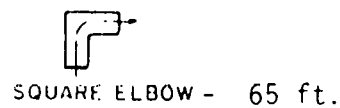


Figure III-2.

Equivalent Length of Pipe
Diameter = 12 in.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
<u>HEAT EXCHANGERS (AIR OR LIQUID)</u>		
225	Storage Side of Heat Exchanger Multiplier	The mass capacitance flow rate for the storage side of the heat exchanger is assumed to be a multiple of the mass capacitance flow rate of the collectors where the multiplication factor is this line number input.
227	F'_R/F_R Ratio for Collector Heat Exchanger	The penalty that the user is willing to pay for inclusion of an exchanger in the collection loop for liquid systems. See Appendices C and E for more discussion of this particular parameter. Also, the collector parameters are not modified to reflect any degradation.
230	Design Point for Crossflow Load HX-Liq. Space Heating (Ratio of $\epsilon C_{min}/UA_{load}$)	The effectiveness of the load heat exchanger for liquid systems is computed using this design point input. See Appendix D for a detailed explanation of how the design point plays a role in the heat exchanger selection.
231	Load HX Air Flow Rate	Load heat exchanger air flow rate is input in standard cubic feet per minute. It is assumed that this flow rate is constant regardless of collector area.
232	Load HX (Liq-to-Air) Water Flow Rate (Also Service Water Coil in Air Systems)	Flow rate of water in gallons per minute for the liquid side of crossflow heat exchangers for both the load heat exchanger and liquid systems and the service hot water coil in air systems.
233	Duct Design Air Velocity	A duct diameter is selected so that the average air velocity is not allowed to exceed this amount. See Appendix D for more discussion.
234	Air Collector Design Flow Rate	The total standard flow rate of the collector is equal to this line number times the total area. This input is in standard cubic feet per minute (SCFM).

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
<u>HEAT EXCHANGERS (AIR OR LIQUID)(cont.)</u>		
235	Air Collector Pressure Drop	Air pressure drop is input in inches of water. SOLCOST assumes that this pressure drop is independent of collector area. In other words, it is proportional only to the length of collector that the air must travel through or the module length.
236	Air System Service Water Coil Pressure Drop	This is the pressure drop in inches of water of the service hot water coil in the air space heating system. It is assumed to be constant irregardless of the collector area.
238	Solar System Site Elevation	This is the altitude of the location where the solar system is being built in feet. It is used to adjust the density of air for a calculation of duct dimensions.
239	Rock Bed Pressure Drop	The total pressure drop of the rock bed in the air system in inches of water.
240	Air System Service Hot Water Coil Effectiveness	Input an effectiveness for each candidate collector area.
250	No. of turns in Air System Collection Ducting (Integer)	Total number of turns in the air system collection loop. This number is used to calculate the total air system pressure drop in the cost of installation.
251	No. of Normally Open Dampers in Air Systems	The number of the normally open dampers in the air system collection loop. This number is used to calculate the total system pressure drop and the cost of installing the solar system.
252	Installed Cost Per Turn in Air Systems	Total cost for installing a turn or elbow in air systems. Includes both materials and labor.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
240	Air System Service Hot Water Coil Effectiveness	Input an effectiveness for each candidate collector area.
241	Maximum Duct Pressure Drop per 100 ft of Duct	When the SOLCOST program calculates the duct diameter it checks to see that the pressure drop per 100 ft of duct does not exceed this amount. If it does it recalculates the diameter and then the square duct dimension for a side.
242	Flag to Indicate that SOLCOST is to Calculate the Rock Box Pressure Drop	Input a "1" so that SOLCOST will ignore line 243 and then use lines 244 and 245 to calculate the rock box pressure drop in inches of water.
243	Rock Bed Pressure Drop	The total pressure drop of the rock bed in the air system in inches of water. Used if line 242 is equal to zero.
244	Rock Bed Inside Height	Put the height of the rocks between the two bed plenums. SOLCOST uses this number to calculate the pressure drop through the bed if line 242 is input as a "1".
246	Maximum Number of Branches for Collector Manifold when the SOLCOST Program is Sizing the Manifolds for Air System Collector Arrays	This is the maximum number of branches which can be utilized, normally 10.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
<u>HEAT EXCHANGERS (AIR OR LIQUID) (cont.)</u>		
253	Installed Cost Per Normally Open Damper in Air Systems	This is the total cost for dampers in the air system. It includes both materials and labor.
254	Equivalent Length of Duct for Each Turn at Ref. Dia. = 1.0 Ft.	This is the total equivalent length of duct for each turn or elbow at a reference diameter of 1 foot. See Figure III-3 for suggested equivalent lengths of round duct other than as defaulted.
255	Equivalent Length of Duct for Each Damper at Ref. Dia. = 1.0 Ft.	This is the equivalent length of duct for each damper installed in the air space heating system collection loop. This input is used to determine the total pressure drop of this loop.

PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS

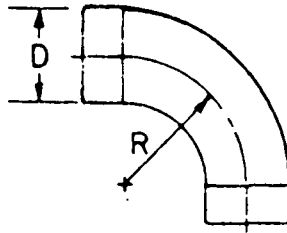
280	No. of Points in Candidate Pump (Head, Flow) Subset	Each number in this array corresponds to the number of flow versus head drop points that exist in arrays 281 and 282. See Table III-10 for example. The first element as defaulted for array 280 is a 4 which means there are 4 flow versus head drop points for this particular pump.
281	Pump Head Values for Candidate Pumps	Input the head drop for each of the pumps to be used in the selection procedure. See Table III-10 for example. For the first pump there are four head drop values which correspond to flow rates. Input these in decreasing order. In other words, the highest drop goes first. After all of the head drops are input for the first pump, proceed to the next pump. SOLCOST internally separates the pump head drop data points depending on what values are input in array 280.

<u>Line No.</u>	<u>Input Parameter</u>	<u>Explanations/Options</u>
260	Total Systems* Optimization Flag (Integer)	0 = Not executed 1 = Executed and short output 2 = Executed with cash flow table output
261	Structure Property Tax Rate	SOLCOST uses this parameter to calculate the property tax paid over time for improvements to reduce the structures total energy requirements.
271	Load and Cost Paired Inputs for Heat Load Reducing Features in the Form of Wall Insula- tion	The input pairs (up to 10) should contain the net heat load per degree-day per square foot of floor area (same form as line 42) and the cost for including the option to change from the line 42 input to the new net load factor input in this line.
272	Same as 271 but for Ceiling Insulation	
273	Same as 271 but for Windows	
274	Same as 271 but for Doors	
275	Same as 271 but for Infiltration Reducing Features	

* See Appendix E for details and an example.

90° SMOOTH ELBOW

$R/D = 1.5$

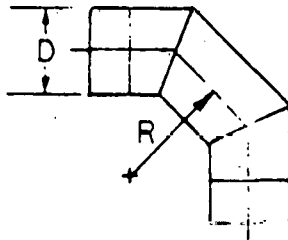


Length-ft.

6

90° 3-PIECE ELBOW

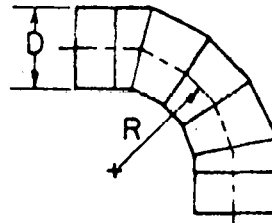
$R/D = 1.5$



17

90° 5-PIECE ELBOW

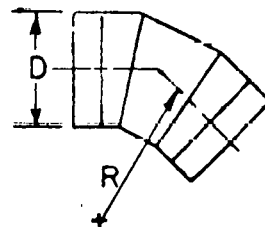
$R/D = 1.5$



12

45° 3-PIECE ELBOW

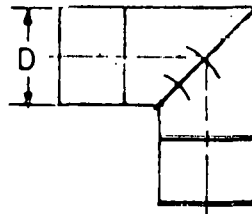
$R/D = 1.5$



6

90° MITER ELBOW

$R/D = .5$



27

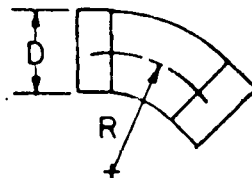
Vaned

65

Not Vaned

45° SMOOTH ELBOW

$R/D = 1.5$



4.5

Figure III-3

Equivalent Length of Round Duct [D=12in]

<u>Line No.</u>	<u>Input Parameters</u>	<u>Explanations/Options</u>
<u>PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS (cont.)</u>		
282	Pump Flow Values Corresponding to Heads in Line 281	These are the corresponding flow rates in gallons per minute for the head drops input in array 281. See Table III-10 for default values.
283	Costs for Candidate Pumps	Cost of the input pumps used in the selection process. The first value for default (see Table III-10) is 75, the second value is 100, etc.
290	No. of Points in Crossflow HX Cost and UA Arrays (Integer)	Input the total number of crossflow heat exchanger cost versus UA values that are included in the array inputs 291 and 292.
291	Crossflow HX Costs	Input costs for the crossflow heat exchangers in increasing order.
292	Crossflow HX UA	Input the corresponding UA value for the crossflow heat exchangers whose costs are listed in array 291.
295	No. of Points in Counterflow HX Cost and UA Arrays (Integer)	This is the number of counterflow heat exchangers whose costs and UA's are listed in arrays 296 and 297. This input cannot exceed 10. Input is similar to line 290.
296	Counterflow HX Costs	See Table III-12 for costs of default heat exchangers. Input these in increasing order.
297	Counterflow HX UA	Input the corresponding heat exchanger UA values for the costs inputted in Line 296. Also, see Table III-12 for default values.
300	No. of Points in Candidate Fan Subsets	This is an array of values where each value corresponds to the number of data point pairs for each fan in the fan head and flow rate arrays. See Table III-13. For example, a first value in this array is 5, which means there are 5 fan head versus flow rate point pairs in arrays 301 and 302.

TABLE III-10. PUMP SELECTION TABLE (DEFAULT)

<u>Number</u>	<u>Flow(GPM)</u>	<u>Head(Ft.)</u>	<u>Cost(\$)</u>
1	0.00	9.50	75.00
1	5.00	8.50	75.00
1	10.00	7.00	75.00
1	19.00	1.20	75.00
2	0.00	14.00	100.00
2	22.00	0.00	100.00
3	0.00	10.00	105.00
3	5.00	6.50	105.00
3	7.50	4.00	105.00
3	10.00	1.70	105.00
4	0.00	8.00	112.00
4	16.00	0.00	112.00
5	0.00	20.00	112.00
5	30.00	0.00	112.00
6	0.00	6.00	135.00
6	14.00	0.00	135.00
7	0.00	14.00	171.00
7	23.00	0.00	171.00
8	0.00	40.00	225.00
8	30.00	0.00	225.00
9	0.00	20.00	225.00
9	60.00	0.00	225.00

TABLE III-11. CROSSFLOW HEAT EXCHANGER UA VS. COST TABLE (DEFAULT)

<u>Number</u>	<u>UA(Btu/hr-°F)</u>	<u>Cost(\$)</u>
1	197.00	45.00
2	295.50	50.00
3	394.00	55.00
4	492.50	63.00
5	591.00	77.00
6	788.00	84.00
7	886.50	85.00
8	985.00	100.00
9	1773.00	128.00
10	1940.00	140.00
11	3546.00	192.00

TABLE III-12. COUNTERFLOW HEAT EXCHANGER UA VS. COST TABLE (DEFAULT)

<u>Number</u>	<u>UA(Btu/hr-°F)</u>	<u>Cost(\$)</u>
1	715.00	112.00
2	1430.00	158.00
3	2172.00	190.00
4	3080.00	292.00
5	4620.00	338.00
6	6160.00	382.00
7	7205.00	482.00
8	9570.00	553.00
9	14492.00	796.00
10	22990.00	925.00
11	27527.00	1040.00
12	32065.00	1144.00
13	36602.00	1313.00
14	45952.00	1690.00

TABLE III-13. FAN TABLE (DEFAULT)

<u>Number</u>	<u>Fan Head(In. of Water)</u>	<u>Flow Rate(CFM)</u>	<u>Cost(\$)</u>
1	0.00	148.00	25.00
1	.20	135.00	25.00
1	.40	121.00	25.00
1	.50	114.00	25.00
1	1.04	0.00	25.00
2	0.00	525.00	55.00
2	.20	475.00	55.00
2	.40	415.00	55.00
2	.50	387.00	55.00
2	1.15	0.00	55.00
3	.30	865.00	60.00
3	.40	825.00	60.00
3	.50	760.00	60.00
3	.60	660.00	60.00
3	.70	520.00	60.00
4	1.00	291.00	80.00
4	2.00	231.00	80.00
4	3.00	156.00	80.00
4	4.00	0.00	80.00
5	1.00	530.00	85.00
5	2.00	475.00	85.00
5	3.00	415.00	85.00
5	4.00	335.00	85.00
5	5.00	160.00	85.00

TABLE III-13. FAN TABLE (DEFAULT) (cont.)

<u>Number</u>	<u>Fan Head(In. of Water)</u>	<u>Flow Rate(CFM)</u>	<u>Cost(\$)</u>
6	.13	1100.00	100.00
6	.25	1000.00	100.00
6	.38	890.00	100.00
6	.50	800.00	100.00
6	.75	475.00	100.00
6	1.00	0.00	100.00
7	1.50	1848.00	175.00
7	1.75	1735.00	175.00
7	2.00	1610.00	175.00
7	2.25	1457.00	175.00
7	2.50	1288.00	175.00
7	2.75	1047.00	175.00
8	.50	2100.00	180.00
8	.75	1980.00	180.00
8	1.00	1460.00	180.00
9	1.00	1200.00	210.00
9	2.00	1137.00	210.00
9	3.00	1069.00	210.00
9	4.00	1011.00	210.00
9	4.50	937.20	210.00
10	1.00	2137.00	330.00
10	3.00	1927.00	330.00
10	5.00	1711.00	330.00

<u>Line No.</u>	<u>Input Parameters</u>	<u>Explanations/Options</u>
<u>PUMP, HEAT EXCHANGER, FAN PERFORMANCE/COST ARRAYS (cont.)</u>		
301	Fan Head Values for Candidate Fans	Input the fan pressure drop in inches of water for each fan to be considered in the selection process.
302	Fan Flow Values Corresponding to Heads in Line 301	Input the corresponding flow rates for the fan pressure drop input in array 301.
303	Costs for Candidate Fans	Input the individual costs for each of the fans inputted in arrays 300, 301, and 302. Enter one cost per fan; not to exceed 10 costs.

IV. SOLCOST INPUT DESCRIPTION WITH SAMPLE DESIGN CASES

Input Description - The SOLCOST input file is free format in nature. Integers can be input for real values and vice-versa. Also, the position of the numeric values on the card is not important: however, they must be separated by a comma or blank. Arrays must be terminated with an asterisk (*). Arrays can also be continued on additional cards, if necessary. A dollar sign (\$) is a special character designating comments. The input subroutine ignores everything after a dollar sign on each input image. The SOLCOST program input file structure is organized in such a way to allow multiple runs. However, the interactive input creation program will edit only one set of inputs at a time. The first character expected by the SOLCOST program is either a T or N. A "T" designates that a title is on the next card (up to 70 characters) and an "N" indicates that the next card contains a line number with the appropriate information. The line number inputs can be in any order and scalars and arrays can be mixed in order as well.

The input file structure would appear as follows:
(See page IV-4 through IV-36 for examples)

TITLE

THIS IS A TITLE

1,8,8,8,8,8,8,8,8,8,8,8,*

.

.

.

RUN

NO TITLE

.

.

.

RUN

EXIT

CASE 1

CASE 2

TO STOP PROGRAM

Figure IV-1. SOLCOST Input File Structure

NOTE: All control words (TITLE, RUN, NO TITLE and EXIT) can be reduced to the first letter only (i.e. instead of TITLE use T, instead of RUN use R, instead of NO TITLE use N, and instead of EXIT use E).

When using the interactive program the input file to the SOLCOST program is constructed for the user. However, the interactive program will not merge outputs together for multiple runs.

A shorthand feature is available for those arrays requiring 12 inputs. The program (SOLCOST and Conversational) will fill the array with the last value encountered. Don't forget the * terminator.

Input Listing Suppression

SOLCOST reformats the input and prints them for easy reading by the user at the start of every run. This first listing of the inputs can be suppressed by the user by simply adding an L to the title cards as follows:

L NO TITLE (This is the first card of input file with
no title).

L TITLE (This is the first card of input file with
a title).

The suppressing of the input listing reduces the number of characters transmitted and reduces the cost of a run.

Service Hot Water System Sample Design Problem - The objective of this design case was to determine the optimum solar collector area for a residential service hot water system in Denver. The collectors under consideration cost \$50/sq. ft. installed. An all electric system was the basis for comparison. The auxiliary heating system for the solar installation also used electricity.

Figure IV-2a and IV-2c illustrate using the interactive program which creates the input file for SOLCOST. Each figure is followed by the SOLCOST analysis for this system. Also illustrated is an example which shows how to use the editing features (Fig. IV-2c). A constant daily hot water load of 0.59 million Btus was also specified. Review the example closely for it includes hints for proper usage.

After execution the SOLCOST program prints the summary sheet shown in Figures IV-2b and IV-2d. This sheet mirrors the inputs and prints the computed loads and weather data used in the analysis. Next the solar system performance summary is output. Finally, the cash flow sheet for the cost optimum collector size is output. Rates of return and payback years are given on the cash flow sheet. If more than one tilt angle has been defined, the program will find the optimum collector area and print a cash flow sheet for each input tilt angle.

The cash flow sheet summarizes the financial aspects of the solar investment. The columns are explained at the bottom of the sheet. Column G is headed by the down payment made on the total system cost.

WELCOME TO THE SOLCOST CONVERSATIONAL INPUT PROGRAM.

NOTES --

- 1) ALL USER COMMANDS MUST BE ENTERED AS SINGLE CHARACTER INPUTS.
- 2) ALL ARRAYS MUST BE TERMINATED WITH THE ASTERISK CHARACTER (*).
- 3) A CARRIAGE RETURN BY ITSELF ON ANY INPUT WILL CAUSE THE JOB TO HALT.
- 4) FOR ARRAYS OF DIMENSION 12, I.E. INPUTS WHICH CORRESPOND TO MONTHLY VALUES, ONLY ONE VALUE NEED BE ENTERED IF ALL VALUES ARE THE SAME

TYPE H(ELP) FOR LIST OF USER COMMANDS-

OTHERWISE INDICATE TYPE OF FILE TO BE PROCESSED BY ENTERING O(LD) OR N(EW) - INPUT

? H

USER COMMANDS (MUST BE ENTERED AS SINGLE-CHARACTERS)

- H(ELP) - LIST USER INPUT COMMANDS
- D(ISP) - DISPLAY LINE INPUT OPTIONS AND/OR DEFAULT VALUES
- G(O) - DEFAULT VALUES O.K., GO TO NEXT INPUT
- L(IST) - LIST CURRENT USER FILE
- C(CURRENT) - SAME AS LIST COMMAND, BUT FOR CURRENT LINE NUMBER ONLY.
- P(URGE) - PURGE CURRENT LINE NUMBER FROM OUTPUT FILE.
- E(XIT) - SAVE THE USER FILE AND END SESSION

NOTES--

1. USER FILE LINES ARE NUMBERED SEQUENTIALLY BEGINNING WITH 1, I.E., 1, 2, ETC. THE LINE NUMBERS ARE AUTOMATICALLY RESEQUENCED AS USER INPUTS ARE ENTERED.
2. USER COMMANDS D, G, L, C, H, OR E MAY BE INPUT AT ANY TIME CONSTANTS AND/OR ARRAYS ARE BEING ENTERED.
3. TO FACILITATE INPUT, ONLY ONE ELEMENT OF A MONTHLY ARRAY NEED BE ENTERED IF ALL ELEMENTS OF THE ARRAY HAVE THE SAME VALUE.
4. ALL PERCENTAGES ARE TO BE ENTERED AS DECIMAL FRACTIONS.

CAUTION:

A CARRIAGE RETURN BY ITSELF ON ANY INPUT WILL CAUSE THE PROGRAM TO HALT, SAVING THE OUTPUT FILE.
REMEMBER TO END ALL ARRAYS WITH THE ASTERISK (*) CHARACTER.

ENTER TYPE OF FILE TO BE PROCESSED (O OR N)

INPUT-

? N

Figure IV-2a. Interactive Example, Interrogation Mode

DO YOU WISH TO ENTER A TITLE? (Y OR N)
INPUT-
? Y

ENTER TITLE (UP TO 70 CHARACTERS)
? THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

TWO INPUT MODES ARE AVAILABLE --
1) INTERROGATION FOR ALL REQUIRED SOLCOST
INPUTS. THIS MODE IS RECOMMENDED FOR ALL
FIRST TIME USERS. (ENTER 1)
2) USER SPECIFIES SOLCOST INPUT LINE NUMBERS.
(ENTER 2)

NOTE --
AFTER COMPLETION OF MODE 1, MODE 2 CAN BE
ENTERED TO MAKE ADDITIONS AND/OR CORRECTIONS.

ENTER 1 OR 2
INPUT-
? 1

ENTER LINE 1: (INTEGER ARRAY)
SOLAR SYSTEM TYPE FLAGS BY MONTH
INPUT-
? 8*

ENTER LINE 2: (REAL ARRAY)
AVG MONTHLY TRANSORT EFFIC/COP - SOLAR SYSTEM
INPUT-
? 0

ENTER LINE 3: (REAL ARRAY)
MONTHLY COLLECTOR INLET TEMP AT DAWN, DEG F
INPUT-
? 0

ENTER LINE 4: (INTEGER ARRAY)
REFERENCE SYSTEM FUEL TYPE
INPUT-
? 2*

ENTER LINE 5: (REAL ARRAY)
AVG MONTHLY EFFIC/COP - REFERENCE SYSTEM
INPUT-
? 0

ENTER LINE 6: (INTEGER)
SOLAR AUXILIARY ENERGY FLAG
INPUT-
? 2

ENTER LINE 7: (REAL VALUE)
AUXILIARY FURNACE EFFICIENCY
INPUT-
? 0

ENTER LINE 10: (INTEGER)
COLLECTOR TYPE FLAG
INPUT-
? 2

ENTER LINE 11: (INTEGER)
COLLECTOR TRACKING FLAG (DEFAULT=FIXED)
INPUT-
? 0

Figure IV-2a. (cont.)

```

COLLECTOR FIXED OR TRACKING TYPE FLAG
TYPE
FLAG
(LINE 11)
-----
1      FIXED COLLECTOR BEAM & DIFFUSE (DEFAULT
2      AZIMUTH TRACKING, BEAM - DIFFUSE
3      ALTITUDE TRACKING, BEAM - DIFFUSE
4      FULL TRACKING, BEAM - DIFFUSE
5      FIXED COLLECTOR, BEAM ONLY
6      AZIMUTH TRACKING, BEAM ONLY
7      ALTITUDE TRACKING, BEAM ONLY
8      FULL TRACKING, BEAM ONLY

ENTER LINE 11: (INTEGER)
COLLECTOR TRACKING FLAG (DEFAULT=FIXED)
INPUT-
? 0

ENTER LINE 12: (REAL VALUE)
COLLECTOR AZIMUTH ANGLE
INPUT-
? 0

ENTER LINE 13: (REAL ARRAY)
COLLECTOR TILT ANGLES, DEGREES
INPUT-
? 40.,.8

ENTER LINE 16: (REAL VALUE)
UPPER LIMIT ON COLLECTOR OUTLET TEMP, DEG F
INPUT-
? 0

ENTER LINE 17: (REAL VALUE)
LIQUID STORAGE (GAL/SQ.FT OF COLLECTOR AREA)
INPUT-
? 2.

ENTER LINE 21: (INTEGER)
FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
INPUT-
? 0

ENTER LINE 23: (REAL VALUE)
COLLECTOR MODULE SIZE (SQ. FT.)
INPUT-
? 16.

ENTER LINE 24: (INTEGER)
FLAG TO INCLUDE LISTING OF SOLCOST WEATHER SITES
ENTER 1 TO LIST SITES, 0 OTHERWISE (DEFAULT IS 0)
INPUT-
? 0

ENTER LINE 25: (INTEGER)
SITE LOCATION CODE
ENTRY OF ZERO REQUIRES INPUTS FOR LINES
26, 27, 29, 30, 31, AND EITHER 28 OR 35.
INPUT-
? 44

ENTER LINE 34: (REAL ARRAY)
GROUND REFLECTANCE BY MONTH
INPUT-
? 0

```

Figure IV-2a. (cont.)

```

      ENTER LINE 41: (INTEGER)
      SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG
INPUT-
? 0

      ENTER LINE 49: (REAL VALUE)
      LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
INPUT-
? .059

      ENTER LINE 55: (REAL VALUE)
      SOLAR SYSTEM FIXED COST, DOLLARS
INPUT-
? 300.

      ENTER LINE 56: (REAL VALUE)
      COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
INPUT-
? .50.

      ENTER LINE 57: (REAL VALUE)
      LIQUID STORAGE COST (DOLLARS/GALLON)
INPUT-
? 1.5

      ENTER LINE 59: (REAL VALUE)
      SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)
INPUT-
? 0

      ENTER LINE 60: (REAL VALUE)
      REFERENCE SYSTEM FIXED COST, DOLLARS
INPUT-
? 0

      ENTER LINE 61: (REAL VALUE)
      REF. SYSTEM MAINTENANCE (FRACTION OF INIT. COST)
INPUT-
? 0

      ENTER LINE 65: (INTEGER)
      FINANCIAL SCENARIO FLAG (RES,BUS,NPD): 1,2, OR 3
INPUT-
? 1

      ENTER LINE 66: (REAL ARRAY)
      INCOME TAX CREDIT
INPUT-
? 0

      ENTER LINE 67: (REAL VALUE)
      DISCOUNT RATE, FRACTION
INPUT-
? 0

      ENTER LINE 68: (REAL VALUE)
      MORTGAGE INTEREST RATE, PERCENT/YEAR
INPUT-
? .212

      ENTER LINE 69: (REAL VALUE)
      LOAN TERM, YEARS
INPUT-
? 7.

```

Figure IV-2a. (cont.)

```

      ENTER LINE 70: (REAL VALUE)
      DOWN PAYMENT (FRACTION OF INITIAL COST)
INPUT-
? .2

      ENTER LINE 71: (REAL VALUE)
      TERM OF LIFE CYCLE ANALYSIS
INPUT-
? 0

      ENTER LINE 72: (REAL VALUE)
      BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)
INPUT-
? 0

      ENTER LINE 73: (REAL VALUE)
      PROPERTY TAX RATE, FRACTION OF INITIAL COST
INPUT-
? 0.

      ENTER LINE 74: (REAL VALUE)
      INCOME TAX RATE, (FRACTION)
INPUT-
? .3

      ENTER LINE 82: (REAL VALUE)
      INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
INPUT-
? .07

      ENTER LINE 84: (INTEGER)
      FLAG FOR COLLECTOR OPTIMIZATION OPTION
INPUT-
? 0

      ENTER LINE 91: (REAL ARRAY)
      ENERGY COST SCHEDULE-ELECTRICITY
INPUT-
? 3.5,0.,.05,100.,.04,1.E9,.10,*

      DO ELECTRICAL DEMAND CHARGES APPLY?
      (YOU MAY WANT TO CONSULT THE MANUAL)
      (DEFAULT VALUE IS 'N')
      ENTER Y OR N :
INPUT-
? N

      DOES A SUMMER COST SCHEDULE APPLY
      FOR REFERENCE FUEL?
      (YOU MAY WANT TO CONSULT THE MANUAL)
      (THE DEFAULT VALUE IS 'N')
      ENTER Y OR N :
INPUT-
? N

      DOES A SUMMER COST SCHEDULE APPLY
      FOR AUXILIARY SYSTEM FUEL?
      (YOU MAY WANT TO CONSULT THE MANUAL)
      (THE DEFAULT VALUE IS 'N')
      ENTER Y OR N :
INPUT-
? N

      ENTER LINE 120: (INTEGER)
      REFLECTOR ANALYSIS FLAG
INPUT-
? 0

```

Figure IV-2a. (cont.)

```

        ENTER LINE 130: (INTEGER)
        EXTENDED PRINT FLAG FOR HOURLY SOLAR FLUXES
INPUT-
? 0

        ENTER LINE 131: (INTEGER)
        PRINTER - PLOTTER FLAG
INPUT-
? 0

        ENTER LINE 132: (INTEGER)
        EXTENDED PRINT FLAG - MONTHLY INSOL. SUMMARY
INPUT-
? 0

        ENTER LINE 133: (INTEGER)
        FLAG TO PRINT INPUTS, LOADS, AND UPDATED PARAMETERS
INPUT-
? 0

        ENTER LINE 134: (INTEGER)
        OUTPUT CONTROL FLAG
INPUT-
? 0

        ENTER LINE 140: (INTEGER)
        FLAG TO SKIP INLET TEMP. ITERATIVE PROCEDURE
INPUT-
? 0

        ENTER LINE 144: (REAL VALUE)
        CONTROL DELTA TEMP. FOR COLLECTOR SHUTDOWN (F)
        (COLLECTOR OUTLET TO STORAGE)
INPUT-
? 0

        ENTER LINE 150: (REAL ARRAY)
        HOURLY HOT WATER LOAD FRACTIONS
INPUT-
? 0

        ENTER LINE 151: (REAL VALUE)
        AUXILIARY WATER HEATER SET TEMP, (F)
INPUT-
? 140.

        ENTER LINE 152: (REAL VALUE)
        WATER DELIVERY (MIXING VALVE) TEMPERATURE (F)
INPUT-
? 140.

        ENTER LINE 153: (REAL ARRAY)
        MONTHLY SUPPLY (OR GROUND) WATER TEMPERATURES (F)
INPUT-
? 0

        ENTER LINE 155: (REAL VALUE)
        AUXILIARY TANK UA, BTU/HR-DEG F
INPUT-
? 0

        ENTER LINE 156: (REAL VALUE)
        PRE-HEAT (OR STORAGE) TANK INSULATION U-VAL
        (BTU/HR-SQ.FT-DEG F)
INPUT-
? 0

```

Figure IV-2a. (cont.)

ENTER LINE 157: (REAL VALUE)
 AMBIENT TEMP. AT AUX. AND PRE-HEAT TANKS, (F)
 INPUT-
 ? G

ENTER LINE 169: (INTEGER)
 FLAG TO UPDATE COLLECTOR PARAMETERS
 INPUT-
 ? G

ENTER LINE 190: (INTEGER)
 FLAG TO EXECUTE SUBSYSTEM SELECTION/SIZING ROUTINES
 ENTER 1 TO EXERCISE ROUTINES, OR
 ENTER 0 (OR G) TO SUPPRESS THEM. (DEFAULT IS 0)
 INPUT-
 ? G

THIS COMPLETES THE LONG FORM OF THE
 QUESTIONS. YOU NOW HAVE THE OPTION OF
 ENTERING THE SHORT FORM OF QUESTIONING
 TO CORRECT ANY ERRORS MADE IN THE LONG
 FORM. IN THE SHORT FORM MODE OF QUESTION-
 ING YOU MERELY ENTER THE NUMBER OF THE
 LINE YOU WISH TO EDIT, AND YOU WILL BE
 PROMPTED WITH THE RESPECTIVE QUESTION.

DO YOU WISH TO CHANGE ANY OF
 YOUR ANSWERS, BY ENTERING THE
 SHORT FORM MODE?
 ANSWER Y OR N --
 INPUT-
 ? L

Figure IV-2a. (cont.)

```

T
THIS IS A SAMPLE SERVICE HOT WATER SYSTEM
1,      8      8      8      8      8      8      8
      8      8      8      8 *
    $ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2
      2      2      2      2 *
    $ REFERENCE SYSTEM FUEL TYPE
6,      2
    $ SOLAR AUXILIARY ENERGY FLAG
10,     2
    $ COLLECTOR TYPE FLAG
13,     .4000E+02 *
    $ COLLECTOR TILT ANGLES, DEGREES
17,     .2000E+01
    $ LIQUID STORAGE (GAL/SQ.FT OF COLLECTOR AREA)
23,     .1600E+02
    $ COLLECTOR MODULE SIZE (SQ. FT.)
25,     44
    $ SITE LOCATION CODE
49,     .5900E-01
    $ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .3000E+03
    $ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .5000E+02
    $ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
57,     .1500E+01
    $ LIQUID STORAGE COST (DOLLARS/GALLON)
65,     1
    $ FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
68,     .2120E+01
    $ MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .7000E+01
    $ LOAN TERM, YEARS
70,     .2000E+00
    $ DOWN PAYMENT (FRACTION OF INITIAL COST)
73,     0.
    $ PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .3000E+00
    $ INCOME TAX RATE, (FRACTION)
82,     .7000E-01
    $ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .3500E+01 0.      .5000E-01 .1000E+03 .4000E-01 .1000E+10
      .1000E+00 *
    $ ENERGY COST SCHEDULE-ELECTRICITY
151,    .1400E+03
    $ AUXILIARY WATER HEATER SET TEMP, (F)
152,    .1400E+03
    $ WATER DELIVERY (MIXING VALVE) TEMPERATURE (F)

```

Figure IV-2a. (cont.)

```

DO YOU WISH TO CHANGE ANY OF
YOUR ANSWERS, BY ENTERING THE
SHORT FORM MODE?
    ANSWER Y OR N --
INPUT-
? Y

ENTER SOLCOST INPUT LINE NUMBER -
INPUT-
? 68

    ENTER LINE 68: (REAL VALUE)
    MORTGAGE INTEREST RATE, PERCENT/YEAR
INPUT-
? .12

ENTER SOLCOST INPUT LINE NUMBER -
INPUT-
? E

DID YOU INTEND TO EXIT THE PROGRAM?
ENTER Y OR N -
INPUT-
? Y

```

Figure IV-2a. (cont.)

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```

T
THIS IS A SAMPLE SERVICE HOT WATER SYSTEM
1,      8      8      8      8      8      8      8
      8      8      8      8 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2
      2      2      2      2 *
$ REFERENCE SYSTEM FUEL TYPE
6,      2
$ SOLAR AUXILIARY ENERGY FLAG
10,     2
$ COLLECTOR TYPE FLAG
13,     .4000E+02 $
$ COLLECTOR TILT ANGLES, DEGREES
17,     .2000E+01
$ LIQUID STORAGE (GAL/SQ.FT OF COLLECTOR AREA)
23,     .1600E+02
$ COLLECTOR MODULE SIZE (SQ. FT.)
25,     44
$ SITE LOCATION CODE
49,     .5900E-01
$ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .3000E+03
$ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .5000E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
57,     .1500E+01
$ LIQUID STORAGE COST (DOLLARS/GALLON)
65,     1
$ FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
68,     .1200E+00
$ MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .7000E+01
$ LOAN TERM, YEARS
70,     .2000E+00
$ DOWN PAYMENT (FRACTION OF INITIAL COST)
73,     0.
$ PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .3000E+00
$ INCOME TAX RATE, (FRACTION)
82,     .7000E-01
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .3500E+01 0.      .5000E-01 .1000E+03 .4000E-01 .1000E+10
      .1000E+00 $
$ ENERGY COST SCHEDULE-ELECTRICITY
151,    .1400E+03
$ AUXILIARY WATER HEATER SET TEMP, (F)
152,    .1400E+03
$ WATER DELIVERY (MIXING VALVE) TEMPERATURE (F)
RUN

```

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

Figure IV-2b. SOLCOST Output for Input
Illustrated in Fig. IV-2a.

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

-----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----

LOCATION --POINT MUGU,CA LATITUDE = 34.1 TILT ANGLES 40.0
 SERVICE WATER HEATING SYSTEM WITH 2.0 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .67
 COL. EFFIC. = .30 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SER. HOT WATER LOAD= .059 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	300.00	0.00
INITIAL COST,	\$/SQ FT	50.00	-----
DOWN PAYMENT,	% OF IN. COST	20.0	20.0
LOAN TERM,	YEARS	7.0	7.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	7.0	7.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD-MIL BTU	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
MEAN MIN TEMP., F	45.	44.	43.	43.	45.	46.	48.	48.	47.	47.	46.	47.
MEAN MAX TEMP., F	58.	59.	60.	60.	62.	64.	66.	66.	67.	67.	64.	61.
PERCENT POSS. SUN	53.	57.	63.	69.	70.	75.	68.	63.	70.	70.	62.	54.
DAILY HOR. INSOL.	927.1	1220.1	1636.1	1951.2	2018.2	2055.2	2118.1	1935.1	1608.1	1296.1	1006.1	856.1
HEATING DEG. DAYS	400.	358.	403.	387.	356.	301.	266.	257.	223.	248.	275.	364.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$3.500 PER UNIT FOR FIRST	0.	UNITS
ELECTRIC	\$.050 PER UNIT FOR NEXT	100.	UNITS
ELECTRIC	\$.040 PER UNIT FOR NEXT	.100E+10	UNITS
ESCALATION RATE = 10.00 PERCENT			

Figure IV-2b. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

SOLAR SYSTEM COST SUMMARY TABLE							
COLLECTOR AREA	16.	32.	48.	64.	80.	96.	112.
STORAGE SIZE	32.	64.	96.	128.	160.	192.	224.
STORAGE COSTS	48.	96.	144.	192.	240.	288.	336.
COLLECTOR COSTS	800.	1600.	2400.	3200.	4000.	4800.	5600.
FIXED COSTS	300.	300.	300.	300.	300.	300.	300.
TOTAL COSTS	1148.	1996.	2844.	3692.	4540.	5388.	6236.

Figure IV-2b. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM .

SYSTEM PERFORMANCE AND COST SUMMARY FOR 40.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
16.0	.260	1148.00	16.1	397.37	2350.21
32.0	.430	1996.00	15.6	638.62	3936.85
48.0	.553	2844.00	12.9	570.83	4777.11
64.0	.652	3692.00	10.8	342.63	5159.53
80.0	.740	4540.00	9.0	-7.90	5192.33
96.0	.809	5388.00	7.6	-382.75	5155.63
112.0	.865	6236.00	6.5	-782.77	5046.98

ENERGY BALANCE BY MONTH FOR 32.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.387	713.1	.71	1.24	2.03
2	.432	797.3	.71	1.06	1.84
3	.466	859.1	.85	1.09	2.03
4	.459	847.0	.81	1.08	1.97
5	.423	779.6	.77	1.19	2.03
6	.414	762.4	.73	1.22	1.97
7	.438	806.7	.80	1.21	2.03
8	.450	829.1	.82	1.13	2.03
9	.447	824.1	.79	1.11	1.97
10	.444	819.1	.81	1.14	2.03
11	.414	762.6	.73	1.16	1.97
12	.383	706.1	.70	1.25	2.03
ANNUAL	.430		9.25	13.87	23.93

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-2b. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 40. DEGREES IS 32. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVERS, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	118.	20.	0.	192.	656.	350.	-399.
2	130.	21.	0.	173.	52.	350.	404.
3	143.	23.	0.	151.	38.	350.	-189.
4	157.	24.	0.	128.	45.	350.	-184.
5	173.	26.	0.	101.	30.	350.	-178.
6	190.	28.	0.	71.	21.	350.	-172.
7	209.	30.	0.	37.	11.	330.	-166.
8	230.	32.	0.	0.	0.	0.	-159.
9	253.	34.	0.	0.	0.	0.	198.
10	278.	37.	0.	0.	0.	0.	218.
11	306.	39.	0.	0.	0.	0.	241.
12	336.	42.	0.	0.	0.	0.	266.
13	370.	45.	0.	0.	0.	0.	294.
14	407.	48.	0.	0.	0.	0.	325.
15	447.	51.	0.	0.	0.	0.	359.
16	492.	55.	0.	0.	0.	0.	396.
17	541.	59.	0.	0.	0.	0.	437.
18	596.	63.	0.	0.	0.	0.	483.
19	655.	67.	0.	0.	0.	0.	533.
20	721.	72.	0.	0.	0.	0.	588.
TOTALS	6752.	016.	0.	833.	833.	2450.	1943.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 598.80 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 10.4 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 1.0 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 638.62 DOLLARS

RATE OF RETURN ON NET CASH FLOW 15.6 PERCENT

ANNUAL PORTION OF LOAN PROVIDED BY SOLAR ... 43.0 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 9.3 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-2b. (cont.)

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WELCOME TO THE SOLCOST CONVERSATIONAL INPUT
PROGRAM.
NOTES --
1) ALL USER COMMANDS MUST BE ENTERED AS
   SINGLE CHARACTER INPUTS.
2) ALL ARRAYS MUST BE TERMINATED WITH THE
   ASTERISK CHARACTER (*).
3) A CARRIAGE RETURN BY ITSELF ON ANY INPUT
   WILL CAUSE THE JOB TO HALT.
4) FOR ARRAYS OF DIMENSION 12, I.E.
   INPUTS WHICH CORRESPOND TO MONTHLY
   VALUES, ONLY ONE VALUE NEED BE ENTERED
   IF ALL VALUES ARE THE SAME

TYPE H(ELP) FOR LIST OF USER COMMANDS-

OTHERWISE INDICATE TYPE OF FILE TO
BE PROCESSED BY ENTERING O(LD) OR N(EW) -
INPUT-
? O

DO YOU WISH TO CHANGE YOUR TITLE? (Y OR N)
INPUT-
? N

ENTER SOLCOST INPUT LINE NUMBER -
INPUT-
? 13

      ENTER LINE 13: (REAL ARRAY)
      COLLECTOR TILT ANGLES, DEGREES
INPUT-
? 30.*

ENTER SOLCOST INPUT LINE NUMBER -
INPUT-
? 131

      ENTER LINE 131: (INTEGER)
      PRINTER - PLOTTER FLAG
INPUT-
? D
      PRINTER PLOTTER FLAG. DEFAULT IS 0. ENTER A 1 FOR
      PRINTER PLOTS.

      ENTER LINE 131: (INTEGER)
      PRINTER - PLOTTER FLAG
INPUT-
? 1

ENTER SOLCOST INPUT LINE NUMBER -
INPUT-
? E

DID YOU INTEND TO EXIT THE PROGRAM?
ENTER Y OR N -
INPUT-
? Y

```

Figure IV-2c. Interactive Example, Editing Mode

T

THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

1,	8	8	8	8	8	8	8	8
	8	8	8	8 *				
	% SOLAR SYSTEM TYPE FLAGS BY MONTH							
4,	2	2	2	2	2	2	2	2
	2	2	2	2 *				
	% REFERENCE SYSTEM FUEL TYPE							
6,	2							
	% SOLAR AUXILIARY ENERGY FLAG							
10,	2							
	% COLLECTOR TYPE FLAG							
13,	.3000E+02 *							
	% COLLECTOR TILT ANGLE, DEGREES							
17,	.2000E+01							
	% LIQUID STORAGE (GAL/SQ.FT OF COLLECTOR AREA)							
23,	.1600E+02							
	% COLLECTOR MODULE SIZE (SQ. FT.)							
25,	44							
	% SITE LOCATION CODE							
49,	.5900E-01							
	% LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)							
55,	.3000E+03							
	% SOLAR SYSTEM FIXED COST, DOLLARS							
56,	.5000E+02							
	% COST OF SOLAR SYSTEM, DOLLARS /SQ.FT							
57,	.1500E+01							
	% LIQUID STORAGE COST (DOLLARS/GALLON)							
65,	1							
	% FINANCIAL SCENARIO FLAG (RES, BUS, NPD): 1, 2, OR 3							
68,	.1200E+00							
	% MORTGAGE INTEREST RATE, PERCENT/YEAR							
69,	.7000E+01							
	% LOAN TERM, YEARS							
70,	.2000E+00							
	% DOWN PAYMENT (FRACTION OF INITIAL COST)							
73,	0.							
	% PROPERTY TAX RATE, FRACTION OF INITIAL COST							
74,	.3000E+00							
	% INCOME TAX RATE, (FRACTION)							
82,	.7000E-01							
	% INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES							
91,	.3500E+01	0.	.5000E-01	.1000E+03	.4000E-01	.1000E+10		
	% ENERGY COST SCHEDULE-ELECTRICITY							
131,	1							
	% PRINTER - PLOTTER FLAG							
151,	.1400E+03							
	% AUXILIARY WATER HEATER SET TEMP. (F)							
152,	.1400E+03							
	% WATER DELIVERY (MIXING VALVE) TEMPERATURE (F)							

RUN

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

Figure IV-2d. SOLCOST Output for Inputs as Edited and Illustrated in Fig. IV-2c.

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

-----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----

LOCATION --POINT MUGU,CA LATITUDE = 34.1 TILT ANGLES 30.0
 SERVICE WATER HEATING SYSTEM WITH 2.0 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .67
 COL. EFFIC. = .30 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SER. HOT WATER LOAD= .059 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	300.00	0.00
INITIAL COST,	\$/SQ FT	50.00	-----
DOWN PAYMENT,	% OF IN. COST	20.0	20.0
LOAN TERM,	YEARS	7.0	7.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN. COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	7.0	7.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD-MIL BTU	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
MEAN MIN TEMP., F	45.	44.	43.	43.	45.	46.	48.	48.	47.	47.	46.	47.
MEAN MAX TEMP., F	58.	59.	60.	60.	62.	64.	66.	66.	67.	67.	64.	61.
PERCENT POSS. SUN	53.	57.	63.	69.	70.	75.	68.	63.	70.	70.	62.	54.
DAILY HOR. INSOL.	927.	1220.	1636.	1951.	2018.	2055.	2118.	1935.	1608.	1296.	1006.	856.
HEATING DEG. DAYS	400.	358.	403.	387.	356.	301.	266.	257.	223.	248.	275.	364.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$3.500 PER UNIT FOR FIRST	0.	UNITS
ELECTRIC	\$.050 PER UNIT FOR NEXT	100.	UNITS
ELECTRIC	\$.040 PER UNIT FOR NEXT	.100E+10	UNITS
ESCALATION RATE = 10.00 PERCENT			

Figure IV-2d. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

SOLAR SYSTEM COST SUMMARY TABLE								
COLLECTOR AREA	16.	32.	48.	64.	80.	96.	112.	128.
STORAGE SIZE	32.	64.	96.	128.	160.	192.	224.	256.
STORAGE COSTS	48.	96.	144.	192.	240.	288.	336.	384.
COLLECTOR COSTS	800.	1600.	2400.	3200.	4000.	4800.	5600.	6400.
FIXED COSTS	300.	300.	300.	300.	300.	300.	300.	300.
TOTAL COSTS	1148.	1996.	2844.	3692.	4540.	5388.	6236.	7084.

Figure IV-2d, (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

SYSTEM PERFORMANCE AND COST SUMMARY FOR 30.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
16.0	.261	1148.00	16.3	410.79	2388.56
32.0	.431	1996.00	15.8	659.31	3995.98
48.0	.555	2844.00	13.1	592.09	4837.85
64.0	.658	3692.00	10.8	340.62	5153.80
80.0	.740	4540.00	9.0	9.11	5240.95
96.0	.808	5388.00	7.7	-363.16	5211.63
112.0	.869	6236.00	6.5	-788.81	5029.73
128.0	.914	7084.00	5.4	-1283.58	4650.27

ENERGY BALANCE BY MONTH FOR 32.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.363	669.2	.66	1.28	2.03
2	.417	769.6	.69	1.09	1.84
3	.464	854.9	.85	1.09	2.03
4	.470	866.7	.83	1.04	1.97
5	.447	824.6	.82	1.13	2.03
6	.441	813.5	.78	1.15	1.97
7	.465	857.2	.85	1.14	2.03
8	.468	862.4	.86	1.09	2.03
9	.450	830.2	.80	1.11	1.97
10	.433	798.8	.79	1.17	2.03
11	.391	721.6	.69	1.20	1.97
12	.358	660.6	.66	1.30	2.03
ANNUAL	.431		9.28	13.79	23.93

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR CONDUCTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-2d. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 30. DEGREES IS 32. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVERS, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	119.	20.	0.	192.	656.	350.	-399.
2	131.	21.	0.	173.	52.	350.	405.
3	144.	23.	0.	151.	45.	350.	-188.
4	158.	24.	0.	128.	38.	350.	-183.
5	174.	26.	0.	101.	30.	350.	-177.
6	191.	28.	0.	71.	21.	350.	-171.
7	211.	30.	0.	37.	11.	350.	-164.
8	232.	32.	0.	0.	0.	0.	-157.
9	255.	34.	0.	0.	0.	0.	200.
10	280.	37.	0.	0.	0.	0.	221.
11	308.	39.	0.	0.	0.	0.	244.
12	339.	42.	0.	0.	0.	0.	269.
13	373.	45.	0.	0.	0.	0.	297.
14	410.	48.	0.	0.	0.	0.	328.
15	451.	51.	0.	0.	0.	0.	362.
16	497.	55.	0.	0.	0.	0.	400.
17	546.	59.	0.	0.	0.	0.	441.
18	601.	63.	0.	0.	0.	0.	407.
19	661.	67.	0.	0.	0.	0.	538.
20	727.	72.	0.	0.	0.	0.	593.
TOTALS	6008.	816.	0.	853.	853.	2450.	655.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 598.80 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 10.3 YEARS
PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 1.0 YEARS
NET PRESENT WORTH OF SOLAR SAVINGS 659.31 DOLLARS
RATE OF RETURN ON NET CASH FLOW 15.8 PERCENT
ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 43.1 PERCENT
ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 9.3 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F
ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-2d. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

PLOT NUMBER 1

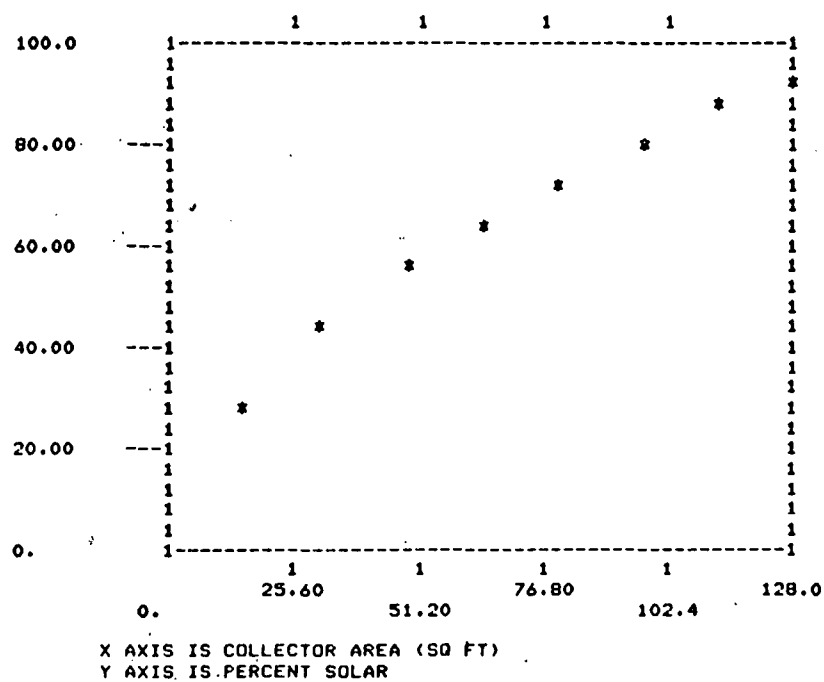


Figure IV-2d. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

PLOT NUMBER 2

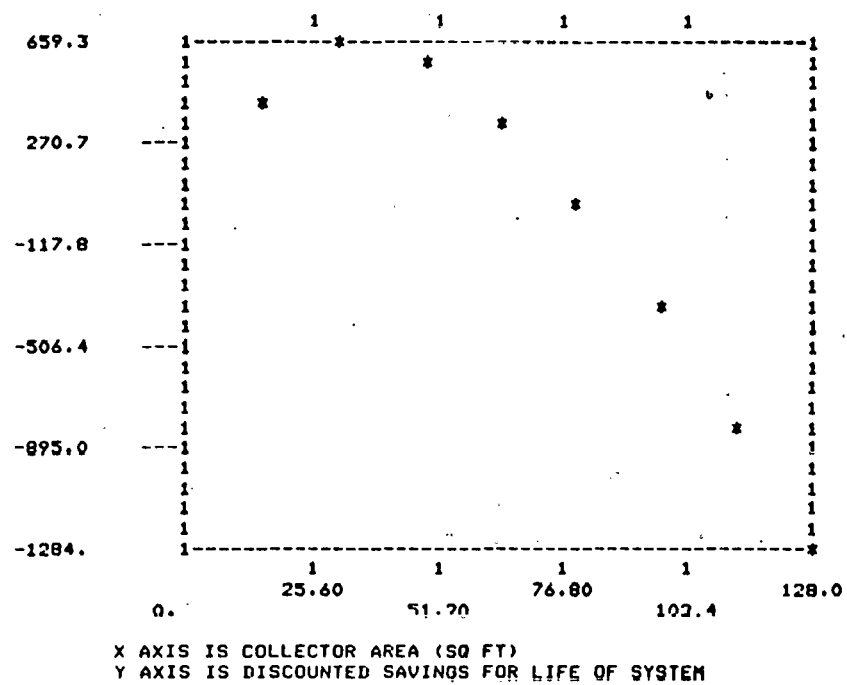
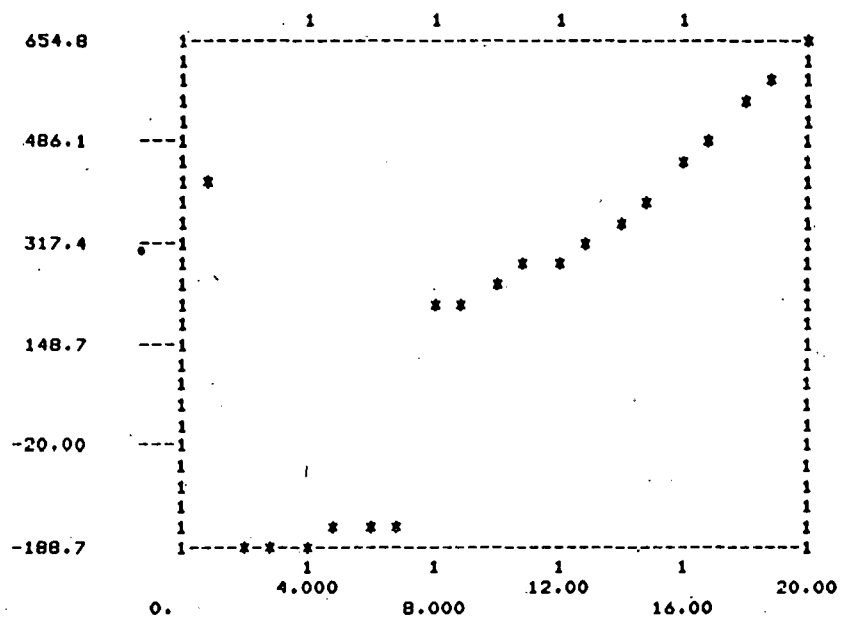


Figure IV-2d. (cont.)

TITLE: THIS IS A SAMPLE SERVICE HOT WATER SYSTEM

PLOT NUMBER 3



X AXIS IS LIFE OF SYSTEM (YEARS)
Y AXIS IS SYSTEM CASH FLOW STATUS (DOLLARS)

Figure IV-2d. (cont.)

Residential Sample Design Problem - The objective of this design case was to determine the optimum solar collector area for a residential space heating system in Denver. The collectors under consideration cost \$24/sq. ft. installed. An all electric system was the basis for comparison. The auxiliary heating system for the solar installation also used electricity.

The input file for this sample problem as well as the SOLCOST output is listed in Figure IV-3. The space heating loads were defined with an input building heat loss coefficient of 7.1 Btu/degree day-sq. ft. A constant daily hot water load of 0.09 million Btu's was also specified.

After execution, the program prints the summary sheet shown in Figure IV-3. This sheet mirrors the inputs and prints the computed loads and weather data used in the analysis. Next, the solar system performance summary is output. Finally, the cash flow sheet is output for the cost optimum collector size. Rates of return and payback years are given on the cash flow sheet. If more than one tilt angle has been defined, the program will find the optimum collector area and print a cash flow sheet for each input tilt angle.

The cash flow sheet summarizes the financial aspects of the solar investment. The columns are explained at the bottom of the sheet. Column G is headed by the down payment made on the total system cost.

```

1
RESIDENTIAL SAMPLE DESIGN PROBLEM
1,      1      1      1      1      1      1      1      1
      1      1      1      1      1 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2      2
      2      2      2      2 *
$ REFERENCE SYSTEM FUEL TYPE
6,      2
$ SOLAR AUXILIARY ENERGY FLAG
10,     21
$ COLLECTOR TYPE FLAG
13,     .5500E+02 *
$ COLLECTOR TILT ANGLES, DEGREES
14,     .7200E+00
$ COLLECTOR EFFICIENCY AT DT/Q = 0.
15,     .3100E+00
$ COLLECTOR EFFICIENCY AT (TIN-TAMD)/Q = 0.5
25,     55
$ SITE LOCATION CODE
40,      2
$ BUILDING LOAD COMPUTE METHOD FLAG
41,      3
$ SERVICE HOT WATER LOAD -- COMPUTE/INPUT FLAG
42,     .7100E+01
$ BUILDING HEAT LOSS FACTOR (BTU/DEG- DAY-SQ.FT)
43,     .1500E+04
$ BUILDING FLOOR AREA (SQ.FT)
49,     .9000E-01
$ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .1500E+04
$ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .2400E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT.
59,     .6000E-02
$ SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)
65,      1
$ FINANCIAL SCENARIO FLAG(RES,RUS,NFO): 1,2, OR 3
67,     .1000E+00
$ DISCOUNT RATE, FRACTION
72,     .7000E-02
$ BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)
73,      0.
$ PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .3000E+00
$ INCOME TAX RATE, (FRACTION)
82,     .1000E+00
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .1420E+00 .1500E+02 .4200E-01 .5000E+02 .4300E-01 .1200E+03
     .3400E-01 .1000E+05 .1000E+00 *
$ ENERGY COST SCHEDULE-ELECTRICITY
145,     1
$ FLAG TO PRINT MONTHLY MAX, MIN, AVG. STORAGE TEMPS
156,     .1000E+00
$ PRE-HEAT (OR STORAGE) TANK INSULATION U-VAL
RUN

```

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

Figure IV-3. Residential Sample Design Problem

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --DENVER,CO LATITUDE = 39.8 TILT ANGLE= 55.0
 LIQUID SOLAR SYSTEM WITH 1.5 GAL. STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .72
 COL. EFFIC. = .31 AT DEL T/FLUX = .5 HR-F-SQ FT/RTU
 INPUT SPACE HEAT U-VALUE = 7.10 RTU/(F-DEG-SQ FT) FLOOR AREA= 1500. SQ FT
 INPUT SER. HOT WATER LOAD= .090 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	1500.00	0.00
INITIAL COST,	\$/SQ FT	24.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	9.0	9.0
DISCOUNT RATE,	%	10.0	10.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.7	.7
MAINTENANCE RATE,	% OF IN COST	.4	.5
GEN INFLATION,	% PER YEAR	10.0	10.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	1	1	1	1	1	1	1	1	1	1	1	1
TRANSPORT EFFIC.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DAILY LOAD-MIL BTU	.46	.43	.39	.28	.18	.12	.09	.09	.13	.23	.36	.43
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	48.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	78.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	68.	69.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.	1127.	1530.	1879.	2135.	2351.	2273.	2044.	1727.	1301.	884.	732.
HEATING DEG. DAYS	1088.	902.	648.	525.	353.	80.	0.	0.	120.	408.	768.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$.142 PER UNIT FOR FIRST	15.0	UNITS
ELECTRIC	\$.042 PER UNIT FOR NEXT	50.0	UNITS
ELECTRIC	\$.043 PER UNIT FOR NEXT	120.	UNITS
ELECTRIC	\$.036 PER UNIT FOR NEXT	.100E+05	UNITS
ESCALATION RATE = 10.00 PERCENT			

Figure IV-3. (Cont.)

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

SOLAR SYSTEM COST SUMMARY TABLE									
COLLECTOR AREA	60.	140.	220.	300.	380.	440.	520.	600.	680.
STORAGE SIZE	90.	210.	340.	450.	520.	650.	780.	900.	1020.
STORAGE COSTS	90.	210.	340.	450.	520.	650.	780.	900.	1020.
COLLECTOR COSTS	1440.	3360.	5280.	7200.	9120.	10560.	12480.	14400.	16320.
FIXED COSTS	1500.	1500.	1500.	1500.	1500.	1500.	1500.	1500.	1500.
TOTAL COSTS	3030.	5070.	7110.	9150.	11190.	13220.	14760.	16800.	18840.

Figure IV-3. (Cont.)

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

SYSTEM PERFORMANCE AND COST SUMMARY FOR 55.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
60.0	.196	3030.00	136.1	1313.14	4734.61
140.0	.410	5070.00	143.6	3700.53	13160.78
220.0	.550	7110.00	129.0	4928.30	17430.01
300.0	.679	9150.00	115.9	5622.28	20339.73
380.0	.781	11190.00	83.0	5620.73	21387.23
440.0	.846	12720.00	56.4	5634.97	21522.34
520.0	.925	14760.00	36.1	4790.80	21222.15
600.0	.970	16800.00	24.4	3671.10	19108.99
680.0	.996	18840.00	16.8	2151.42	15735.00

ENERGY BALANCE BY MONTH FOR 380.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (MBTU/DAY-SQ.FT.)	TOTAL USEFUL SOLAR ENERGY (MIL. BTU/MO)	AUXILIARY ENERGY (MIL. BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL. BTU/MO)
1	.502	710.8	8.37	6.00	14.38
2	.677	771.8	8.21	3.91	12.13
3	.759	775.4	9.13	2.90	12.03
4	.985	716.2	8.16	.13	8.29
5	1.000	469.8	5.48	0.00	5.48
6	1.000	315.9	3.55	0.00	3.55
7	1.000	267.3	2.79	0.00	2.79
8	1.000	318.6	2.79	0.00	2.79
9	1.000	403.3	3.98	0.00	3.98
10	1.000	419.1	7.14	0.00	7.14
11	.752	718.0	8.19	2.69	10.88
12	.586	670.9	7.90	5.58	13.48
ANNUAL	.781		75.70	21.22	96.92

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 10.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-3. (Cont.)

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 55. DEGREES IS 390. SQ. FT.
COLLECTOR TYPE = USER DEFINED, LIQUID TYPE
FINANCIAL SCENARIO---RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	822.	145.	0.	906.	2472.	1103.	-1119.
2	905.	160.	0.	889.	267.	1103.	2046.
3	995.	176.	0.	869.	261.	1103.	-91.
4	1095.	194.	0.	848.	254.	1103.	-22.
5	1204.	213.	0.	825.	248.	1103.	52.
6	1325.	234.	0.	800.	240.	1103.	136.
7	1457.	258.	0.	773.	232.	1103.	227.
8	1603.	283.	0.	743.	223.	1103.	328.
9	1763.	312.	0.	711.	213.	1103.	439.
10	1939.	343.	0.	676.	203.	1103.	561.
11	2133.	377.	0.	637.	191.	1103.	696.
12	2346.	415.	0.	595.	179.	1103.	844.
13	2581.	457.	0.	550.	165.	1103.	1007.
14	2839.	502.	0.	500.	150.	1103.	1186.
15	3123.	552.	0.	445.	134.	1103.	1384.
16	3435.	608.	0.	386.	116.	1103.	1601.
17	3779.	668.	0.	322.	97.	1103.	1840.
18	4157.	735.	0.	251.	75.	1103.	2104.
19	4573.	809.	0.	175.	52.	1103.	2394.
20	5030.	890.	0.	91.	27.	1103.	2713.
TOTALS	47104.	8331.	0.	11992.	5799.	22060.	21390.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 2200.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 9.0 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT5 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 5620.73 DOLLARS

RATE OF RETURN ON NET CASH FLOW 83.1 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 70.1 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 75.7 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-3. (Cont.)

TITLE: RESIDENTIAL SAMPLE DESIGN PROBLEM

MONTH	TEMPERATURE AND ENERGY INFORMATION FOR COLLECTOR AREA			STORAGE LOSSES (BTU/DAY)	NUMBER OF ITERATIONS	380.
	STORAGE DRAIN (DEGREE F)	TEMPERATURE MAXIMUM	AVERAGE			
1	100.	134.	116.	9549.	2	
2	100.	139.	119.	10077.	2	
3	100.	140.	119.	10167.	2	
4	109.	145.	125.	11560.	2	
5	146.	171.	156.	19195.	4	
6	180.	197.	187.	26567.	5	
7	188.	200.	193.	28096.	6	
8	187.	200.	193.	28006.	6	
9	182.	200.	190.	27274.	6	
10	155.	191.	171.	22605.	5	
11	100.	141.	120.	10271.	2	
12	100.	133.	116.	9434.	2	

Figure IV-3. (Cont.)

Business Sample Design Problem - The objective of this design case was to size a solar water heating system for a car wash business. The installation qualifies for the solar incentive (enter .20 for investment tax credit) and additional first year depreciation, since the system is income producing equipment. (Note - solar space heating and service water systems also qualify for the solar incentive (enter .10 for investment tax credit); however, the additional first year depreciation cannot be claimed because the system is not income producing. They can be depreciated over their useful life, since they are part of the building's HVAC equipment.)

The applicable financial parameters for this sample case are:

Line 67 Owner's discount rate	.15 (15%)
Line 74 Owner's income tax rate	.50 (50%)
Line 75 Depreciation method	1 (Straight Line)
Line 77 Investment tax credit	.20 (20% for solar incentive)
Line 78 Additional first year depreciation	.20 (20%)
Line 79 Solar System useful life	15. (15 years)
Line 80 Water tank useful life	20. (20 years)
Line 81 Solar System salvage value	.10 (10%)

For this example, the reference system and the solar auxiliary systems were assumed to be an electric boiler, so the capital costs considered in the analysis are due to the solar system alone. Electricity was assumed to escalate at 8% per year. The useful life of the solar system for tax purposes was assumed to be 15 years; however, the solar system life was expected to be 20 years. Figure IV-4 lists the data file for this run and shows the processed input summary.

The solar system performance and financial summary reports for this sample problem are shown in Figure IV-4. SOLCOST computed a collector area of 1720 sq. ft. as being the most economic for this sample problem. The rate of return on the solar investment is 104%. (Users are cautioned that rates of return are very sensi-

tive to the amount of down payment, and indeed rates of return can become ridiculously large for minimum down payment conditions. Also, if alternatives are being considered, they must be financed under similar terms in order for rate of return comparisons to be valid.)

Some additional explanation of the depreciation column may be helpful. SOLCOST computes separate depreciation for 1) the water storage components and 2) the rest of the system. The procedure is as follows:

1. Compute basis for depreciation, where

Basis = Initial Cost - Salvage Value - Additional First Year Depreciation

Add. First Year Dep. = Rate x Initial Cost

(Note: For corporations, there is a \$2,000 upper limit for AFYD*.

This is checked internally by SOLCOST.)

	<u>Storage</u>	<u>System-Storage</u>
Initial Cost	2580.	43280.
Salvage Value (1.0%)	258.	4328.
Add. First Yr. Dep. (20%)	516.	2000.
Basis	1806.	36952.

2. Compute allowable straight line depreciation per year:

SL Dep. = Basis/Life

	<u>Storage</u>	<u>System-Storage</u>
Basis	1806.	36952.
Life	20.	15.
SSL Dep.	90.	2463.

*Tax Guide for Small Business, 1977 Edition, IRS Publication 334.

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BUSINESS SAMPLE DESIGN PROBLEM

1,	8	8	8	8	8	8	8
	8	8	8	8 *			
	% SOLAR SYSTEM TYPE FLAGS BY MONTH						
4,	2	2	2	2	2	2	2
	2	2	2	2 *			
	% REFERENCE SYSTEM FUEL TYPE						
6,	2						
	% SOLAR AUXILIARY ENERGY FLAG						
10,	21						
	% COLLECTOR TYPE FLAG						
13,	.4500E+02 *						
	% COLLECTOR TILT ANGLES, DEGREES						
14,	.7400E+00						
	% COLLECTOR EFFICIENCY AT DT/Q = 0.						
15,	.7100E+00						
	% COLLECTOR EFFICIENCY AT (TIN-TAMB)/Q = 0.5						
25,	55						
	% SITE LOCATION CODE						
40,	5						
	% BUILDING LOAD COMPUTE METHOD FLAG						
46,	.1500E+01	.1400E+01	.1400E+01	.1250E+01	.1320E+01	.1500E+01	
	.1500E+01	.1400E+01	.1400E+01	.1500E+01	.1300E+01	.1300E+01 *	
	% USER INPUT LOADS ARRAY						
55,	.2000E+04						
	% SOLAR SYSTEM FIXED COST, DOLLARS						
56,	.2400E+02						
	% COST OF SOLAR SYSTEM, DOLLARS /SQ.FT						
59,	.1000E-01						
	% SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)						
65,	2						
	% FINANCIAL SCENARIO FLAG(RES,BUS,NFO): 1,2, OR 3						
67,	.1500E+00						
	% DISCOUNT RATE, FRACTION						
68,	.1200E+00						
	% MORTGAGE INTEREST RATE, PERCENT/YEAR						
71,	.2000E+02						
	% TERM OF LIFE CYCLE ANALYSIS						
72,	.6000E-02						
	% BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)						
73,	.1500E-01						
	% PROPERTY TAX RATE, FRACTION OF INITIAL COST						
74,	.5000E+00						
	% INCOME TAX RATE, (FRACTION)						
75,	1						
	% DEPRECIATION METHOD						
77,	.2000E+00						
	% INVESTMENT CREDIT (FRACTION OF INITIAL COST)						
78,	.2000E+00						
	% ADDITIONAL 1ST YEAR DEP. RATE, (FRACT. OF I.C.)						
79,	.1500E+02						
	% HVAC SYSTEM USEFUL LIFE, YEARS						
80,	.2000E+02						
	% STORAGE TANK USEFUL LIFE, YEARS						
81,	.1000E+00						
	% SYSTEM SALVAGE VALUE (FRACTION OF INITIAL COST)						
82,	.1000E+00						
	% INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES						

Figure IV-4. Business Sample Design Problem

```

91, .1420E+00 .1500E+02 .6200E-01 .5000E+02 .4300E-01 .1200E+03
    .3600E-01 .1000E+05 .1000E+00 *
    $ ENERGY COST SCHEDULE-ELECTRICITY
143, 1
    $ FLAG TO PRINT MONTHLY MAX, MIN, AVG. STORAGE TEMPS
155, 0.
    $ AXILARY TANK UA, BTU/HR-DEG F
156, .1000E+00
    $ PRE-HEAT (OR STORAGE) TANK INSULATION U-VAL
RUN

```

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

Figure IV-4. (Cont.)

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --DENVER,CO LATITUDE = 39.8 TILT ANGLE 45.0
 SERVICE WATER HEATING SYSTEM WITH 1.5 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .74
 COL. EFFIC. = .21 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 SOLAR SYSTEM LOAD HAS BEEN INPUT BY USER, SEE BELOW
 INPUT SER. HOT WATER LOAD= 0.000 MTION Btus/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	2000.00	0.00
INITIAL COST,	\$/SQ FT	24.00	
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	15.0	15.0
INCOME TAX RATE,	%	50.0	50.0
PROP. TAX RATE,	% OF IN COST	1.5	1.5
INSURANCE RATE,	% OF IN COST	.6	.6
MAINTENANCE RATE,	% OF IN COST	1.0	.5
GEN INFLATION,	% PER YEAR	10.0	10.0
SALVAGE VALUE,	% OF IN. COST	10.0	10.0
DEPRECIATION YEARS--HVAC SYS.		15.0	15.0
DEPRECIATION YEARS--STORAGE		20.0	20.0
TAX DEREC. METHOD		SL	SL
INVESTMENT CREDIT, % OF IN. COST		20.0	20.0
ACC. 1ST YR DEPREC, % OF IN. COST		20.0	20.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD HIL. BTU	1.50	1.40	1.40	1.25	1.32	1.50	1.50	1.50	1.50	1.50	1.30	1.30
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	40.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	70.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	60.	60.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.	1127.	1530.	1879.	2135.	2351.	2273.	2044.	1727.	1301.	804.	732.
HEATING DEG. DAYS	1089.	902.	848.	525.	253.	80.	0.	0.	120.	408.	740.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$.142 PER UNIT FOR FIRST	15.0	UNITS
ELECTRIC	\$.062 PER UNIT FOR NEXT	50.0	UNITS
ELECTRIC	\$.043 PER UNIT FOR NEXT	120.	UNITS
ELECTRIC	\$.036 PER UNIT FOR NEXT	.100E+05	UNITS
ESCALATION RATE = 10.00 PERCENT			

Figure IV-4. (Cont.)

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	340.	700.	1040.	1380.	1720.	2060.	2400.	2740.	3100.
STORAGE SIZE	510.	1050.	1560.	2070.	2580.	3090.	3600.	4110.	4650.
STORAGE COSTS	510.	1050.	1560.	2070.	2580.	3090.	3600.	4110.	4650.
COLLECTOR COSTS	8160.	16800.	24960.	33120.	41280.	49440.	57600.	65760.	74400.
FIXED COSTS	2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.
TOTAL COSTS	10670.	19850.	28520.	37190.	45860.	54530.	63200.	71870.	81050.

Figure IV-4. (Cont.)

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

SYSTEM PERFORMANCE AND COST SUMMARY FOR 45.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
340.0	.263	10670.00	0.0	-3157.35	-18463.32
700.0	.402	19850.00	0.0	-219.70	-4858.74
1040.0	.649	20520.00	113.8	2405.35	7263.54
1380.0	.781	37190.00	110.9	3908.41	13930.21
1720.0	.884	45860.00	104.2	4240.18	14901.45
2060.0	.954	54530.00	95.1	3430.11	10320.55
2400.0	.982	63200.00	0.0	1089.39	-1703.15
2740.0	.994	71870.00	0.0	1922.39	-16989.82
3100.0	.997	81050.00	0.0	-5330.61	-34241.98

ENERGY BALANCE BY MONTH FOR 1720.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (QU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.739	644.5	34.37	13.56	51.67
2	.837	681.1	32.80	6.87	43.56
3	.870	708.4	37.77	5.87	40.22
4	.935	679.3	35.05	2.39	41.67
5	.921	706.4	37.67	3.35	45.47
6	.920	802.6	41.41	3.80	50.00
7	.953	831.1	44.31	2.24	51.67
8	.938	872.2	46.50	3.21	55.11
9	.938	872.6	45.03	2.95	53.33
10	.919	801.5	42.74	3.08	51.67
11	.839	633.8	32.70	6.94	43.33
12	.779	588.9	31.40	10.21	44.78
ANNUAL	.804		461.75	65.28	580.47

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 15.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-4. (Cont.)

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

TEMPERATURE AND ENERGY INFORMATION FOR COLLECTOR AREA					1720.	
MONTH	STORAGE TEMPERATURE		STORAGE	AUXILIARY	NUMBER OF	
	DWN	MAXIMUM	LOSSES	ENERGY	ITERATIONS	
	(DEGREE F.)		(BTU/DAY)	(BTU/DAY)		
1	90.	121.	100.	16857.	393616.	2
2	98.	130.	109.	22256.	220737.	3
3	101.	133.	112.	24308.	170486.	3
4	109.	139.	120.	29315.	71777.	3
5	106.	138.	119.	28469.	92272.	3
6	105.	140.	119.	28433.	114097.	3
7	109.	146.	124.	31025.	64706.	3
8	107.	145.	121.	30102.	94280.	3
9	108.	147.	123.	31239.	88591.	3
10	106.	143.	119.	28885.	112700.	3
11	98.	128.	100.	21856.	208196.	3
12	93.	121.	103.	18313.	296354.	2

Figure IV-4. (Cont.)

TITLE: BUSINESS SAMPLE DESIGN PROBLEM

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 45. DEGREES IS 1720. SQ. FT.
COLLECTOR TYPE = USER DEFINED, LIQUID TYPE
FINANCIAL SCENARIO---BUSINESS

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT,INSUR PROP. TAX	(C) DEPRE- CIATION	(D) LOAN INTEREST	(E) INCOME TAXES	(F) LOAN PAYMENT	(G) NET CASH FLOW
0							-4584.
0					-9172.		9172.
1	3711.	1421.	5069.	4952.	-13030.	5525.	9802.
2	4082.	1563.	2553.	4884.	-2459.	5525.	-547.
3	4490.	1720.	2553.	4807.	-2295.	5525.	-459.
4	4939.	1892.	2553.	4720.	-2113.	5525.	-364.
5	5433.	2084.	2553.	4624.	-1912.	5525.	-260.
6	5977.	2289.	2553.	4516.	-1691.	5525.	-146.
7	6574.	2510.	2553.	4395.	-1446.	5525.	-23.
8	7232.	2770.	2553.	4259.	-1175.	5525.	111.
9	7955.	3047.	2553.	4107.	-876.	5525.	259.
10	8751.	3352.	2553.	3937.	-545.	5525.	419.
11	9626.	3687.	2553.	3746.	-180.	5525.	593.
12	10589.	4056.	2553.	3533.	223.	5525.	784.
13	11647.	4461.	2553.	3293.	669.	5525.	991.
14	12812.	4907.	2553.	3026.	1162.	5525.	1216.
15	14094.	5390.	2553.	2726.	1707.	5525.	1461.
16	15503.	5930.	90.	2390.	3542.	5525.	496.
17	17053.	6532.	90.	2014.	4708.	5525.	787.
18	18759.	7185.	90.	1592.	4945.	5525.	1102.
19	20635.	7904.	90.	1120.	5759.	5525.	1445.
20	22698.	8694.	90.	592.	6660.	5525.	1817.
	212560.	81415.	41261.	69233.	1145.	110500.	14098.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 0.4 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT5 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS 4240.18 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 104.2 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 88.4 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM ... 442. MILLION BTUS

INCOME TAX = TAX RATE X (A - B - C - D)
 NET CASH FLOW = A - B - E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS
 YEAR 0 ENTRY IN NET CASH FLOW COLUMN IS DOWN PAYMENT
 YEAR 1 ENTRY IN TAX COLUMN INCLUDES INVESTMENT TAX CREDIT

CAUTION... A FUEL QUANTITY USED IN THIS CASE
 EXCEEDED THE INPUT FUEL COST TABLE

Figure IV-4 (cont.)

Note: SOLCOST informs the user when the fuel quantity used exceeds the input fuel table. However, the program uses the last block price for exceeded quantities.

On the following pages, four additional sample SOLCOST analyses are shown. They are:

Figure IV-5. Residential Solar Service Hot Water System Analysis
for Sunnyvale, CA

Figure IV-6. Residential Solar Service Hot Water System Analysis
for Sioux City, IA

Figure IV-7. Residential Air Solar Space Heating System Analysis
for Madison, WI

Figure IV-8. Residential Solar Service Hot Water System Analysis
for Albany, NY

T

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SUNNYVALE,CA EXAMPLE
1,      8      8      8      8      8      8      8      8
      8      8      8      8 *
    $ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2      2
      2      2      2      2 *
    $ REFERENCE SYSTEM FUEL TYPE
6,      2
    $ SOLAR AUXILIARY ENERGY FLAG
10,     1
    $ COLLECTOR TYPE FLAG
12,     .5000E+01
    $ COLLECTOR AZIMUTH ANGLE
21,     3
    $ FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
22,     .4000E+02
    $ SPECIFIED COLLECTOR AREA WHEN LINE 21=1, 2 OR 3
25,     52
    $ SITE LOCATION CODE
49,     .3000E-01
    $ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .2000E+03
    $ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .4500E+02
    $ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
65,     1
    $ FINANCIAL SCENARIO FLAG(RES,BUS,NFO): 1,2, OR 3
66,     .5500E+00 .3000E+04 0. .1000E+07 *
    $ INCOME TAX CREDIT
68,     .1200E+00
    $ MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .7000E+01
    $ LOAN TERM, YEARS
73,     -.1000E+01
    $ PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .3400E+00
    $ INCOME TAX RATE, (FRACTION)
82,     .1000E+00
    $ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
83,     0. .4000E+01 .1000E-01 .1600E+02 *
    $ PROPERTY TAX RATE VS TIME
91,     .5000E-01 .1000E+07 .9000E-01 *
    $ ENERGY COST SCHEDULE-ELECTRICITY
RUN

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TITLE: SUNNYVALE,CA EXAMPLE

Figure IV-5. Residential Solar Service Hot Water System Analysis for Sunnyvale, CA

TITLE: SUNNYVALE, CA EXAMPLE

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --SUNNYVALE,CA LATITUDE = 37.4 TILT ANGLES 37.4 44.9 52.4
 SERVICE WATER HEATING SYSTEM WITH 1.5 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .02
 COL. EFFIC. = .24 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SER. HOT WATER LOAD= .030 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	200.00	0.00
INITIAL COST,	\$/SQ FT	45.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	7.0	7.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	34.0	34.0
PROP. TAX RATE,	% OF IN COST	0.0	1.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	10.0	10.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD-MIL BTU	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
MEAN MIN TEMP., F	44.	44.	47.	49.	54.	57.	59.	59.	58.	53.	46.	43.
MEAN MAX TEMP., F	57.	59.	64.	66.	71.	75.	77.	77.	78.	73.	64.	57.
PERCENT POSS. SUN	53.	57.	63.	69.	70.	75.	68.	63.	70.	70.	62.	54.
DAILY HOR. INSOL.	738.	1038.	1485.	1944.	2277.	2453.	2441.	2167.	1760.	1248.	843.	660.
HEATING DEG. DAYS	481.	349.	322.	229.	122.	50.	13.	14.	13.	90.	275.	455.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ELECTRIC \$.050 PER UNIT FOR FIRST .100E+07. UNITS
 ESCALATION RATE = 9.00 PERCENT

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE	
COLLECTOR AREA	40.
STORAGE SIZE	60.
STORAGE COSTS	60.
COLLECTOR COSTS	1800.
FIXED COSTS	200.

TOTAL COSTS	2060.

Figure 1V-5. (cont.)

TITLE: SUNNYVALE, CA EXAMPLE

ENERGY BALANCE BY MONTH FOR 40.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.665	499.0	.62	.34	1.03
2	.783	586.9	.66	.19	.93
3	.882	661.4	.82	.11	1.03
4	.919	689.6	.83	.06	1.00
5	.935	701.6	.87	.04	1.03
6	.953	714.4	.86	.03	1.00
7	.955	716.4	.89	.02	1.03
8	.963	722.0	.90	.02	1.03
9	.952	714.2	.86	.02	1.00
10	.901	675.6	.84	.09	1.03
11	.754	565.9	.68	.24	1.00
12	.644	482.6	.60	.37	.03
ANNUAL	.859		9.41	1.53	12.17

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 37. DEGREES IS 40. SQ. FT.
 COLLECTOR TYPE = LIQUID, FLAT PLATE, 1 COVER, PAINT
 FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	156.	21.	0.	222.	1209.	406.	-206.
2	170.	23.	0.	200.	68.	406.	938.
3	185.	25.	0.	176.	60.	406.	-190.
4	202.	27.	0.	148.	50.	406.	-185.
5	220.	30.	21.	117.	47.	406.	-180.
6	240.	33.	23.	82.	36.	406.	-189.
7	261.	36.	25.	44.	23.	406.	-186.
8	285.	40.	27.	0.	9.	0.	-182.
9	311.	44.	30.	0.	10.	0.	227.
10	339.	49.	33.	0.	11.	0.	246.
11	369.	53.	36.	0.	12.	0.	268.
12	402.	59.	40.	0.	14.	0.	291.
13	438.	65.	44.	0.	15.	0.	317.
14	478.	71.	49.	0.	17.	0.	345.
15	521.	78.	53.	0.	18.	0.	375.
16	568.	86.	59.	0.	20.	0.	407.
17	619.	95.	65.	0.	22.	0.	443.
18	675.	104.	71.	0.	24.	0.	481.
19	735.	115.	78.	0.	27.	0.	523.
20	801.	126.	86.	0.	29.	0.	569.
TOTALS	7975.	1180.	740.	989.	1721.	2842.	4731.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 1133.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 9.1 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT2 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 1343.52 DOLLARS

RATE OF RETURN ON NET CASH FLOW 327.4 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 85.7 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 9.4 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE	
COLLECTOR AREA	40.
STORAGE SIZE	60.
STORAGE COSTS	60.
COLLECTOR COSTS	1800.
FIXED COSTS	200.

TOTAL COSTS	2060.

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

ENERGY BALANCE BY MONTH FOR 40.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.693	519.6	.64	.31	1.03
2	.799	599.6	.67	.18	.93
3	.881	660.8	.82	.11	1.03
4	.903	677.6	.81	.08	1.00
5	.909	681.7	.85	.07	1.03
6	.923	692.3	.83	.06	1.00
7	.939	704.3	.87	.04	1.03
8	.955	716.1	.89	.03	1.03
9	.947	710.3	.85	.02	1.00
10	.910	682.8	.85	.08	1.03
11	.779	584.2	.70	.21	1.00
12	.673	504.9	.63	.33	1.03
ANNUAL	.860		9.41	1.53	12.17

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 45. DEGREES IS 40. SQ. FT.
COLLECTOR TYPE - LIQUID, FLAT PLATE, 1 CUEN, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	156.	21.	0.	222.	1209.	406.	-206.
2	170.	23.	0.	200.	68.	406.	938.
3	185.	25.	0.	176.	60.	406.	-190.
4	202.	27.	0.	148.	50.	406.	-185.
5	220.	30.	21.	117.	47.	406.	-181.
6	240.	33.	23.	82.	36.	406.	-189.
7	261.	36.	25.	44.	23.	406.	-186.
8	285.	40.	27.	0.	9.	0.	-182.
9	311.	44.	30.	0.	10.	0.	227.
10	338.	49.	33.	0.	11.	0.	246.
11	369.	53.	36.	0.	12.	0.	268.
12	402.	59.	40.	0.	14.	0.	291.
13	438.	65.	44.	0.	15.	0.	317.
14	478.	71.	49.	0.	17.	0.	345.
15	521.	78.	53.	0.	18.	0.	375.
16	569.	86.	59.	0.	20.	0.	407.
17	619.	95.	65.	0.	22.	0.	443.
18	674.	104.	71.	0.	24.	0.	481.
19	735.	115.	78.	0.	27.	0.	523.
20	801.	124.	86.	0.	29.	0.	569.
TOTALS	7973.	1180.	740.	989.	1721.	2842.	618.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 1133.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 9.1 YEARS
PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT2 YEARS
NET PRESENT WORTH OF SOLAR SAVINGS 1343.03 DOLLARS
RATE OF RETURN ON NET CASH FLOW 327.4 PERCENT
ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 86.0 PERCENT
ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 9.4 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F
ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA, EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	40.
STORAGE SIZE	60.
STORAGE COSTS	60.
COLLECTOR COSTS	1800.
FIXED COSTS	200.

TOTAL COSTS	2060.

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

ENERGY BALANCE BY MONTH FOR 40.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL UCCFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.711	533.3	.66	.29	1.03
2	.808	605.8	.68	.17	.93
3	.872	654.1	.81	.12	1.03
4	.879	659.2	.79	.11	1.00
5	.872	654.1	.81	.11	1.03
6	.882	661.6	.79	.10	1.00
7	.904	678.2	.84	.08	1.03
8	.931	698.1	.87	.06	1.03
9	.945	708.6	.85	.03	1.00
10	.912	684.2	.85	.08	1.03
11	.793	595.0	.71	.19	1.00
12	.694	520.2	.65	.31	1.03
---			---	---	---
ANNUAL	.850		9.31	1.66	12.17

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-5. (Cont.)

TITLE: SUNNYVALE, CA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 52. DEGREES IS 40. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	154.	21.	0.	222.	1209.	406.	-206.
2	168.	23.	0.	200.	68.	406.	936.
3	183.	25.	0.	176.	60.	406.	-192.
4	199.	27.	0.	148.	50.	406.	-187.
5	217.	30.	21.	117.	47.	406.	-183.
6	237.	33.	23.	82.	36.	406.	-192.
7	258.	36.	25.	44.	23.	406.	-188.
8	282.	40.	27.	0.	9.	0.	-185.
9	307.	44.	30.	0.	10.	0.	223.
10	334.	49.	33.	0.	11.	0.	243.
11	365.	53.	36.	0.	12.	0.	264.
12	397.	59.	40.	0.	14.	0.	287.
13	433.	65.	44.	0.	15.	0.	312.
14	472.	71.	49.	0.	17.	0.	339.
15	515.	78.	53.	0.	18.	0.	369.
16	561.	86.	59.	0.	20.	0.	401.
17	611.	95.	65.	0.	22.	0.	436.
18	666.	104.	71.	0.	24.	0.	474.
19	726.	115.	78.	0.	27.	0.	515.
20	792.	126.	86.	0.	29.	0.	560.
TOTALS	7877.	1180.	740.	989.	1721.	2842.	609.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 1133.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 9.2 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT2 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 1309.28 DOLLARS

RATE OF RETURN ON NET CASH FLOW 326.0 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 85.0 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 9.3 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-5. (Cont.)

T

```

SIOUX CITY,IA EXAMPLE
1,      8      8      8      8      8      8      8
      8      8      8      8 *
* SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2
      2      2      2      2 *
* REFERENCE SYSTEM FUEL TYPE
6,      2
* SOLAR AUXILIARY ENERGY FLAG
10,     1
* COLLECTOR TYPE FLAG
12,     .5000E+01
* COLLECTOR AZIMUTH ANGLE
21,     3
* FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
22,     .1000E+03
* SPECIFIED COLLECTOR AREA WHEN LINE 21=1, 2 OR 3
25,     102
* SITE LOCATION CODE
41,     3
* SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG
49,     .5500E-01
* LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .2000E+03
* SOLAR SYSTEM FIXED COST, DOLLARS
56,     .3500E+02
* COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
65,     1
* FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
66, 0.     .1000E+07 *
* INCOME TAX CREDIT
68,     .1200E+00
* MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .7000E+01
* LOAN TERM, YEARS
73,     .1000E-01
* PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .2500E+00
* INCOME TAX RATE, (FRACTION)
82,     .8000E-01
* INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .6000E-01 .1000E+07 -.1000E+01 *
* ENERGY COST SCHEDULE-ELECTRICITY
101,    .1200E+00 .8000E+01 .1000E+00 .1200E+02 *
* ESCALATION TABLE FOR ELECTRICITY
131,    1
* PRINTER - PLOTTER FLAG
RUN

```

TITLE: SIOUX CITY,IA EXAMPLE

Figure IV-6. Residential Solar Service Hot Water System Analysis for Sioux City, IA

TITLE: SIOUX CITY, IA EXAMPLE

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --SIOUX CITY, IA LATITUDE = 42.4 TILT ANGLES 42.4 49.9 57.4
 SERVICE WATER HEATING SYSTEM WITH 1.5 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .82
 COL. EFFIC. = .24 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SER. HOT WATER LOAD= .055 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	200.00	0.00
INITIAL COST,	\$/SQ FT	35.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	7.0	7.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	25.0	25.0
PROP. TAX RATE,	% OF IN COST	1.0	1.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	8.0	8.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD-MIL BTU	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
MEAN MIN TEMP., F	8.	13.	23.	37.	49.	59.	64.	62.	51.	40.	26.	14.
MEAN MAX TEMP., F	28.	33.	43.	61.	73.	81.	87.	86.	75.	66.	47.	33.
PERCENT POSS. SUN	55.	58.	58.	59.	63.	67.	75.	72.	67.	65.	53.	50.
DAILY HOR. INSOL.	569.	842.	1170.	1578.	1901.	2124.	2122.	1845.	1421.	1038.	643.	469.
HEATING DEG. DAYS	1457.	1165.	986.	474.	189.	33.	0.	10.	113.	378.	861.	1287.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ELECTRIC \$.060 PER UNIT FOR FIRST .100E+07 UNITS
 ESCALATION RATE = 12.00 PERCENT FOR 8. YEARS
 ESCALATION RATE = 10.00 PERCENT FOR 12. YEARS

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	100.
STORAGE SIZE	150.
STORAGE COSTS	150.
COLLECTOR COSTS	3500.
FIXED COSTS	200.

TOTAL COSTS	3850.

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

ENERGY BALANCE BY MONTH FOR 100.0 SQ. FT. COLLECTOR					
MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.616	338.7	1.05	.71	1.89
2	.737	405.3	1.13	.42	1.71
3	.806	443.6	1.38	.32	1.89
4	.923	507.4	1.52	.12	1.83
5	.967	531.8	1.65	.03	1.89
6	1.000	553.7	1.65	0.00	1.83
7	1.000	552.8	1.71	0.00	1.89
8	1.000	556.1	1.71	0.00	1.89
9	.996	547.8	1.64	.00	1.83
10	.950	522.5	1.62	.05	1.89
11	.742	408.4	1.23	.46	1.83
12	.574	315.9	.98	.80	1.89
ANNUAL	.860		17.26	2.92	22.31

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 42. DEGREES IS 100. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	341.	38.	38.	416.	114.	759.	-385.
2	382.	42.	42.	375.	104.	759.	-381.
3	427.	45.	45.	328.	93.	759.	-327.
4	479.	48.	48.	277.	81.	759.	-295.
5	536.	52.	52.	219.	68.	759.	-259.
6	601.	57.	57.	154.	53.	759.	-218.
7	673.	61.	61.	81.	36.	759.	-172.
8	753.	66.	66.	0.	16.	0.	638.
9	829.	71.	71.	0.	18.	0.	704.
10	912.	77.	77.	0.	19.	0.	777.
11	1003.	83.	83.	0.	21.	0.	857.
12	1103.	90.	90.	0.	22.	0.	946.
13	1213.	97.	97.	0.	24.	0.	1044.
14	1335.	105.	105.	0.	26.	0.	1151.
15	1468.	113.	113.	0.	28.	0.	1270.
16	1615.	122.	122.	0.	31.	0.	1401.
17	1776.	132.	132.	0.	33.	0.	1546.
18	1954.	142.	142.	0.	36.	0.	1705.
19	2150.	154.	154.	0.	38.	0.	1880.
20	2935.	166.	166.	0.	42.	0.	2644.
TOTALS	22485.	1761.	1761.	1850.	903.	5313.	14170.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 7.5 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 10.3 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS 2670.66 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 17.9 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 86.0 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 17.3 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + F - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

PLOT NUMBER 1

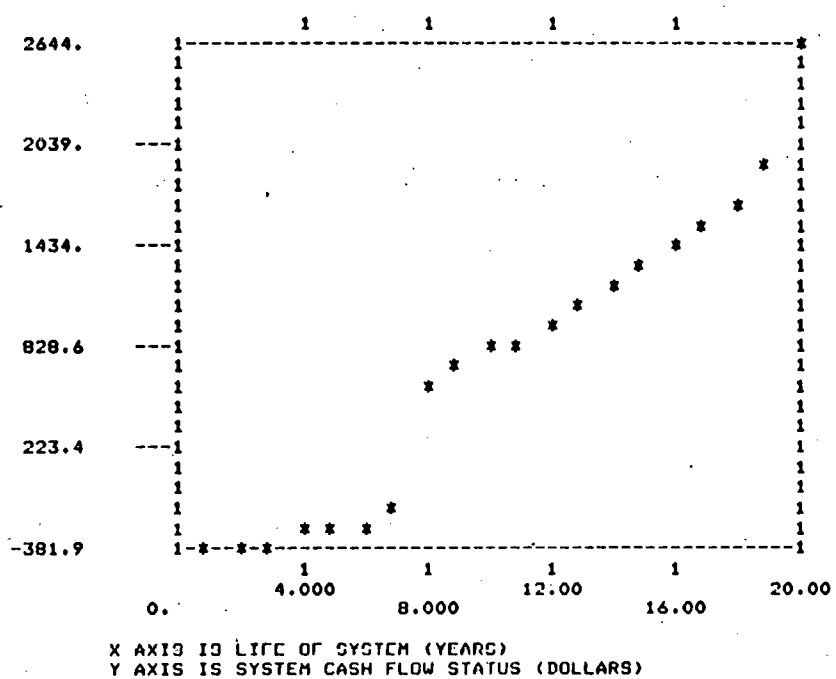


Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE	
COLLECTOR AREA	100.
STORAGE SIZE	150.
STORAGE COSTS	150.
COLLECTOR COSTS	3500.
FIXED COSTS	200.

TOTAL COSTS	3850.

Figure IV-6, (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

ENERGY BALANCE BY MONTH FOR 100.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.651	357.9	1.11	.66	1.89
2	.758	417.0	1.17	.38	1.71
3	.807	443.8	1.38	.32	1.89
4	.905	497.8	1.49	.15	1.83
5	.941	517.3	1.60	.07	1.89
6	.979	538.6	1.62	.01	1.83
7	1.000	553.0	1.71	0.00	1.89
8	1.000	557.5	1.71	0.00	1.89
9	.993	545.9	1.64	.01	1.83
10	.960	527.8	1.64	.04	1.89
11	.771	423.8	1.27	.41	1.83
12	.606	333.4	1.03	.74	1.89
ANNUAL	.864		17.35	2.79	22.31

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 50. DEGREES IS 100. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	343.	38.	38.	416.	114.	759.	-305.
2	384.	42.	42.	375.	104.	759.	-379.
3	430.	45.	45.	328.	93.	759.	-353.
4	482.	48.	48.	277.	81.	759.	-324.
5	540.	52.	52.	219.	68.	759.	-292.
6	605.	57.	57.	154.	53.	759.	-255.
7	677.	61.	61.	81.	36.	759.	-214.
8	759.	66.	66.	0.	16.	0.	-168.
9	834.	71.	71.	0.	18.	0.	643.
10	918.	77.	77.	0.	19.	0.	710.
11	1010.	83.	83.	0.	21.	0.	783.
12	1111.	90.	90.	0.	22.	0.	864.
13	1222.	97.	97.	0.	24.	0.	954.
14	1344.	105.	105.	0.	26.	0.	1052.
15	1478.	113.	113.	0.	28.	0.	1161.
16	1626.	122.	122.	0.	31.	0.	1280.
17	1789.	132.	132.	0.	33.	0.	1412.
18	1968.	142.	142.	0.	36.	0.	1558.
19	2164.	154.	154.	0.	38.	0.	1718.
20	2955.	166.	166.	0.	42.	0.	1895.
TOTALS	22639.	1761.	1761.	1850.	903.	5313.	2665.

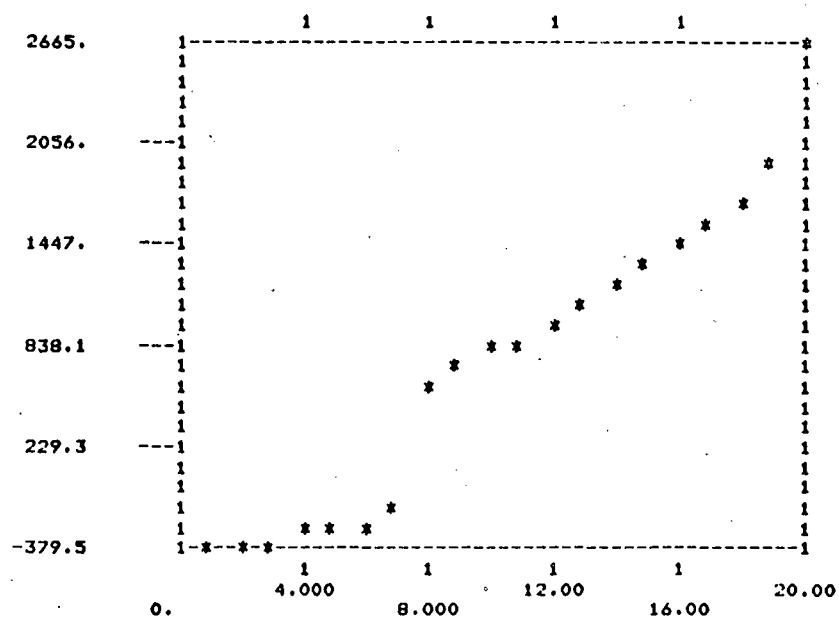
PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 7.5 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 10.3 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS 2743.41 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 18.0 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 86.4 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 17.4 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

PLOT NUMBER 1



X AXIS IS LIFE OF SYSTEM (YEARS)
Y AXIS IS SYSTEM CASH FLOW STATUS (DOLLARS)

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	100.
STORAGE SIZE	150.
STORAGE COSTS	150.
COLLECTOR COSTS	3500.
FIXED COSTS	200.

TOTAL COSTS	3850.

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

ENERGY BALANCE BY MONTH FOR 100.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-50 FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.670	368.6	1.14	.62	1.89
2	.768	422.3	1.18	.36	1.71
3	.797	438.1	1.36	.35	1.89
4	.867	476.8	1.43	.20	1.83
5	.905	497.7	1.54	.14	1.89
6	.951	522.9	1.57	.06	1.83
7	.969	533.0	1.65	.01	1.89
8	1.000	551.9	1.71	.01	1.89
9	.970	533.5	1.60	.01	1.83
10	.961	528.8	1.64	.04	1.89
11	.787	433.0	1.30	.37	1.83
12	.635	349.0	1.08	.72	1.89
ANNUAL	.857		17.20	2.88	22.31

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-6. (Cont.)

TITLE: SIOUX CITY, IA EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 57. DEGREES IS 100. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

CASH FLOW SUMMARY

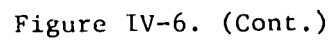
YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	342.	38.	38.	416.	114.	759.	-385.
2	383.	42.	42.	375.	104.	759.	-380.
3	428.	45.	45.	328.	93.	759.	-326.
4	480.	48.	48.	277.	81.	759.	-294.
5	537.	52.	52.	219.	68.	759.	-258.
6	602.	57.	57.	154.	53.	759.	-217.
7	674.	61.	61.	81.	36.	759.	-171.
8	755.	66.	66.	0.	16.	0.	640.
9	831.	71.	71.	0.	18.	0.	706.
10	914.	77.	77.	0.	19.	0.	779.
11	1005.	83.	83.	0.	21.	0.	860.
12	1106.	90.	90.	0.	22.	0.	949.
13	1216.	97.	97.	0.	24.	0.	1046.
14	1338.	105.	105.	0.	26.	0.	1155.
15	1472.	113.	113.	0.	28.	0.	1274.
16	1619.	122.	122.	0.	31.	0.	1405.
17	1781.	132.	132.	0.	33.	0.	1550.
18	1959.	142.	142.	0.	36.	0.	1709.
19	2154.	154.	154.	0.	38.	0.	1885.
20	2942.	166.	166.	0.	42.	0.	2651.
TOTALS	22538.	1761.	1761.	1850.	903.	5313.	14223.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 7.5 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 10.3 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS 2708.46 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 17.9 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 85.7 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 17.2 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-6. (Cont.)

PLOT NUMBER 1



```

T
MADISON,WI EXAMPLE
1,      7      7      7      7      7      7      7      7
      7      7      7      7 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      4      4      4      4      4      4      4
      4      4      4      4 *
$ REFERENCE SYSTEM FUEL TYPE
6,      4
$ SOLAR AUXILIARY ENERGY FLAG
10,     7
$ COLLECTOR TYPE FLAG
21,     3
$ FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
22,     .6000E+03
$ SPECIFIED COLLECTOR AREA WHEN LINE 21=1, 2 OR 3
25,     303
$ SITE LOCATION CODE
40,     2
$ BUILDING LOAD COMPUTE METHOD FLAG
42,     .8000E+01
$ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)
43,     .1200E+04
$ BUILDING FLOOR AREA (SQ.FT)
55,     .5000E+03
$ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .3000E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
65,     1
$ FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
66,     0.      .1000E+07 *
$ INCOME TAX CREDIT
74,     .2100E+00
$ INCOME TAX RATE, (FRACTION)
82,     .8000E-01
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
93,     .4200E+00      .1000E+07      -.1000E+01 *
$ ENERGY COST SCHEDULE-PROPANE
103,    .1800E+00      .6000E+01      .1400E+00      .5000E+01      .1100E+00      .9000E+01 *
$ ESCALATION TABLE FOR LP GAS
131,    1
$ PRINTER - PLOTTER FLAG
RUN

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TITLE: MADISON,WI EXAMPLE

Figure IV-7. Residential Air Solar Space Heating System Analysis for Madison, WI

TITLE: MADISON, WI EXAMPLE

-----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----

LOCATION --MADISON, WI LATITUDE = 43.1 TILT ANGLES 43.1 50.6 58.1
 AIR SOLAR SYSTEM WITH 30.0 LBS OF ROCK STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INLETTEMP = .80
 COL. EFFIC. = .17 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SPACE HEAT U-VALUE = 8.00 BTU/(F-HAY-SQ FT) FLOOR AREA= 1200. SQ FT
 INPUT SER. HOT WATER LOAD= 0.000 MILLION BTUS/DAY
 AUXILIARY ENERGY IS LP GAS LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	500.00	0.00
INITIAL COST,	\$/SQ FT	30.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	9.0	9.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	21.0	21.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	8.0	8.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	7	7	7	7	7	7	7	7	7	7	7	7
TRANSPORT EFFIC.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
COL. INLET TEMP.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.
REF. FUEL TYPE	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG
REF. SYSTEM EFFIC.	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
DAILY LOAD-MIL BTU	.46	.43	.33	.19	.09	.02	.00	.01	.06	.15	.29	.41
MEAN MIN TEMP., F	8.	11.	21.	35.	45.	55.	59.	57.	49.	39.	26.	14.
MEAN MAX TEMP., F	25.	30.	39.	56.	67.	77.	81.	80.	71.	61.	43.	30.
PERCENT POSS. SUN	44.	49.	52.	53.	58.	64.	70.	66.	60.	56.	41.	38.
DAILY HOR. INSOL.	515.	804.	1136.	1398.	1743.	1948.	1934.	1708.	1299.	911.	504.	389.
HEATING DEG. DAYS	1494.	1252.	1079.	591.	297.	72.	14.	39.	173.	474.	909.	1336.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

LP GAS \$.420 PER UNIT FOR FIRST .100E+07 UNITS
 ESCALATION RATE = 18.00 PERCENT FOR 6. YEARS
 ESCALATION RATE = 14.00 PERCENT FOR 5. YEARS
 ESCALATION RATE = 11.00 PERCENT FOR 9. YEARS

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	600.
STORAGE SIZE	15.
STORAGE COSTS	750.
COLLECTOR COSTS	18000.
FIXED COSTS	500.

TOTAL COSTS	19250.

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

ENERGY BALANCE BY MONTH FOR 600.0 SQ. FT. COLLECTOR					
MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.419	323.4	6.02	11.90	20.49
2	.638	456.6	7.67	6.21	17.17
3	.989	551.0	10.25	.16	14.80
4	1.000	658.3	5.67	0.00	8.11
5	1.000	823.2	2.85	0.00	4.07
6	1.000	960.5	.69	0.00	.99
7	1.000	1032.4	.13	0.00	.19
8	1.000	1007.2	.37	0.00	.53
9	1.000	855.4	1.66	0.00	2.37
10	1.000	677.8	4.55	0.00	6.50
11	.655	317.8	5.72	4.30	12.47
12	.349	240.4	4.47	11.93	18.32

ANNUAL	.675		50.06	34.50	106.01

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 43. DEGREES IS 600. SQ. FT.
COLLECTOR TYPE = AIR, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	328.	192.	0.	1559.	327.	1898.	-1925.
2	387.	208.	0.	1529.	321.	1898.	-1434.
3	457.	225.	0.	1496.	314.	1898.	-1396.
4	539.	242.	0.	1459.	306.	1898.	-1294.
5	636.	262.	0.	1420.	298.	1898.	-1224.
6	751.	283.	0.	1377.	289.	1898.	-1140.
7	856.	305.	0.	1330.	279.	1898.	-1067.
8	976.	330.	0.	1279.	269.	1898.	-982.
9	1113.	356.	0.	1223.	257.	1898.	-884.
10	1268.	385.	0.	1162.	244.	1898.	-769.
11	1446.	416.	0.	1096.	230.	1898.	-636.
12	1605.	449.	0.	1024.	215.	1898.	-526.
13	1782.	485.	0.	945.	199.	1898.	-401.
14	1978.	524.	0.	860.	181.	1898.	-262.
15	2195.	565.	0.	766.	161.	1898.	-106.
16	2437.	611.	0.	664.	140.	1898.	68.
17	2705.	659.	0.	553.	116.	1898.	243.
18	3002.	712.	0.	432.	91.	1898.	483.
19	3332.	769.	0.	300.	63.	1898.	728.
20	3699.	831.	0.	157.	33.	1898.	1003.
TOTALS	31492.	8809.	0.	20631.	4333.	37960.	-12851.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 16.2 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 0.0 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS -9837.46 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 67.5 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 50.1 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

PLOT NUMBER 1

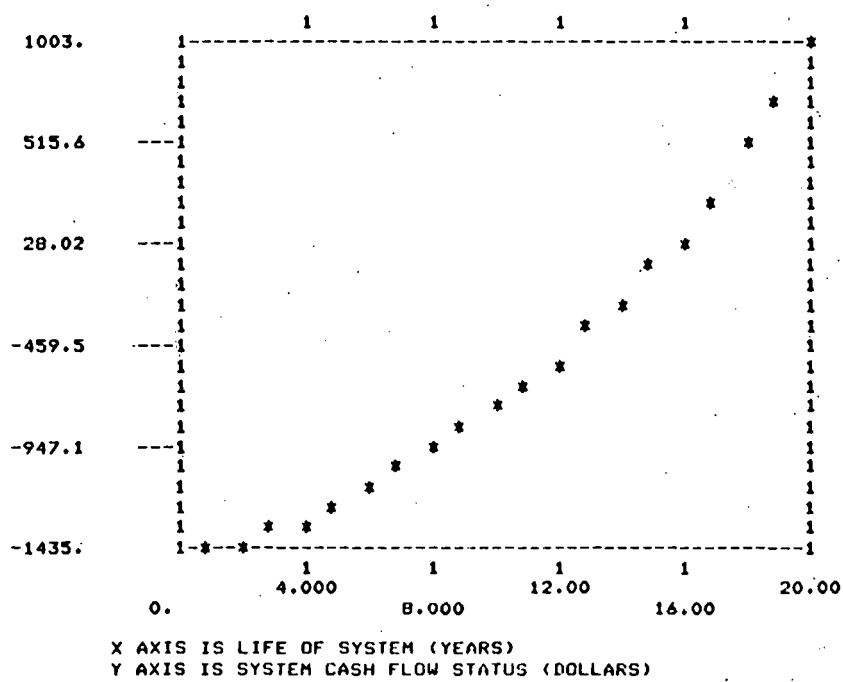


Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	600.
STORAGE SIZE	15.
STORAGE COSTS	750.
COLLECTOR COSTS	18000.
FIXED COSTS	500.

TOTAL COSTS	19250.

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

ENERGY BALANCE BY MONTH FOR 600.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.448	345.1	6.42	11.32	20.49
2	.664	475.3	7.98	5.76	17.17
3	.983	547.6	10.18	.25	14.80
4	1.000	630.8	5.67	0.00	8.11
5	1.000	774.4	2.85	0.00	4.07
6	1.000	899.3	.69	0.00	.99
7	1.000	974.2	.13	0.00	.19
8	1.000	967.3	.37	0.00	.53
9	1.000	843.2	1.66	0.00	2.37
10	1.000	688.8	4.55	0.00	6.50
11	.691	335.0	6.03	3.85	12.47
12	.374	258.2	4.80	11.46	18.32
---			---	---	---
ANNUAL	.692		51.36	32.65	106.01

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 51. DEGREES IS 600. SQ. FT.
COLLECTOR TYPE = AIR, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	337.	192.	0.	1559.	327.	1898.	-1925.
2	397.	208.	0.	1529.	321.	1090.	-1425.
3	469.	225.	0.	1496.	314.	1898.	-1386.
4	553.	242.	0.	1459.	306.	1090.	-1338.
5	653.	262.	0.	1420.	298.	1090.	-1280.
6	770.	283.	0.	1377.	289.	1898.	-1208.
7	878.	305.	0.	1330.	279.	1090.	-1120.
8	1001.	330.	0.	1279.	269.	1898.	-1046.
9	1141.	356.	0.	1223.	257.	1090.	-957.
10	1301.	385.	0.	1162.	244.	1898.	-855.
11	1483.	416.	0.	1096.	230.	1090.	-736.
12	1647.	449.	0.	1024.	215.	1898.	-599.
13	1828.	485.	0.	945.	199.	1090.	-484.
14	2029.	524.	0.	860.	181.	1898.	-355.
15	2252.	565.	0.	764.	161.	1090.	-211.
16	2500.	611.	0.	664.	140.	1898.	-49.
17	2775.	659.	0.	553.	116.	1090.	131.
18	3080.	712.	0.	432.	91.	1898.	333.
19	3419.	769.	0.	300.	63.	1090.	560.
20	3795.	831.	0.	167.	33.	1898.	815.
TOTALS	32308.	8809.	0.	20631.	4333.	37960.	-12035.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 16.0 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 0.0 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS -9570.52 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 69.2 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 51.4 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

PLOT NUMBER 1

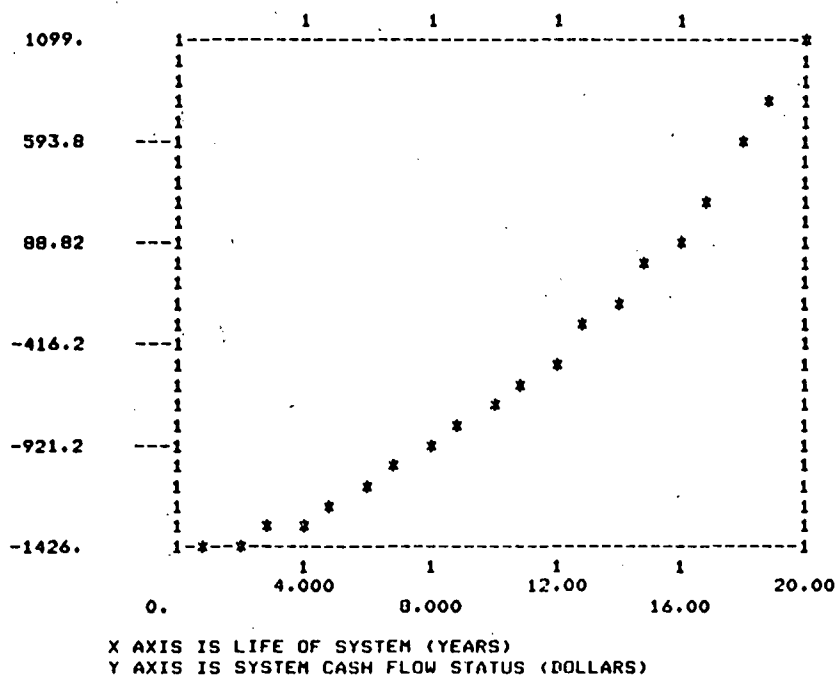


Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	600.
STORAGE SIZE	15.
STORAGE COSTS	750.
COLLECTOR COSTS	18000.
FIXED COSTS	500.

TOTAL COSTS	19250.

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

ENERGY BALANCE BY MONTH FOR 600.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.466	359.2	6.68	10.94	20.49
2	.676	483.8	8.13	5.56	17.17
3	.958	533.8	9.93	.61	14.80
4	1.000	593.6	5.67	0.00	8.11
5	1.000	715.3	2.85	0.00	4.07
6	1.000	827.4	.69	0.00	.99
7	1.000	904.7	.13	0.00	.19
8	1.000	915.4	.37	0.00	.53
9	1.000	818.9	1.66	0.00	2.37
10	1.000	688.6	4.55	0.00	6.50
11	.714	346.0	6.23	3.57	12.47
12	.392	270.3	5.03	11.14	18.32
	-----		-----	-----	-----
ANNUAL	.700		51.93	31.83	106.01

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 58. DEGREES IS 600. SQ. FT.
COLLECTOR TYPE = AIR, FLAT PLATE, 1 COVER, PAINT
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	341.	192.	0.	1559.	327.	1898.	-1925.
2	402.	208.	0.	1529.	321.	1898.	-1421.
3	474.	225.	0.	1496.	314.	1898.	-1382.
4	559.	242.	0.	1459.	306.	1898.	-1333.
5	660.	262.	0.	1420.	298.	1898.	-1273.
6	779.	283.	0.	1377.	289.	1898.	-1200.
7	888.	305.	0.	1330.	279.	1898.	-1112.
8	1012.	330.	0.	1279.	269.	1898.	-1035.
9	1154.	356.	0.	1223.	257.	1898.	-946.
10	1316.	385.	0.	1162.	244.	1898.	-842.
11	1500.	416.	0.	1096.	230.	1898.	-722.
12	1665.	449.	0.	1024.	215.	1898.	-582.
13	1848.	485.	0.	945.	199.	1898.	-466.
14	2051.	524.	0.	860.	181.	1898.	-335.
15	2277.	565.	0.	766.	161.	1898.	-188.
16	2528.	611.	0.	664.	140.	1898.	-24.
17	2806.	659.	0.	553.	116.	1898.	159.
18	3114.	712.	0.	432.	91.	1898.	364.
19	3457.	769.	0.	300.	63.	1898.	595.
20	3837.	831.	0.	157.	33.	1898.	853.
TOTALS	32668.	8809.	0.	20631.	4333.	37960.	1141.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 15.9 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 0.0 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS -9452.27 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 70.0 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 51.9 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-7. (Cont.)

TITLE: MADISON, WI EXAMPLE

PLOT NUMBER 1

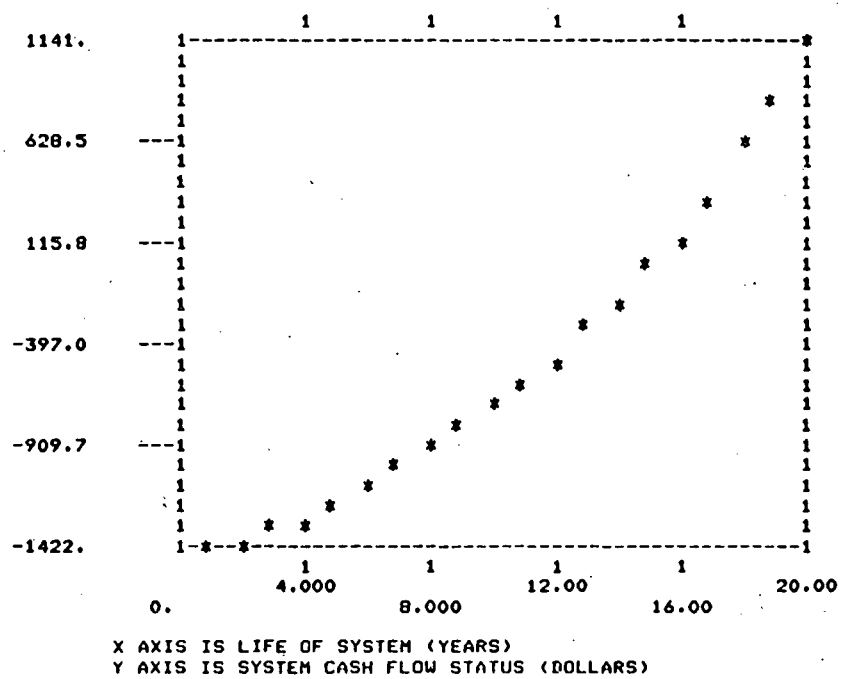


Figure IV-7. (Cont.)

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T
ALBANY, NY EXAMPLE
1,      8      8      8      8      8      8      8
      8      8      8      8 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2
      2      2      2      2 *
$ REFERENCE SYSTEM FUEL TYPE
6,      4
$ SOLAR AUXILIARY ENERGY FLAG
10,     2
$ COLLECTOR TYPE FLAG
13,     .4000E+02 *
$ COLLECTOR TILT ANGLES, DEGREES
21,     0
$ FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS
25,     188
$ SITE LOCATION CODE
49,     .5000E-01
$ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
55,     .2000E+03
$ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .2500E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
57,     .9000E+00
$ LIQUID STORAGE COST (DOLLARS/GALLON)
60,     0.
$ REFERENCE SYSTEM FIXED COST, DOLLARS
65,     1
$ FINANCIAL SCENARIO FLAG(RES,BUS,NFO): 1,2, OR 3
66,     0. .1000E+07 *
$ INCOME TAX CREDIT
68,     .1200E+00
$ MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .7000E+01
$ LOAN TERM, YEARS
70,     .2000E+00
$ DOWN PAYMENT (FRACTION OF INITIAL COST)
74,     .2000E+00
$ INCOME TAX RATE, (FRACTION)
82,     .8000E-01
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
84,     3
$ FLAG FOR COLLECTOR OPTIMIZATION OPTION
91,     .5000E-01 .1000E+07 .1000E+00 *
$ ENERGY COST SCHEDULE-ELECTRICITY
93,     .4500E+00 .1000E+07 .1000E+00 *
$ ENERGY COST SCHEDULE-PROPANE
131,    1
$ PRINTER - PLOTTER FLAG
RUN

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TITLE: ALBANY, NY EXAMPLE

Figure IV-8. Residential Solar Service Hot Water System Analysis for Albany, NY

TITLE: ALBANY, NY EXAMPLE

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --ALBANY,NY LATITUDE = 42.8 TILT ANGLES 40.0
 SERVICE WATER HEATING SYSTEM WITH 1.5 GAL STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .67
 COL. EFFIC. = .30 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SER. HOT WATER LOAD= .050 MILLION BTUS/DAY
 AUXILIARY ENERGY IS LP GAS LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	200.00	0.00
INITIAL COST,	\$/SQ FT	25.00	-----
DOWN PAYMENT,	% OF IN. COST	20.0	20.0
LOAN TERM,	YEARS	7.0	7.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	20.0	20.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	8.0	8.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	8	8	8	8	8	8	8	8	8	8	8	8
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DAILY LOAD-MIL BTU	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
MEAN MIN TEMP., F	13.	14.	24.	36.	46.	56.	60.	58.	50.	40.	31.	18.
MEAN MAX TEMP., F	30.	33.	43.	58.	70.	79.	84.	81.	74.	63.	48.	34.
PERCENT POSS. SUN	43.	51.	53.	53.	57.	62.	63.	61.	58.	54.	39.	38.
DAILY HOR. INSOL.	457.	688.	986.	1335.	1570.	1730.	1725.	1499.	1170.	817.	457.	356.
HEATING DEG. DAYS	1349.	1162.	980.	543.	253.	39.	9.	22.	135.	422.	762.	1212.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA	
ELECTRIC	\$.050 PER UNIT FOR FIRST .100E+07 UNITS
ESCALATION RATE	= 10.00 PERCENT
LP GAS	\$.450 PER UNIT FOR FIRST .100E+07 UNITS
ESCALATION RATE	= 10.00 PERCENT

Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE									
COLLECTOR AREA	20.	60.	100.	140.	180.	220.	260.	280.	320.
STORAGE SIZE	30.	90.	150.	210.	270.	330.	390.	420.	480.
STORAGE COSTS	27.	81.	135.	189.	243.	297.	351.	378.	432.
COLLECTOR COSTS	500.	1500.	2500.	3500.	4500.	5500.	6500.	7000.	8000.
FIXED COSTS	200.	200.	200.	200.	200.	200.	200.	200.	200.
TOTAL COSTS	727.	1781.	2835.	3889.	4943.	5997.	7051.	7578.	8632.

Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

SYSTEM PERFORMANCE AND COST SUMMARY FOR 40.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
20.0	.265	727.00	70.1	2965.59	9629.77
60.0	.561	1781.00	26.9	2601.58	10262.11
100.0	.738	2835.00	17.2	1869.76	9843.16
140.0	.835	3889.00	12.0	884.96	8701.21
180.0	.884	4943.00	8.4	-218.35	7220.51
220.0	.914	5997.00	5.7	-1386.45	5554.66
260.0	.934	7051.00	3.6	-2568.16	3849.88
280.0	.940	7578.00	2.6	-3164.55	2981.69
320.0	.950	8632.00	1.0	-4370.85	1206.63

ENERGY BALANCE BY MONTH FOR 60.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.339	282.4	.53	1.61	1.72
2	.414	345.3	.58	1.29	1.56
3	.504	419.9	.78	1.25	1.72
4	.617	513.8	.92	.93	1.67
5	.672	560.0	1.04	.78	1.72
6	.740	616.9	1.11	.60	1.67
7	.780	650.1	1.21	.52	1.72
8	.756	629.9	1.17	.58	1.72
9	.681	567.4	1.02	.72	1.67
10	.586	488.7	.91	1.05	1.72
11	.350	292.0	.53	1.52	1.67
12	.284	236.7	.44	1.74	1.72
ANNUAL	.561		10.24	12.60	20.28

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR CONDUCTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

COLLECTOR SIZE OPTIMIZATION BY SOLLOCUS

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 40. DEGREES IS 60. SQ. FT.
 COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVER, PAINT
 FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	235.	18.	0.	171.	34.	312.	-356.
2	259.	19.	0.	154.	31.	312.	-60.
3	284.	21.	0.	135.	27.	312.	-41.
4	313.	22.	0.	114.	23.	312.	-20.
5	344.	24.	0.	90.	18.	312.	1.
6	379.	26.	0.	63.	13.	312.	26.
7	417.	28.	0.	33.	7.	312.	53.
8	458.	31.	0.	0.	0.	0.	83.
9	504.	33.	0.	0.	0.	0.	428.
10	554.	36.	0.	0.	0.	0.	471.
11	610.	38.	0.	0.	0.	0.	519.
12	671.	42.	0.	0.	0.	0.	571.
13	738.	45.	0.	0.	0.	0.	629.
14	812.	48.	0.	0.	0.	0.	693.
15	893.	52.	0.	0.	0.	0.	763.
16	982.	56.	0.	0.	0.	0.	841.
17	1080.	61.	0.	0.	0.	0.	926.
18	1188.	66.	0.	0.	0.	0.	1019.
19	1307.	71.	0.	0.	0.	0.	1123.
20	1439.	77.	0.	0.	0.	0.	1236.
TOTALS	13466.	814.	0.	760.	153.	2184.	1341.

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 5.9 YEARS
 PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 7.7 YEARS
 NET PRESENT WORTH OF SOLAR SAVINGS 2601.58 DOLLARS
 RATE OF RETURN ON NET CASH FLOW 27.0 PERCENT
 ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 56.1 PERCENT
 ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 10.2 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
 NET CASH FLOW = A - B - C + E - F
 ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

PLOT NUMBER 1

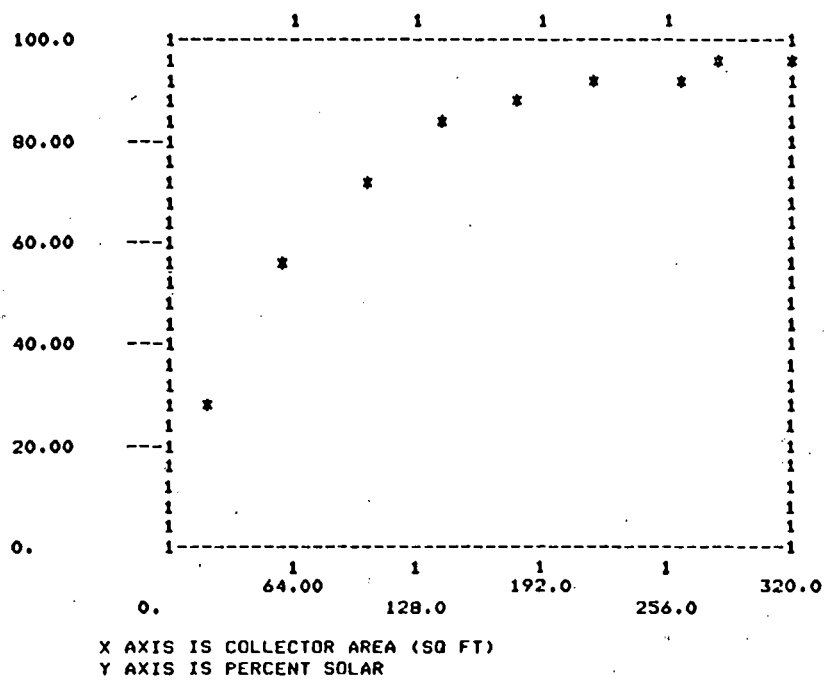
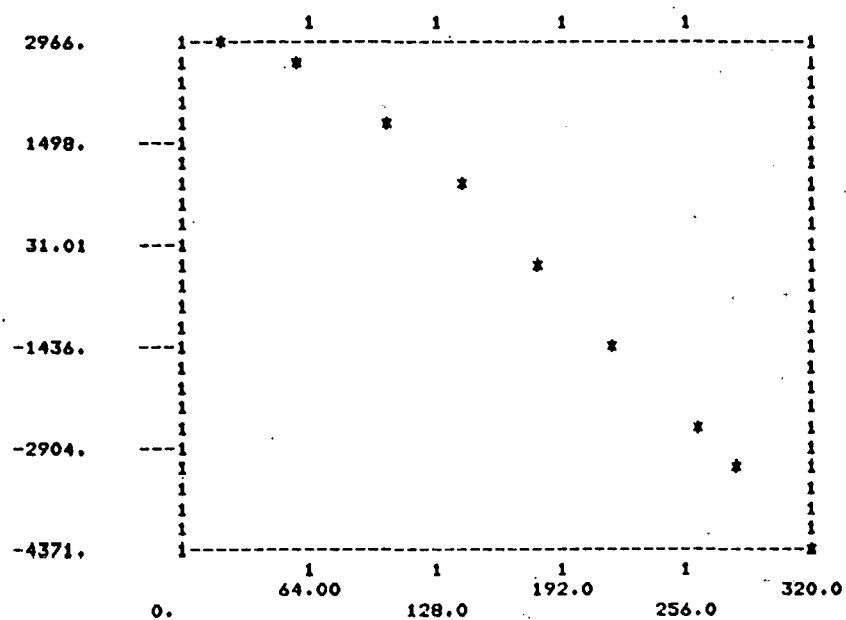


Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

PLOT NUMBER 2



X AXIS IS COLLECTOR AREA (SQ FT)
Y AXIS IS DISCOUNTED SAVINGS FOR LIFE OF SYSTEM

Figure IV-8. (Cont.)

TITLE: ALBANY, NY EXAMPLE

PLOT NUMBER 3

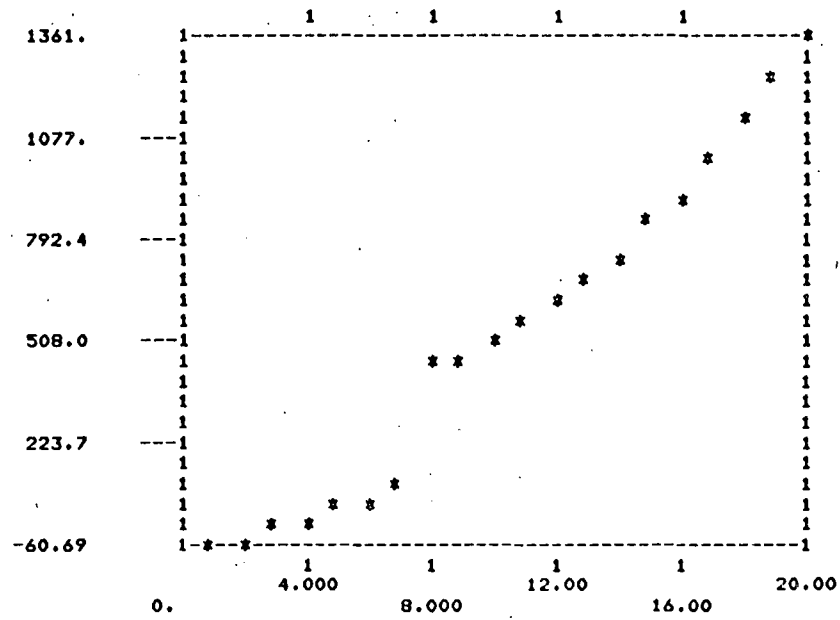


Figure IV-3. (Cont.)

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IV-92

APPENDIX A. SOLCOST SOLAR RADIATION MODEL

The SOLCOST methodology is based on a one day simulation performed on the 15th day of each month. Hourly steps are taken during the daylight hours of the simulation, so radiation incident on the collector must be available on an hourly basis. The simulation also requires that the collector be driven with two radiation profiles, one for a clear day and one for a totally cloudy day.

The starting point for the clear day model was the ASHRAE model (Ref. A-1) in which the direct normal irradiation is estimated by:

$$I_{DN} = \frac{A}{\exp(B \sin \beta)} \quad (1)$$

where A is the apparent extraterrestrial irradiation at air mass = 0, and B, the atmospheric extinction coefficient, are functions of the month which take into account the earth-sun distance and the air's water vapor content. The angle β is the solar altitude angle above the horizon. Values for A and B are given in Table A-1. The values of A and B were selected so that the resulting value of I_{DN} would be in agreement with the Threlkeld and Jordan measured radiation values (Ref A-2) on average cloudless days.

In order to account for local values of atmospheric water content and variable aerosols, the ASHRAE model uses a parameter called clearness number to modify the direct normal solar component. This term is given by

$$CN = \frac{I_{DN}(\text{measured})}{I_{DN}(\text{calculated})} \quad (2)$$

where $I_{DN}(\text{measured})$ is the measured direct normal irradiance and $I_{DN}(\text{calculated})$ is computed by Eqn. (1) above.

Unfortunately very little direct normal radiation is available to allow direct calculation of clearness numbers. The recent work by Randall and

Whitson (Ref. A-3) has resulted in improved direct normal insolation estimates which are now available for 26 SOLMET sites (Ref. A-4).

TABLE A-1. CONSTANTS A, B, AND C FOR ASHRAE SOLAR RADIATION MODEL

Month	A	B	C
	Apparent Solar Constant,* (Btu/Hr-Sq.Ft)	Atmospheric Extinction Coef.	Diffuse to DN Ratio
Jan	391	.142	.058
Feb	386	.144	.060
Mar	378	.154	.068
Apr	362	.177	.092
May	351	.194	.118
Jun	345	.206	.133
Jul	344	.207	.137
Aug	349	.203	.126
Sep	363	.182	.096
Oct	376	.163	.076
Nov	386	.151	.064
Dec	391	.143	.058

The Department of Energy has recently recommended that the SOLMET data base be used in all solar simulation and design work. This insolation data base has been available in SOLCOST since Version 2.0 (i.e., monthly average total insolation values). However, in Version 2.1, an additional step has been taken to further align the SOLCOST radiation model with the SOLMET data set. Specifically, monthly clearness numbers have been derived for 26 cities from the clear sky, solar noon total irradiance values used by the SOLMET developers to generate their data base (see Appendix A in Ref. A-4). These clearness numbers are shown in Table A-2. Based on these clearness numbers, the set of default monthly clearness numbers given in Table A-2 were calculated. Obviously, this default set does not apply to all the cities in the data bank, so a parameter called the clearness factor has been estimated for each city in the data bank. This factor is a multiplier on the default monthly clearness

* Apparent solar constant for air mass zero.

numbers to account for location. The map in Fig. A-1 shows the clearness factors which have been assigned to the cities in the SOLCOST data bank. These default values are printed in the insolation summary (Line 132 = 1).

Users can input their own monthly clearness numbers (Line 36) or clearness factor (Line 27). If clearness numbers are input directly on Line 36, users should input a value of 1.0 for the clearness factor. Caution should be used in changing clearness factors, since the SOLCOST results are very sensitive to the radiation input to the collector.

The diffuse component for clear day radiation in the ASHRAE model is based on the work of Threlkeld (Refs. A-2 and A-5) in which a dimensionless parameter C is defined:

$$C = I_{dH} / I_{DN} \quad (3)$$

where I_{dH} is the diffuse radiation on a horizontal surface for a clear day. Values for C are listed above in Table A-1.

In SOLCOST, Threlkeld's diffuse term is divided by the clearness number squared to account for varying atmospheric clarity.

$$I_{dH} = C \text{ CN } I_{DN} / \text{CN}^2 = C I_{DN} / \text{CN} \quad (4)$$

This modification to the ASHRAE model was based on the work of Kusada (Ref. A-6) and checked experimentally by Hulstrum (Ref. A-7) for Boulder, Colorado, conditions.

The total radiation incident on a horizontal surface, I_{tH} , is given by the sum of the direct normal and the diffuse components.

$$I_{tH} = \text{CN } I_{DN} \cos \theta_o + C I_{DN} / \text{CN} \quad (5)$$

where θ_o is the angle between the direct normal radiation and the horizontal surface.

TABLE A-2. Clearness Numbers Required in SOLCOST to Match SOLMET Clear Day Noon Solar Irradiance

Location	Clearness Factor	J	F	M	A	M	J	J	A	S	O	N	D
Albuquerque, NM	1.12	1.11	1.13	1.08	1.05	1.02	1.00	.97	.98	1.03	1.09	1.12	1.11
Apalachicola, FL	.92	.89	.94	.91	.89	.85	.83	.81	.80	.84	.89	.90	.88
Bismark, ND	1.05	1.02	1.08	1.02	.99	.94	.92	.90	.92	.97	1.04	1.07	1.04
Boston, MA	.98	.96	1.01	.97	.93	.89	.87	.86	.87	.92	.97	.96	.96
Brownsville, TX	.96	.95	.96	.93	.93	.88	.87	.86	.87	.89	.93	.95	.94
Cape Hatteras, NC	.96	.94	.98	.95	.93	.89	.87	.83	.83	.86	.93	.96	.94
Caribou, ME	1.04	1.02	1.06	1.03	1.01	.95	.92	.89	.91	.96	1.02	1.04	1.01
Charleston, SC	.95	.94	.96	.94	.91	.87	.84	.83	.82	.84	.92	.96	.93
Columbia, MO	1.01	1.02	1.05	1.0	.95	.94	.88	.87	.87	.91	.97	1.01	1.0
Dodge City, KS	1.06	1.06	1.08	1.05	1.0	.95	.92	.91	.92	.97	1.04	1.07	1.06
El Paso, TX	1.07	1.06	1.07	1.04	1.03	1.0	.96	.94	.95	.96	1.04	1.06	1.05
Ely, NV	1.13	1.11	1.14	1.10	1.06	1.03	1.03	.98	.99	1.05	1.12	1.14	1.12
Ft. Worth, TX	.97	.97	.98	.96	.93	.89	.88	.86	.84	.88	.95	.98	.97
Fresno, CA	1.02	.96	1.0	.99	.97	.94	.94	.93	.94	.97	1.01	1.0	.9
Great Falls, MT	1.08	1.05	1.10	1.05	1.02	.98	.96	.96	.97	1.01	1.06	1.10	1.0
Lake Charles, LA	.92	.91	.93	.92	.88	.85	.83	.81	.82	.84	.89	.90	.8
Madison, WI	1.02	1.02	1.06	1.03	.96	.91	.88	.87	.88	.92	.98	1.03	1.0
Medford, OR	.99	.96	.98	.96	.95	.92	.91	.91	.92	.93	.96	.97	.96
Miami, FL	.91	.88	.91	.90	.87	.84	.83	.82	.82	.83	.86	.88	.87
New York, NY	.97	.96	1.01	.96	.93	.89	.87	.84	.86	.88	.95	.95	.95
N. Omaha, NE	1.03	1.05	1.06	1.03	.96	.93	.90	.88	.88	.93	1.0	1.05	1.04
Phoenix, AZ	1.03	1.0	1.03	1.02	.98	.97	.95	.89	.90	.95	1.01	1.02	1.0
Santa Maria, CA	.98	.95	.97	.94	.93	.91	.90	.88	.91	.92	.93	.95	.94
Nashville, TN	.97	.96	.99	.96	.93	.89	.86	.84	.85	.87	.95	.96	.95
Seattle, WA	.94	.86	.91	.91	.91	.88	.87	.88	.88	.89	.92	.90	.85
Washington, D.C.	.95	.95	.97	.95	.93	.88	.84	.83	.84	.87	.92	.95	.93
SOLCOST Default CNs	Varied By Location	.98	1.01	.98	.95	.92	.90	.88	.89	.92	.97	.99	.98

Note: Only the above clearness factors are in the SOLCOST data bank.

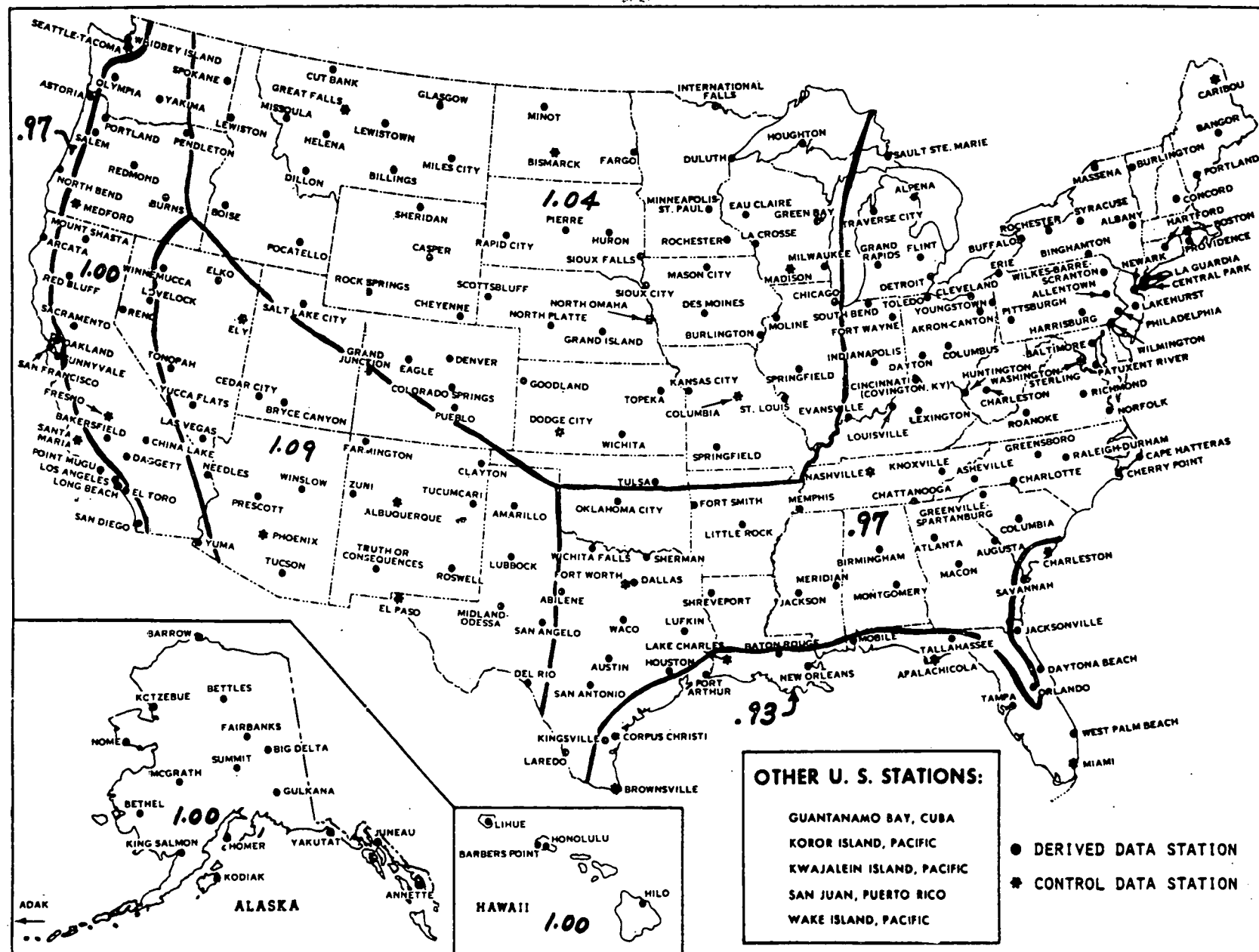


Figure A-1. Default Clearness Factors for SOLCOST Radiation Model

For tilted collectors, the incident solar energy is given by:

$$I_{t\theta} = CN I_{DN} \cos \theta + I_{d\theta} + I_r \quad (6)$$

where $I_{d\theta}$ = Diffuse sky radiation

and I_r = Diffuse ground reflected radiation.

The diffuse sky radiation is computed directly from the product of the clear day diffuse radiation incident on a horizontal surface, I_{dH} and the angle factor between the collector and the sky, F_{ss} , where:

$$F_{ss} = (1 + \cos(\text{TILT}))/2 \quad (7)$$

Hence, the diffuse sky radiation is given by:

$$I_{d\theta} = I_{dH} F_{ss} \quad (8)$$

The diffuse ground reflected radiation, I_r , is computed from the product of the total horizontal radiation, I_{tH} , with the ground reflectance, GR, and the angle factor between the collector and the ground, F_{sg} , given by:

$$F_{sg} = (1 - \cos(\text{TILT}))/2 \quad (9)$$

$$\text{and, } I_r = I_{tH} GR F_{sg} \quad (10)$$

The default value for ground reflectance in SOLCOST is 0.2, although the user can input an array of monthly values for the ground reflectance, depending on the location and ground cover conditions.

Cloudy Day Methodology - For cloudy conditions, SOLCOST assumes a totally cloudy day, i.e., no direct normal radiation is incident on the collector. The diffuse radiation on a horizontal surface is calculated from the following relation taken from the work of Kimura and Stephenson (Ref. A-8):

$$I_{dH,cl} = I_{dH} [CCF - K(1 - CC/10)] \quad (11)$$

where

$I_{dH,cl}$ = Cloudy day horizontal diffuse radiation

I_{dH} = Clear day horizontal diffuse radiation From Eqn. (5)
above

CCF = Cloud cover factor

CC = Cloud cover amount

K = Variable, depending on solar altitude angle and C
(ASHRAE diffuse sky factor)

For totally cloudy conditions, CC is equal to 10, and Eqn. (11) reduces to:

$$I_{dH,cl} = I_{dH} CCF \quad (12)$$

Kimura and Stephenson determined that the cloud cover factor, CCF, was dependent on the season and the amount of cloud cover, CC. They correlated their data with the following expression:

$$CCF = P + Q(CC) + R(CC^2) \quad (13)$$

where the values of P, Q, and R are given in Table A-3. Since CC is assumed to be equal to 10, the values of CCF can be computed directly, in fact, the values of P, Q, and R have been interpolated monthly and input to the CCF array in SOLCOST.

Once the value of $I_{dH,cl}$ is determined from Eqn. 12, angle factors to the sky and ground are applied to compute the diffuse energy incident on the tilted collector:

$$I_{t\theta,cl} = I_{dH,cl} \cdot (F_{ss} + F_{sg}) \quad (14)$$

TABLE A-3. VALUES OF CLOUDY DAY PARAMETERS P, Q, AND R* AND CLOUD COVER FACTOR FOR CC = 10

Season	P	Q	R	CCF
Spring	1.05	0.012	-0.0084	0.34
Summer	0.96	0.033	-0.0106	0.23
Autumn	0.95	0.030	-0.0108	0.17
Winter	1.14	0.003	-0.0082	0.35

REFERENCES

- A-1. ASHRAE Applications Handbook, Chapter 58, 1978 Edition.
- A-2. J. Threlkeld and R. Jordan: Direct Radiation Available on Clear Days, ASHRAE Transactions, Vol. 64, 1958, p. 45.
- A-3. C. Randall, M. Whitson, Jr.: "Hourly Insolation and Meteorological Data Bases Including Improved Direct Normal Insolation Estimates, Aerospace Corporation," Report No. ATR-78(7592)-1, (Sandia Doc. SAND78-7047), Dec. 1977.
- A-4. "SOLMET Manual", Vol. 2, TD-9724, Prepared by National Climatic Center for DOE, Feb. 1979.
- A-5. J. Threlkeld: Solar Irradiation on Surfaces on Clear Days, ASHRAE Transactions, Vol. 69, 1963, p. 24.
- A-6. T. Kusada: "The Computer Program for Heating and Cooling Loads in Buildings", NBS Building Science Series No. 69, July 1976.
- A-7. R. Hulstrum: "Definition Study for Photovoltaic Residential Prototype System", NASA Contract no. NAS3-19768, NASA Report No. NAS-CR-135056, Martin Marietta Report No. MCR-76-394, Sept. 1976.
- A-8. K. Kumura, D. Stephenson: Solar Radiation on Cloudy Days, ASHRAE Transactions, Vol. 75, Part 1, 1969.

*P, Q, and R values from Ref. A-8.

APPENDIX B. ITERATIVE DAWN STORAGE TEMPERATURE PROCEDURE

This procedure was developed to assist the user in estimating the starting collector inlet temperature which is key to the SOLCOST average day methodology. The procedure consists of an iterative process which checks the storage temperature at dawn against the previous dawn value. If the difference is outside a reasonable limit, the average day analysis is repeated using a refined estimate of the dawn storage temperature. Specifically, the following steps are executed for an average day each month:

- I. Hourly radiation incident on the collector is generated using a modified ASHRAE insolation algorithm. Profiles for a clear day and a totally cloudy day are constructed for the 15th of each month.
- II. The required collector area for a 100% system is estimated, then a maximum of 9 candidate areas covering approximately 0.10 to 0.90 solar fractions are chosen. The chosen areas are integer multiples of the module size.
- III. The system performance for an average day is simulated with the following procedure executed on hourly steps:
 1. Compute collector average day output from:

$$Q_{\text{col}} = PP(\eta I)_{\text{clear day}} + (1-PP)(\eta I)_{\text{cloudy day}}$$

where:

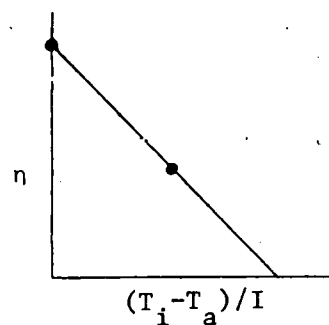
PP = Percent of Possible Sunshine
(from data bank⁺ or estimated
with horizontal radiation)

η = Collector Efficiency

I = Incident Radiation, Btu/Hr-Ft²

T_i = Inlet Temperature, °F

T_a = Ambient Temperature, °F



⁺V. Cinquemani, et al, Input Data for Solar Systems, Nov. 1978, prepared by NOAA for U.S. Department of Energy, Division of Solar Technology, under Interagency Agreement No. E(49-26)-1041.

2. Compute new storage temperature from:

$$T_{\text{stor}} = T_{\text{stor old}} + \frac{1}{MC_P} (\eta_{\text{sys}} \dot{Q}_{\text{col}} - \dot{Q}_{\text{load}} - \dot{Q}_{\text{stor loss}})$$

where:

M = Mass of Storage Water, Lbs.

C_p = Specific Heat of Storage, Btu/lb-°F

η_{sys} = Efficiency Factor (Accounts for piping losses between collector and storage, see additional description in this appendix.)

$$\dot{Q}_{\text{load}} = UA (68. - T_{\text{outside}}) \quad \text{For space heating}$$
$$\dot{Q}_{\text{load}} = f(t) * Q_{\text{daily load}}$$

For service water heating

$$\dot{Q}_{\text{stor}} = UA_{\text{tank}}(T_{\text{stor}} - T_{\text{surr}}) \quad \text{For space and service water heating.}$$

A_{tank} = Storage Tank Surfaced Area. SOLCOST defaults to a cylindrical tank with L/D = 1.

The minimum allowable storage tank temperature can be specified by the user (Line 143). Below this temperature, the solar system cannot supply useful energy to the load. The upper limit for storage temperature can be specified with Line 16.

The user can also specify the minimum temperature rise across the collector allowed for energy collection (Line 144). Knowing the collector flow rate (Line 201), SOLCOST verifies that the collector can operate at the dawn and dusk low radiation levels. In practice, the dawn start-up temperature difference from the collector outlet to storage is usually 10°F to 20°F, and the shutdown criteria is typically 3°F. SOLCOST cannot evaluate the dynamics of dawn pump cycling; however, by specifying Line 144, the user can investigate the effect of the temperature shutdown control criteria.

IV. At the end of the above average day analysis, SOLCOST checks the new dawn storage temperature against the previous value. If the difference is not within acceptable limits (Line 141), the analysis is repeated with a refined estimate of the dawn storage temperature. If convergence is not achieved, a warning message is printed and the analysis continues.

SOLCOST defaults to this iterative procedure. However, the original methodology can still be accessed by setting Line 140 = 0 and inputting the starting inlet temperatures in Line 2. For those users who are interested, Line 145 can be input as a 1 to cause the monthly minimum, maximum, and average storage temperatures to be printed for the optimum or user specified set Line 145 to a 2 to get a printout for all candidate areas.

Blank

B-4

APPENDIX C. COLLECTOR PARAMETER MODIFICATION

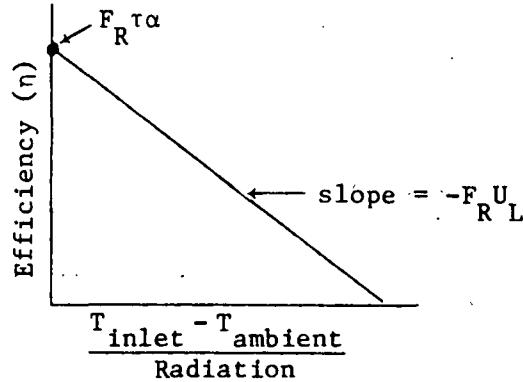
C1. General Description⁺ - There are five different situations of importance that can arise which could require redefinition of the collector efficiency curve.

They are:

- 1) The efficiency parameters have been defined in terms of different variables than the ones required by SOLCOST which needs functions of $F_R \tau \alpha$ and $F_R U_L$.
- 2) The flow rate has been varied from the conditions under which the $F_R \tau \alpha$ and $F_R U_L$ were empirically determined.
- 3) Two or more collectors with different efficiency parameters are connected in parallel. This can occur by using different flow rates in the same type of collector.
- 4) Two or more collectors are coupled in series. They may be the same or different collectors.
- 5) A heat exchanger is located between the collectors and storage.
- 6) The user wishes to adjust the collector parameters to reflect losses due to manifold conduction losses.
- 7) Air collectors leak air primarily at the inlet and outlet.
The collector parameters can be modified to reflect this leakage.

Before showing how the efficiency parameters can be easily adjusted to reflect the above mentioned perturbations, the SOLCOST collector efficiency methodology must be defined so that the user can understand how the parameters are modified. The SOLCOST program assumes a linear efficiency curve for the collector system. The curve has two parameters. The first is $F_R \tau \alpha$ which is the curve intercept when $(T_{inlet} - T_{ambient})/\text{Radiation}$ is equal to zero. See the following figure.

⁺ Duffie, J.A., and Beckman, W.A., Solar Energy Thermal Processes, Wiley, New York, 1974.



The second parameter is $F_R U_L$ which is the negative of the slope of the efficiency line. More specifically the efficiency (η) is defined:

$$\eta = F_R \tau \alpha - F_R U_L \left(\frac{T_{\text{inlet}} - T_{\text{ambient}}}{\text{Radiation}} \right).$$

In reality this efficiency representation is only valid for one collector and under precisely the same conditions that the $F_R \tau \alpha$ and $F_R U_L$ were derived empirically. If the panel flow rate (\dot{m}) or the specific heat of the fluid (c_p) are changed, if two or more collectors are placed in series, if two or more dissimilar collectors are placed in parallel, if a heat exchanger is included in the collection loop, if the inlet and outlet manifolds have conduction losses, or if there are air leaks in an air collection system these parameters must be adjusted. The new parameters can be easily estimated using basic heat transfer principles that are stated below.

- C2. Definition of F_R as a Function of Inlet Temperature - The efficiency of a collector can be alternatively defined as a function of T_{fluid} instead of T_{inlet} . To further complicate the issue the fluid temperature can be approximated by an arithmetic average of T_{outlet} and T_{inlet} or $(T_{\text{inlet}} + T_{\text{outlet}})/2$. If the fluid temperature is defined to be an average of the inlet and outlet temperatures then the $F_R U_L(T_{\text{inlet}})$ and $F_R \tau \alpha(T_{\text{inlet}})$ can be defined as follows:

$$F_R \tau \alpha(T_{\text{inlet}}) = \frac{F_R \tau \alpha(T_{\text{fluid}})}{1 + \frac{F_R U_L(T_{\text{fluid}}) A_c}{2 \dot{m} c_p}}$$

$$F_{R L} U_L (T_{inlet}) = \frac{F_{R L} U_L (T_{fluid})}{1 + \frac{F_{R L} U_L (T_{fluid}) A_c}{\dot{m} c_p}}$$

where A_c is the area of the collector plate, \dot{m} is the collector panel total flow rate and c_p is the specific heat of the fluid. The flow rate and specific heat are the same as used to empirically define $F_R (T_{fluid})$. These must be provided by the manufacturer and must be the ones used when the panel was tested. If efforts have been taken to obtain the bulk fluid temperature then the $F_R \tau \alpha$ and $F_{R L} U_L$ have an alternative definition. That is:

$$F_R \tau \alpha = F' \tau \alpha \left(\frac{\dot{m} c_p}{F' U_L A_c} \right) \left(1 - \exp \left(- \frac{F' U_L A_c}{\dot{m} c_p} \right) \right)$$

$$F_{R L} U_L = \frac{\dot{m} c_p}{A_c} \left(1 - \exp \left(- \frac{F' U_L A_c}{\dot{m} c_p} \right) \right)$$

where \dot{m} , c_p , and A_c are as defined above. F' is the collector efficiency factor; $\tau \alpha$ is the effective transmittance-absorptance product and U_L is the overall loss coefficient. For flow rates that are commonly used in collectors, either method of correction should give approximately the same answer. Care must be taken to ensure that the units check.

- C3. Adjust $F_R \tau \alpha$ and $F_{R L} U_L$ for Different Flow - To redefine the $F_R \tau \alpha$ and $F_{R L} U_L$ products to reflect different flow capacitance rates is a simple process. Two things can happen to cause the flow capacitance rate ($\dot{m} c_p$) to change. They are: the flow rate (\dot{m}) could change or the fluid could be altered or changed to cause the specific heat (c_p) to change.

The following equation has superscript numbers which reflect the state of conditions; i.e., state 1 and state 2. The required relationship is as follows:

$$\frac{F_R \tau \alpha_1}{F_R \tau \alpha_2} = \frac{F_{R L} U_{L1}}{F_{R L} U_{L2}} = \frac{A_c F_{R L} U_{L1} / \dot{m}_1 c_{p1}}{\frac{\dot{m}_1 c_{p1}}{\dot{m}_2 c_{p2}} \left(1 - \left(1 - \frac{F_{R L} U_{L1} A_c}{\dot{m}_1 c_{p1}} \right) \right)}$$

- C4. Parallel Collectors of Different Efficiencies - Occasionally collectors of different efficiencies are connected in parallel. They could be the same collector but with different flow rates. The following relationship will transform the efficiency parameters:

$$F_{R\tau\alpha} = \frac{\sum_{i=1}^n A_{c_i} F_{R\tau\alpha_i}}{\sum_{i=1}^n A_{c_i}}$$

$$F_{RU_L} = \frac{\sum_{i=1}^n A_{c_i} F_{RU_L_i}}{\sum_{i=1}^n A_{c_i}}$$

where i designates the i^{th} parameter for n parallel collectors.

- C5. Series Collector Combination⁺ - When two or more collectors of the same or different type are connected in series the resultant efficiency parameters will most likely be different than the ones for any one collector. This comes about by the fact that the inlet temperatures to the individual collectors are different. The resultant $F_{R\tau\alpha}$ and F_{RU_L} are:

$$F_R = \frac{\dot{m} c_p}{A_{c(\text{total})}} \sum_{i=1}^n \left\{ \frac{F_{R\tau\alpha_i}}{F_{RU_L_i}} \left[1 - \exp\left(-\frac{A_{c_i} F'U_{L_i}}{\dot{m} c_p}\right) \right] \cdot \exp\left[-\sum_{j=i+1}^n \left(\frac{A_{c_j} F'U_{L_j}}{\dot{m} c_p}\right)\right] \right\}$$

$$F_{RU_L} = \frac{\dot{m} c_p}{A_{c(\text{total})}} \left[1 - \exp\left(-\sum_{i=1}^n \frac{A_{c_i} F'U_{L_i}}{\dot{m} c_p}\right) \right]$$

where $A_{c(\text{total})}$ is the total series collector area, $\dot{m} c_p$ is the capacitance flow rate through each of n collectors and A_{c_i} is the i^{th} collector area. The sum of the individual A_{c_i} must equal $A_{c(\text{total})}$. A helpful equation to remember for calculating $F'U_{L_i}$ is:

⁺ Armstrong, P.R., "Extension of the Hottel-Whillier-Bliss Model to Multi-Stage Collector Systems," Proceedings of the 1978 Annual Meeting, AS of ISES, August 28-31, 1978.

$$F'U_{L_i} = - \frac{\dot{m} c_p}{A_{c_i}} \ln \left(1 - \frac{F_R U_{L_i} A_{c_i}}{\dot{m} c_p} \right) \quad \dagger\dagger$$

C6. Modification Due to Heat Exchangers - $F'_R \tau \alpha$ and $F'_R U_L$ are terms used as effective efficiency parameters whenever heat exchangers are included between the collection and storage systems. The inclusion of a heat exchanger in general degrades the overall collection efficiency by increasing the collector inlet temperature. In general the designer picks the heat exchanger depending on how much of a collection efficiency penalty he is willing to withstand. This is done by defining the ratio F'_R/F_R , which must be less than one.

$$\frac{F'_R}{F_R} = \frac{1}{1+y(x-1)}$$

$$y = \frac{A_{c_i} F_R U_L}{\dot{m} c_p (\text{collector})}$$

$$x = \frac{\dot{m} c_p (\text{collector})}{E \min(\dot{m} c_p (\text{collector}), \dot{m} c_p (\text{storage}))}$$

where E is the heat exchanger effectiveness which, with the flow rates, defines the heat exchanger. If the F'_R/F_R ratio is picked by the designer and the flow rates are established, the heat exchanger has been defined. The exchanger can be selected from this information. Likewise, the F'_R/F_R ratio can be defined by knowing the flow rates and the heat exchanger effectiveness, E.

C7. Manifold Conduction Losses⁺ - Conduction losses to the ambient air from inlet and outlet manifolds can be accounted for by modifying the net $F_R \tau \alpha$ and $F_R U_L$. Let U_{p_i} and U_{p_o} represent the thermal loss coefficient for the inlet and outlet manifolds respectively with net areas A_i and A_o . The total array mass capacitance flow rate is $\dot{m} c_p$. Then the resultant $F'_R \tau \alpha$ and $F'_R U_L$ are as follows:

$$F'_R \tau \alpha = F_R \tau \alpha / \left(1 + \frac{U_{p_o} A_o}{\dot{m} c_p} \right)$$

⁺ Beckman, W.A., "Duct and Pipe Losses in Solar Energy Systems," Solar Energy, Vol. 21, 1978.

^{††} The capacitance flow rate ($\dot{m} c_p$) used here should be the same as used to test the individual collector panels; not the rate through each of n panels as signified above.

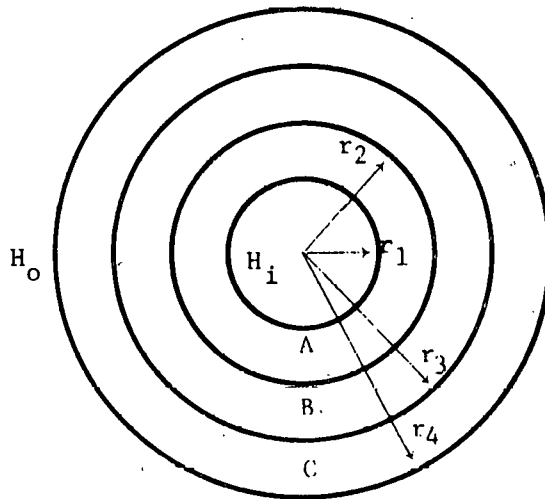
$$F_{RL}' = F_{RL} \left(1 - \frac{U_{p_i} A_i}{m c_p} + \frac{U_{p_i} A_i + U_{p_o} A_o}{A_c F_{RL}} \right) / \left(1 + \frac{U_{p_o} A_o}{m c_p} \right)$$

A_c is the total collector area and F_{RL} and F_{RL}' are the resultant products after taking into account effects due to varying flow rate, etc.

The UA for a pipe may be estimated by the following equation:

$$UA = \frac{1}{\frac{\ln(r_2/r_1)}{2\pi k_A L} + \frac{\ln(r_3/r_2)}{2\pi k_B L} + \frac{\ln(r_4/r_3)}{2\pi k_C L} + \frac{1}{H_i} + \frac{1}{H_o}}$$

where k_i is the thermal conductance of material i and the r 's are as in the following figure. L is the length and H_o and H_i are the outside and inside net convective heat transfer coefficients.



C8. Air Leakage To/From Manifolds

Air systems leak primarily to/from the array inlet and outlet. This results in an overall net collector array efficiency change. This change can be accounted for by modifying the collector parameters. Two types of leakage occur: 1) leakage into the array when negative pressures occur and 2) leakage out of the array when under positive pressure. These leaks usually occur at the inlet and outlet of the array. These situations will be dealt with separately.

Negative pressure: + when the array is under a negative pressure the ambient air leaks into the array. This leakage rate will be designated as follows:

+ In this development, it was assumed the blower was located on the collector outlet, and the net useful energy collected is defined to be a function of the blower flow rate and collector inlet and outlet temperatures.

$$(1-\beta) \dot{m} \text{ (to system)} = \dot{m}_{\text{collector}}$$

$$0 \leq \beta \leq 1$$

If β is equal to zero there is no leakage and if β equals 0.2 then the collector flow rate equals 80% of the flow rate going to storage or the load. Also a leakage rate can be defined similarly for the inlet to the collector array.

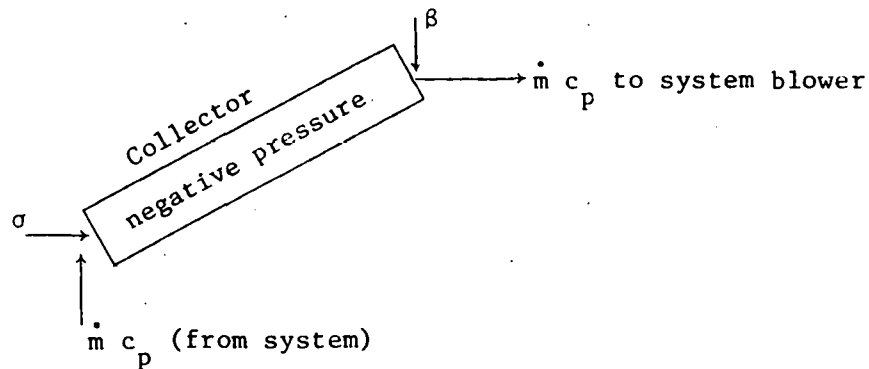
$$\dot{m} \text{ (from system)} = (1-\sigma) \dot{m}_{\text{collector}}$$

$$0 \leq \sigma \leq 1$$

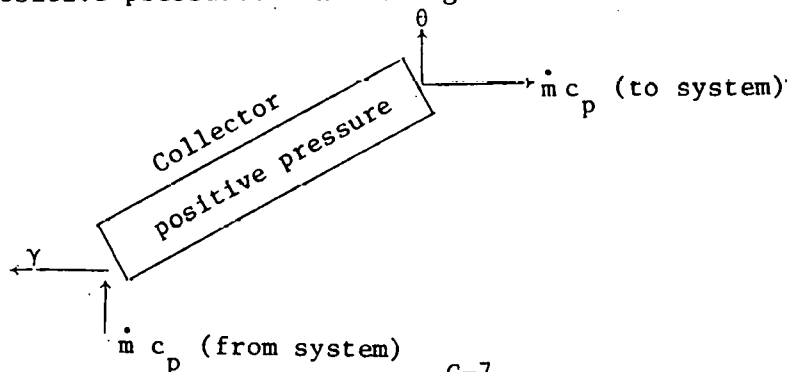
As before, if σ is zero there is no inlet leakage. If σ is 0.2, the rate from the storage or load is 80% of what is going through the collector array. The F_{RL} product for the collector is not effected by leakage but the F_{RL} is:

$$F_{RL_{\text{new}}}^U = (1-\sigma) F_{RL}^U + [\sigma(1-\beta) + \beta] \frac{\dot{m} c_p}{A_c}$$

$$\dot{m} c_p = \text{flow capacitance rate to system}$$



Positive pressure: The above definition is not valid when the array is under positive pressure: the leakage is outward.



As before the flow rates through the system are defined in a similar manner:

$$\dot{m} \text{ (to system)} = (1-\theta) \dot{m}_{\text{collector}}$$

$$(1-\gamma) \dot{m} \text{ (from system)} = \dot{m}_{\text{collector}}$$

In this situation the resultant energy collected by the collectors is passed onto the heated space except for any leaked energy. The resultant parameters are:

$$F_{R\tau\alpha_{\text{new}}} = F_{R\tau\alpha_{\text{old}}} (1-\theta)$$

$$F_{R U_{L_{\text{new}}}} = F_{R U_{L_{\text{old}}}} (1-\theta)$$

However, as in the case where the collectors were under negative pressure the collector parameters should be modified to reflect any different flow rates than as tested. For example, if $\gamma = .5$ then the collector flow rate will be one half of the flow rate coming from the heating system.

Note: Air collection systems leak somewhat and leakage rates of approximately 20% are observed frequently. However, if the leakage rate is excessive, the load will be effected by increasing or decreasing the infiltration rate to or from the heated space. Therefore, it is recommended that this procedure not be used in situations where the leakage rate is excessive; and that possibly a detailed simulation type of analysis would be appropriate.

C9. Example

Following is an example illustrating the automatic parameter update feature included in SOLCOST. Refer to section III for the input list. This example is the same as the air subcomponent sizing example in Appendix D, except the collector parameters have been updated to illustrate degradation due to varying flow rates from which they were tested, air leakage and manifold conduction losses.

T

COLLECTOR PARAMETER ADJUSTMENT EXAMPLE									
1,	7	7	7	7	7	7	7	7	7
	7	7	7	7 *					
	\$ SOLAR SYSTEM TYPE FLAGS BY MONTH								
4,	2	2	2	2	2	2	2	2	2
	2	2	2	2 *					
	\$ REFERENCE SYSTEM FUEL TYPE								
6,	2								
	\$ SOLAR AUXILIARY ENERGY FLAG								
10,	23								
	\$ COLLECTOR TYPE FLAG								
13,	.5500E+02 *								
	\$ COLLECTOR TILT ANGLES, DEGREES								
14,	.4900E+00								
	\$ COLLECTOR EFFICIENCY AT DT/Q = 0.								
15,	.1200E+00								
	\$ COLLECTOR EFFICIENCY AT (TIN-TAMB)/Q = 0.5								
21,	3								
	\$ FLAG FOR COLLECTOR AREA USED IN LCC ANALYSIS								
22,	.3000E+03								
	\$ SPECIFIED COLLECTOR AREA WHEN LINE 21-1, 2 OR 3								
25,	55								
	\$ SITE LOCATION CODE								
40,	2								
	\$ BUILDING LOAD COMPUTE METHOD FLAG								
41,	3								
	\$ SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG								
42,	.7100E+01								
	\$ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)								
43,	.1500E+04								
	\$ BUILDING FLOOR AREA (SQ.FT)								
49,	.9000E-01								
	\$ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)								
55,	.3750E+03								
	\$ SOLAR SYSTEM FIXED COST, DOLLARS								
56,	.4500E+02								
	\$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT								
59,	.6000E-02								
	\$ SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)								
65,	1								
	\$ FINANCIAL SCENARIO FLAG(RES,BUS,NFO): 1,2, OR 3								
67,	.1000E+00								
	\$ DISCOUNT RATE, FRACTION								
68,	.1000E+00								
	\$ MORTGAGE INTEREST RATE, PERCENT/YEAR								
72,	.7000E-02								
	\$ BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)								
73,	0.								
	\$ PROPERTY TAX RATE, FRACTION OF INITIAL COST								
74,	.3000E+00								
	\$ INCOME TAX RATE, (FRACTION)								
82,	.1000E+00								
	\$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES								
91,	.1420E+00	.1500E+02	.4200E-01	.5000E+02	.4400E-01	.1200E+03			
	.3200E-01	.1000E+05	.1000E+00 *						
	\$ ENERGY COST SCHEDULE-ELECTRICITY								
169,	1								
	\$ FLAG TO UPDATE COLLECTOR PARAMETERS								
172,	.1800E+01 *								
	\$ M-DOT C-SUB-P REF SQ. FOOT OF COLLECTOR AS USED								
173,	.4900E+00 *								
	\$ F-SUB-R TAU ALPHA INPUT FOR EACH COLLECTOR PATH								
174,	.7400E+00 *								
	\$ F-SUB-R U-SUB-L INPUT FOR EACH COLLECTOR PATH								

Figure C-1. Collector Parameter Update
Example for an Air System


```

180,      1
      $ FLAG TO INDICATE LEAKY COLLECTORS IN AIR SYSTEM
183,      .1000E+00
      $ LEAK PARAMETERS (SEE APPENDIX C)
187,      1
      $ MANIFOLD CONDUCTION FLAG
188,      .5000E+02
      $ INLET UA OF PIPING/DUCTING BTU/(HR. DEG-F)
189,      .2000E+02
      $ OUTLET UA OF PIPING/DUCTING BTU/(HR. DEG-F)
RUN

```

TITLE: COLLECTOR PARAMETER ADJUSTMENT EXAMPLE

Figure C-1. (Cont.)

TITLE: COLLECTOR PARAMETER ADJUSTMENT EXAMPLE

-----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----

LOCATION --DENVER,CO LATITUDE = 39.0 TILT ANGLE= 55.0
 AIR SOLAR SYSTEM WITH 50.0 LBS OF ROCK STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .49
 COL. EFFIC. = .12 AT DEL T/FLUX = .5 HR-F SQ FT/BTU
 INPUT SPACE HEAT U VALUE = 7.10 BTU/(F-DAY-SQ FT) FLOOR AREA= 1500. SQ FT
 INPUT SER. HOT WATER LOAD= .020 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	375.00	0.00
INITIAL COST,	\$/SQ FT	45.00	
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	10.0	10.0
DISCOUNT RATE,	%	10.0	10.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.7	.7
MAINTENANCE RATE,	% OF IN COST	.6	.5
GEN INFLATION,	% PER YEAR	10.0	10.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	7	7	7	7	7	7	7	7	7	7	7	7
TRANSPORT EFFIC.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
COL. INLET TEMP.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DAILY LOAD-MIL. BTU	.46	.43	.39	.28	.18	.12	.09	.09	.13	.23	.36	.43
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	48.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	79.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	62.	60.	60.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.	1127.	1530.	1929.	2135.	2351.	2273.	2044.	1727.	1301.	884.	732.
HEATING DEG. DAYS	1000.	902.	860.	825.	803.	80.	0.	0.	120.	409.	760.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$.142 PER UNIT FOR FIRST	15.0	UNITS
ELECTRIC	\$.062 PER UNIT FOR NEXT	50.0	UNITS
ELECTRIC	\$.043 PER UNIT FOR NEXT	120.	UNITS
ELECTRIC	\$.036 PER UNIT FOR NEXT	.100E+05	UNITS

ESCALATION RATE = 10.00 PERCENT

Figure C-1. (Cont.)

COLLECTOR PARAMETER MODIFICATION INPUTS
 NO. OF PARALLEL SECTIONS WITH DIFFERENT PARAMETERS = 1
 NO. OF SERIES COLLECTORS = 2

PATH NO -- 1-- --

FRTA(IN) .490

FRUL(IN) .740

PANEL AREA
 SOFT 20.0

COLLECTOR FLOW RATE BTU/HR-DEGF-SOFT
 1.0

TEST FLOW RATE, BTU/HR-DEGF-SOFT
 2.0

AVG OR INLET TEMP FLAG
 0

AIR COLLECTOR PRESSURE FLAG = 1

SIGMA = 0.000

BETA = .100

THETA = .200

MANIFOLD CONDUCTION LOSS INDICATED

INLET UA (BTU/HR-DEGF) 50.0

OUTLET UA (BTU/HR-DEGF) 20.0

*****FINAL PARAMETERS FOR THE COLLECTOR

FINAL FRTA = .3745

FINAL FRUL = 1.7224

Figure C-1. (Cont.)

TITLE: COLLECTOR PARAMETER ADJUSTMENT EXAMPLE

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	300.
STORAGE SIZE	8.
STORAGE COSTS	375.
COLLECTOR COSTS	13500.
FIXED COSTS	375.

• TOTAL COSTS	14250.

Figure C-1. (Cont.)

TITLE: COLLECTOR PARAMETER ADJUSTMENT EXAMPLE

ENERGY BALANCE BY MONTH FOR 300.0 SQ. FT. COLLECTOR					
MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)

1	.166	256.4	2.38	11.99	14.38
2	.221	318.4	2.67	9.45	12.13
3	.265	343.1	3.19	8.84	12.03
4	.458	422.0	3.90	4.49	8.29
5	.878	517.9	4.82	.67	5.48
6	1.000	688.0	3.55	0.00	3.55
7	1.000	835.3	2.79	0.00	2.79
8	1.000	819.6	2.79	0.00	2.79
9	1.000	725.3	3.98	0.00	3.98
10	.743	570.3	5.30	1.83	7.14
11	.280	338.7	3.05	7.83	10.88
12	.177	256.9	2.39	11.09	13.48
---			---	---	---
ANNUAL	.420		40.72	56.21	96.92

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS - PRESENT WORTH OF NET CASH
FLOWS (FOR A 10.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure C-1. (Cont.)

TITLE: COLLECTOR PARAMETER ADJUSTMENT EXAMPLE

COLLECTOR SIZE INPUT BY USER

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 55. DEGREES IS 300. SQ. FT.
COLLECTOR TYPE = USER DEFINED, AIR TYPE
FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	444.	185.	0.	1202.	2505.	1506.	-1425.
2	409.	204.	0.	1260.	378.	1506.	1337.
3	538.	224.	0.	1235.	371.	1506.	-842.
4	591.	247.	0.	1208.	363.	1506.	-821.
5	651.	271.	0.	1179.	354.	1506.	-798.
6	716.	298.	0.	1146.	344.	1506.	-772.
7	787.	328.	0.	1110.	333.	1506.	-744.
8	866.	361.	0.	1070.	321.	1506.	-713.
9	953.	397.	0.	1026.	308.	1506.	-679.
10	1048.	437.	0.	978.	294.	1506.	-642.
11	1153.	480.	0.	926.	278.	1506.	-601.
12	1260.	529.	0.	868.	260.	1506.	-556.
13	1395.	581.	0.	804.	241.	1506.	-506.
14	1534.	640.	0.	733.	220.	1506.	-451.
15	1688.	703.	0.	656.	197.	1506.	-391.
16	1856.	774.	0.	571.	171.	1506.	-325.
17	2042.	851.	0.	478.	143.	1506.	-252.
18	2246.	936.	0.	375.	112.	1506.	-171.
19	2471.	1030.	0.	261.	78.	1506.	-83.
20	2718.	1133.	0.	137.	41.	1506.	13.
TOTALS	25454.	10609.	0.	17303.	7392.	30120.	119.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 2200.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 15.1 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 0.0 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS -4912.42 DOLLARS

RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 42.0 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 40.7 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure C-1. (Cont.)

Blank

C-16

APPENDIX D. SOLCOST COMPONENT SIZING CAPABILITY

SOLCOST can size typical solar system components, including pipes, ducts, pumps, fans, and heat exchangers. The cost for these components can be accounted for in the SOLCOST analysis at the users option. This Appendix outlines the key features of the sizing methodology and explains the input parameters (Lines 190-303) with sample problems.

Users are cautioned that the component sizes defined by these routines should be approved by a qualified system designer prior to their use in an actual solar system.

If the user wants to use these options, he should set the following flags:

- Line 190 = 1 Control flag to exercise sizing routines
A liquid system is assumed, unless Line 1 = 7.
- Line 191 = 1 Flag to size a counterflow liquid-to-liquid heat exchanger in the collection loop.
- Line 192 = 1 Flag to size a crossflow air-to-liquid or a liquid-to-air heat exchanger in the collection loop (or in the load distribution loop).
- Line 193 = 1 Flag to include component costs in life cycle cost analysis.

The default for the above flags is 0, so the user must specify the options he desires.

Liquid System Components: Pipe and Pump Sizing

The collection loop supply and return pipe inside diameter is determined from the input pipe design velocity and the flow rate per unit collector area.

$$D = \sqrt{\frac{4}{\pi} \frac{Q}{A_c} A_c / V_D} \quad (\text{Ft})$$

where:

A_c = Collector area

Q/A_c = Volume flow rate per unit collector area (Input on Line 201)

V_D = Pipe design velocity (Input on Line 210)

The computed diameter is rounded up to the next one-eighth increment of pipe size. One-quarter inch is the lowest pipe size allowed.

Next, the total head loss in the collection loop is computed from the generalized Bernoulli equation (in head form) applied at the inlet and outlet of the pump.

$$H_m = \frac{P_o - P_i}{\rho} + \frac{V_o^2 - V_i^2}{2g} + (Z_o - Z_i) + H_L \quad (\text{Ft})$$

where:

H_m = Total head across pump

$\frac{P_o - P_i}{\rho}$ = Static pressure head (Input on Line 208)

$\frac{V_o^2 - V_i^2}{2g}$ = Velocity head (Input on Line 207)

$Z_o - Z_i$ = Elevation head (Input on Line 209)

H_L = Losses due to friction, collector array, and heat exchanger

$H_L = f (L_{eq}/D) (V_D^2/2g) + \Delta P_{col} + \Delta P_{HX} \quad (\text{Ft})$

where

$L_{eq} = L_{pipe} + (N_{valves} L_{eq_{valve}} + N_{elbows} L_{eq_{elbow}} + N_{tees} L_{eq_{tee}}) D$

f = Friction factor (Input on Line 221)

L_{pipe} = Pipe length (Input on Line 204)

D = Pipe diameter (Computed by SOLCOST)

V_D = Design velocity (Input on Line 210)

ΔP_{col} = Pressure drop across collector array (Input on Line 202)

P_{HX} = Pressure drop across heat exchanger (If used) (Input on Line 203)

N_{valves} = No. of valves in loop (Input on Line 211)

L_{eq} = Equivalent pipe diameters per valve (Input on Line 222)

N_{elbows} = No. of elbows in loop (Input on Line 212)

L_{eq} = No. of pipe diameter per elbow (Input on Line 223)

N_{tees} = No. of tees in loop (Input on Line 213)

L_{eq} = No. of pipe diameters per tee (Input on Line 224)

Once the total head loss H_m is known, the routine searches the candidate pump tables for the pump which can satisfy the flow and head requirements at a reasonable operating point on the pump curve.

Air System Components: Duct and Fan Sizing

This routine follows the same approach as the pipe and pump sizing algorithm, with the properties of air corrected for site elevation.

$$ADR = \frac{530}{(460+T) \exp \frac{ALT}{27000}}$$

where T is the air temperature in °F and ALT is the location altitude (Line 238) in feet. The routine uses 120°F for sizing purposes.

The required actual air flow is then computed from

$$FLRATE = COLFLW * A_c / ADR \quad (CFM)$$

where COLFLW is the input air flow per unit collector area (Line 234) in standard CFM and A_c is the collector area.

The duct diameter is then determined from

$$DIA = 24. (FLRATE / \pi V_D)^{1/2}$$

where V_D is the design air velocity. The diameter is rounded up to the next one-inch duct size and the minimum duct size is five inches.

Next the equivalent duct length is computed from:

$$\text{DUCTL} = \text{DLEN} + (N_{\text{turns}} L_{\text{eq turn}} + N_{\text{dampers}} L_{\text{eq damper}}) \text{DIA}$$

and then the standard air velocity (V_s) in the duct is calculated from:

$$V_s = \frac{576 \cdot \text{FLRATE} \cdot \text{ADR}}{\pi \text{DIA}^2}$$

The duct heat loss can now be computed with:

$$\text{HL} = \frac{.027 (\text{IF}) \text{DUCTL}}{\text{DIA}^{1.23} \text{ADR}} \left(\frac{V_s}{1000} \right)^{1.845}$$

where IF = insulation friction factor

The head loss is compared with the maximum head loss and, if excessive, a duct diameter is calculated that results in an actual head loss lower than the maximum value.

An equivalent square duct is also determined. By equivalent, it has the same head loss per unit length.

Finally, the total head loss (TDP) in the air collection system is summed as follows:

$$\text{TDP} = \text{DPCOL} + \text{DPBED} + \text{DPHX} + \text{HL}$$

where:

DPCOL = Collector pressure drop (Input as Line 235)

DPBED = Rock bed pressure drop (Input as Line 239)

DPHX = Heat exchanger pressure drop (If present) (Input as Line 236)

HL = Duct losses as defined above.

Rock Bed Pressure Drop Calculation

The user may elect to allow SOLCOST to calculate the pressure drop of the rock bed, or he may input the pressure drop manually (line 243). To calculate the pressure drop, the bed inside height (line 244) and the rock density (line 245) must be supplied. The internal procedure is as follows:

$$\text{ADR} = \frac{530}{(460 + T) \exp \left(\frac{\text{ALT}}{27000} \right)}$$

where T and ALT are defined on the previous page. The density of air (ρ) is

$$\rho = .075 \text{ ADR}$$

and the velocity (V) of the air in the bed is

$$V = \frac{\text{Actual volumetric flow rate}}{\text{Box inside cross sectional area}}$$

then the Reynolds number (R_e) is calculated to be

$$R_e = 106 \rho V$$

and the friction factor (f) is

$$f = 180 + 3.96(R_e)^{0.9}$$

and finally, the rock box pressure drop Δh is

$$\Delta h \text{ (inches of water)} = (3.41 \times 10^{-6}) f H V$$

where H is the bed inside height. It should be observed that as long as the bed height remains constant and the quantity of rock and air flow rate is a constant multiplied by the collector area, then the pressure drop will be independent of the collector area.

Heat Exchangers for Air and Liquid Systems

For liquid systems, typically two heat exchangers need to be sized: 1) the collector-to-storage heat exchanger for systems with anti-freeze fluids, and 2) the liquid-to-air load distribution heat exchangers. The first option requires the following inputs:

Line 190	= 1	SOLCOST to access the sizing routines
Line 191	= 1	Flag for counterflow HX in collection loop
Line 201	= .025	Flow rate per unit collector area
Line 225	= 3.	Ratio of $(MC)_p^{\text{storage}} / (MC)_p^{\text{collection loop}}$

Line 227 = .95 Ratio of F'_R/F_R for collector-storage HX

The counterflow heat exchanger UA is calculated as follows. Specify F'_R/F_R (normally 0.95-0.97); then determine the heat exchanger effectiveness (E):

$$E = \frac{A_c F_R U_L}{\dot{M}C_{p,\min} \left(\frac{A_c F_R U_L}{\dot{M}C_{p,\text{collector}}} + \left(\frac{F'_R}{F_R} \right)^{-1} - 1 \right)}$$

Determine NTU (the number of transfer units) from

$$NTU = \frac{1}{(1-Z)} \ln \left(\frac{1-EZ}{1-E} \right), \quad Z \neq 1$$

$$\text{for } Z = 1 \quad NTU = \frac{E}{1-E}$$

where

$$Z = \dot{M}C_{p,\min} / \dot{M}C_{p,\max}$$

Determine the heat exchanger area conductance product from

$$UA = (NTU) \dot{M}C_{p,\min}$$

Once the UA has been determined, the heat exchanger is selected from the input tables.

The sizing of the liquid-to-air crossflow load distribution heat exchanger requires input of the above parameters (except Line 191) and:

Line 192 = 1. Flag for crossflow liquid-to-air HX in load distribution

Line 230 = 2. Design point for crossflow load HX

Line 231 = 1000. Air flow rate in load HX

Line 232 = 15. Water flow rate in load HX

The effectiveness of load heat exchanger (E) is computed as

$$E = DP * UA / \dot{M}C_{p,\min}$$

where DP is from Line 230, UA is the building heat loss coefficient (computed from Line 42*Line 43/24.), and $\dot{MC}_{p,min}$ is determined from the input water and air flow rates.

For air systems, the routines will size the service water coil located in the collector outlet ducting. The user must specify the effectiveness in this case for each of the candidate areas; Array 240. Inputs required are the same as for the load distribution heat exchanger, only the service water flow rate should be input on Line 232.

The UA for crossflow heat exchangers is calculated as follows; once the effectiveness (E) has been determined.

When the mass capacitance flow rate of the air side is greater than the liquid side then the UA is:

$$UA = -\dot{MC}_{p,max} \ln \left[1 + \frac{\dot{MC}_{p,min}}{\dot{MC}_{p,max}} \ln(1-E) \right]$$

when the largest mass capacitance flow rate is the liquid side then the following equation is used.

$$UA = -\dot{MC}_{p,min} \ln \left[1 + \frac{C_{max}}{C_{min}} \ln \left(1 - E \frac{\dot{MC}_{p,min}}{\dot{MC}_{p,max}} \right) \right]$$

Once the UA has been determined, the heat exchanger can be selected from the input tables.

SOLCOST Component Sizing Examples, Liquid System

Assume that a residential solar space heating system with liquid collectors is in the design stages. Figure D-1 shows a schematic of the proposed system. The designer wants to include component sizing in his SOLCOST analysis. He elects to use the default values with the exception of the collector flow rate and the length of pipe in his system. Figure D-2 is the SOLCOST output for this system.

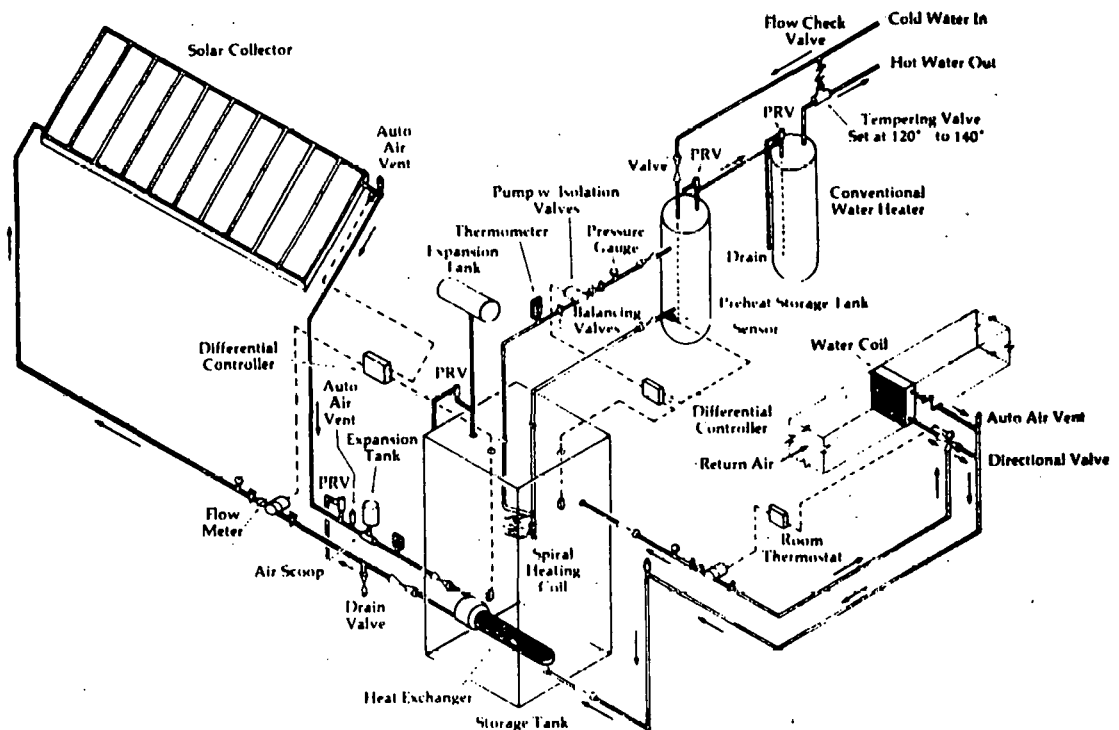


Figure D-1. Liquid Space Heating System
for Component Sizing Example

T

LIQUID SYSTEM COMPONENT SIZING EXAMPLE

1,	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1
	* SOLAR SYSTEM TYPE FLAGS BY MONTH							
4,	2	2	2	2	2	2	2	2
	2	2	2	2	2	2	2	2
	* REFERENCE SYSTEM FUEL TYPE							
6,	2							
	* SOLAR AUXILIARY ENERGY FLAG							
10,	21							
	* COLLECTOR TYPE FLAG							
13,	.5500E+02	*						
	* COLLECTOR TILT ANGLES, DEGREES							
14,	.7200E+00							
	* COLLECTOR EFFICIENCY AT DT/R = 0.							
15,	.3100E+00							
	* COLLECTOR EFFICIENCY AT (TIN-TAMB)/R = 0.5							
25,	55							
	* SITE LOCATION CODE							
40,	2							
	* BUILDING LOAD COMPUTE METHOD FLAG							
41,	3							
	* SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG							
42,	.7100E+01							
	* BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)							
43,	.1500E+04							
	* BUILDING FLOOR AREA (SQ.FT)							
49,	.9000E-01							
	* LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)							
55,	.1500E+04							
	* SOLAR SYSTEM FIXED COST, DOLLARS							
56,	.2400E+02							
	* COST OF SOLAR SYSTEM, DOLLARS /SQ.FT							
59,	.6000E-02							
	* SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)							
65,	1							
	* FINANCIAL SCENARIO FLAG (RES,BUS,NFO): 1,2, OR 3							
67,	.1000E+00							
	* DISCOUNT RATE, FRACTION							
68,	.1000E+00							
	* MORTGAGE INTEREST RATE, PERCENT/YEAR							
72,	.7000E-02							
	* BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)							
73,	0.							
	* PROPERTY TAX RATE, FRACTION OF INITIAL COST							
74,	.3000E+00							
	* INCOME TAX RATE, (FRACTION)							
82,	.1000E+00							
	* INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES							
91,	.1420E+00	.1500E+02	.6200E-01	.5000E+02	.4300E-01	.1200E+03		
	.3600E-01	.1000E+05	.1000E+00	*				
	* ENERGY COST SCHEDULE-ELECTRICITY							
190,	1							
	* FLAG TO EXECUTE SUBSYSTEM SELECTION/SIZING ROUTINES							
191,	1							
	* FLAG FOR COUNTERFLOW LIQ-LIQ HX IN COLLECTION LOOP							
192,	1							
	* FLAG FOR CROSSFLOW AIR-LQ (OR LQ-AIR) HX IN COL LOOP							
204,	.6500E+02							
	* TOTAL PIPE OR DUCT LENGTH IN COLLECTION LOOP							

RUN

Figure D-2. SOLCOST Output for Liquid System Subcomponent Sizing Example

TITLE: LIQUID SYSTEM COMPONENT SIZING EXAMPLE

Figure D-2. (Cont.)

TITLE: LIQUID SYSTEM COMPONENT SIZING EXAMPLE

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --DENVER,CO LATITUDE = 39.8 TILT ANGLE= 55.0
 LIQUID SOLAR SYSTEM WITH 1.5 GAL. STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .72
 COL. EFFIC. = .31 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SPACE HEAT U-VALUE = 7.10 BTU/(F-DAY-SQ FT) FLOOR AREA= 1500. SQ FT
 INPUT SER. HOT WATER LOAD= .090 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	1500.00	0.00
INITIAL COST,	\$/SQ FT	24.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	10.0	10.0
DISCOUNT RATE,	%	10.0	10.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.7	.7
MAINTENANCE RATE,	% OF IN COST	.6	.5
GEN INFLATION,	% PER YEAR	10.0	10.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	1	1	1	1	1	1	1	1	1	1	1	1
TRANSPORT EFFIC.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DAILY LOAD-MIL BTU	.46	.43	.39	.28	.18	.12	.09	.09	.13	.23	.36	.43
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	40.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	78.	67.	53.	44.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	68.	60.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.1127	1530.1879	2135.2351	2273.2044	1727.1301	884.732.						
HEATING DEG. DAYS	1089.	702.	840.	525.	253.	80.	0.	0.	120.	408.	768.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
ENERGY COST DATA												
ELECTRIC	\$.142	PER UNIT FOR FIRST	15.0	UNITS								
ELECTRIC	\$.062	PER UNIT FOR NEXT	50.0	UNITS								
ELECTRIC	\$.043	PER UNIT FOR NEXT	120.	UNITS								
ELECTRIC	\$.036	PER UNIT FOR NEXT	100E+05	UNITS								
ESCALATION RATE =	10.00	PERCENT										

Fig. D-2. (Cont.)

+++++SUBCOMPONENT INPUT SUMMARY FOR A LIQUID SYSTEM

ADDITIONAL VELOCITY HEAD	.10 FEET
SYSTEM PRESSURE HEAD LOSS	.50 FEET
SYSTEM TOTAL ELEVATION HEAD LOSS	.50 FEET
HEAT EXCHANGER HEAD LOSS	.50 FEET
COLLECTOR HEAD LOSS	.60 FEET
TOTAL COLLECTOR LOOP PIPE LENGTH	65.00 FEET
NUMBER OF VALVES IN SYSTEM	2
NUMBER OF ELBOWS IN SYSTEM	10
NUMBER OF TEES IN SYSTEM	0
DESIGN VELOCITY FOR PIPE FLOW	5.00 FEET PER SECOND
COST OF EACH VALVE	3.00 DOLLARS
COST OF EACH ELBOW	1.00 DOLLARS
COST OF EACH TEE	1.00 DOLLARS
COST OF PIPING	4.00 DOLLARS/FOOT

+++++PUMP SELECTION TABLE

NUMBER	FLOW(GPM)	HEAD(FT)	COST(\$)
1	0.00	7.50	75.00
1	5.00	0.50	75.00
1	10.00	7.00	75.00
1	19.00	1.20	75.00
2	0.00	14.00	100.00
2	22.00	0.00	100.00
3	0.00	10.00	105.00
3	5.00	6.50	105.00
3	7.50	4.00	105.00
3	10.00	1.70	105.00
4	0.00	0.00	112.00
4	16.00	0.00	112.00
5	0.00	20.00	112.00
5	30.00	0.00	112.00
6	0.00	6.00	135.00
6	14.00	0.00	135.00
7	0.00	14.00	171.00
7	23.00	0.00	171.00
8	0.00	40.00	225.00
8	30.00	0.00	225.00
9	0.00	20.00	225.00
9	60.00	0.00	225.00

Figure D-2. (Cont.)

+++++COUNTER FLOW HEAT EXCHANGER INPUT SUMMARY
HEAT EXCHANGER FR PRIME/FR RATIO

.9500

HEAT EXCHANGER UA VS COST TABLE		
NUMBER-----	UA(BTU/HR-DEGF)-----	COST(\$)
1	715.00	112.00
2	1430.00	150.00
3	2172.00	190.00
4	3080.00	292.00
5	4620.00	330.00
6	6160.00	382.00
7	7205.00	482.00
8	9570.00	553.00
9	14492.00	726.00
10	22990.00	925.00
11	27527.00	1040.00
12	32065.00	1144.00
13	36602.00	1313.00
14	45952.00	1690.00

+++++INPUT SUMMARY FOR CROSS FLOW HEAT EXCHANGER
(AS USED IN THE LIQUID HEATING SYSTEM)

STRUCTURE UA 443.75 BTU/(HR-DEGF)
CALCULATED EFFECTIVENESS = $2.00 * (UA \text{ OF STRUCTURE}) / (\text{MIN FLOW CAP RATE})$

CROSS FLOW HEAT EXCHANGER UA VS COST TABLE		
NUMBER-----	UA(BTU/HR-DEGF)-----	COST(\$)
1	197.00	45.00
2	295.50	50.00
3	394.00	55.00
4	492.50	63.00
5	591.00	77.00
6	788.00	84.00
7	886.50	85.00
8	985.00	100.00
9	1773.00	120.00
10	1940.00	140.00
11	3546.00	192.00

Figure D-2. (Cont.)

TITLE: LIQUID SYSTEM COMPONENT SIZING EXAMPLE

+++++THIS IS A LIQUID SYSTEM

COLLECTOR AREA	60.	140.	220.	300.	380.	440.	520.	600.	680.
SURCOMPONENT COST	276.	276.	276.	276.	276.	276.	276.	276.	276.
PIPE DIAMETER (INCHES)	.38	.63	.75	.88	1.00	1.00	1.13	1.13	1.25
SYSTEM HEAD LOSS (FEET)	13.76	9.88	8.91	8.22	7.70	7.70	7.30	7.30	6.97
PUMP COST (DOLLARS)	112.	100.	100.	100.	100.	112.	112.	112.	112.
PUMP SELECTION (NUMBER)	5	2	2	2	2	5	5	5	5
COUNTER FLOW HX UA (BTU/DEG-F-HR)	639.	1491.	2342.	3194.	4046.	4685.	5537.	6389.	7240.
COUNTER FLOW HX COST (\$)	112.	190.	292.	330.	330.	382.	382.	482.	553.
COUNTER FLOW HX SELECTION	1	3	4	5	5	6	6	7	8
LOAD HEAT EXCHANGER COST(\$)					192.				
LOAD HEAT EXCHANGER UA					2788.				
LOAD HEAT EXCHANGER EFFECTIVENESS					.880				
LOAD HEAT EXCHANGER SELECTION					11				

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	60.	140.	220.	300.	380.	440.	520.	600.	680.
STORAGE SIZE	90.	210.	330.	450.	570.	660.	780.	900.	1020.
COMPONENT COSTS	692.	758.	860.	906.	906.	962.	962.	1062.	1133.
THE SURCOMPONENTS ARE NOT INCLUDED IN THE TOTAL									
STORAGE COSTS	90.	210.	330.	450.	570.	660.	780.	900.	1020.
COLLECTOR COSTS	1440.	3360.	5280.	7200.	9120.	10560.	12480.	14400.	16320.
FIXED COSTS	1500.	1500.	1500.	1500.	1500.	1500.	1500.	1500.	1500.
TOTAL COSTS	3030.	5070.	7110.	9150.	11190.	12720.	14760.	16800.	18840.

Figure D-2. (Cont.)

TITLE: LIQUID SYSTEM COMPONENT SIZING EXAMPLE

SYSTEM PERFORMANCE AND COST SUMMARY FOR 55.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
60.0	.103	3030.00	110.1	944.91	3654.78
140.0	.387	5070.00	127.4	3114.55	11176.99
220.0	.531	7110.00	114.2	4134.80	15118.49
300.0	.654	9150.00	102.1	4777.03	17049.16
380.0	.750	11190.00	66.8	4572.34	18355.52
440.0	.816	12720.00	42.2	4214.11	18328.05
520.0	.897	14760.00	27.5	3623.46	17935.40
600.0	.950	16800.00	19.1	2513.58	15907.11
680.0	.985	18840.00	13.3	1099.14	12919.44

ENERGY BALANCE BY MONTH FOR 300.0 SQ. FT. COLLECTOR

MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ.FT.)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.438	677.5	6.30	0.00	14.38
2	.512	739.6	6.21	5.91	12.13
3	.573	741.2	6.89	5.14	12.03
4	.747	687.9	6.19	2.10	8.29
5	1.000	593.4	5.48	0.00	5.48
6	1.000	396.6	3.55	0.00	3.55
7	1.000	305.1	2.79	0.00	2.79
8	1.000	304.0	2.79	0.00	2.79
9	1.000	442.1	3.98	0.00	3.98
10	1.000	338.4	7.14	0.00	7.14
11	.562	679.8	6.12	4.76	10.88
12	.439	635.9	5.91	7.57	13.48
ANNUAL	.654		63.36	33.56	96.92

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES (I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH FLOWS (FOR A 10.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure D-2. (Cont.)

TITLE: LIQUID SYSTEM COMPONENT SIZING EXAMPLE

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 35. DEGREES IS 300. SQ. FT.
COLLECTOR TYPE = USER DEFINED, LIQUID TYPE
FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	691.	119.	0.	823.	2777.	967.	-915.
2	760.	131.	0.	809.	243.	967.	1802.
3	836.	144.	0.	793.	230.	967.	-95.
4	919.	158.	0.	776.	233.	967.	-36.
5	1011.	174.	0.	757.	237.	967.	26.
6	1112.	192.	0.	736.	221.	967.	97.
7	1224.	211.	0.	713.	214.	967.	174.
8	1346.	232.	0.	687.	206.	967.	259.
9	1481.	255.	0.	659.	190.	967.	353.
10	1629.	280.	0.	628.	181.	967.	456.
11	1791.	309.	0.	594.	170.	967.	569.
12	1971.	339.	0.	557.	157.	967.	694.
13	2168.	373.	0.	516.	155.	967.	831.
14	2384.	411.	0.	471.	141.	967.	902.
15	2623.	452.	0.	421.	126.	967.	1148.
16	2885.	497.	0.	367.	110.	967.	1330.
17	3174.	547.	0.	307.	92.	967.	1531.
18	3491.	601.	0.	241.	72.	967.	1752.
19	3840.	661.	0.	168.	50.	967.	1995.
20	4224.	727.	0.	89.	26.	967.	2262.
TOTALS	39560.	6013.	0.	11111.	3362.	19340.	2556.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 2030.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 0.8 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT5 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 4777.03 DOLLARS

RATE OF RETURN ON NET CASH FLOW 102.3 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 45.4 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 63.4 MILLION BTUS

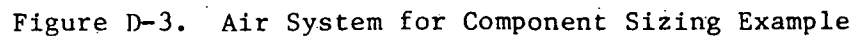
TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure D-2. (Cont.)

Assume everything is identical to the previous example, except that the air system shown in Figure D-3 is being considered. The designer accepts the default for parameters. A crossflow service hot water preheating coil is called for in the air handler, hence the designer must input its design water flow rate so that coil size can be determined. The SOLCOST output follows in Figure D-4.




```

T
AIR SYSTEM COMPONENT SIZING EXAMPLE
1,      7      7      7      7      7      7      7      7
      7      7      7      7 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
4,      2      2      2      2      2      2      2      2
      2      2      2      2 *
$ REFERENCE SYSTEM FUEL TYPE
6,      2
$ SOLAR AUXILIARY ENERGY FLAG
10,     23
$ COLLECTOR TYPE FLAG
13,     .5500E+02 *
$ COLLECTOR TILT ANGLES, DEGREES
14,     .4900E+00
$ COLLECTOR EFFICIENCY AT DT/Q = 0.
15,     .1200E+00
$ COLLECTOR EFFICIENCY AT (TIN-TAMB)/Q = 0.5
22,     .6000E+03
$ SPECIFIED COLLECTOR AREA WHEN LINE 21=1, 2 OR 3
25,     55
$ SITE LOCATION CODE
40,      2
$ BUILDING LOAD COMPUTE METHOD FLAG
41,      3
$ SERVICE HOT WATER LOAD - COMPUTE/INPUT FLAG
42,     .7100E+01
$ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)
43,     .1500E+04
$ BUILDING FLOOR AREA (SQ.FT)
49,     .9000E-01
$ LOAD FOR WATER HEATING, ETC. (MIL BTU/DAY)
56,     .4500E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
59,     .6000E-02
$ SOLAR SYSTEM MAINTENANCE (FRACTION OF INIT COST)
65,      1
$ FINANCIAL SCENARIO FLAG(RES,BUS,NFO): 1,2, OR 3
67,     .1000E+00
$ DISCOUNT RATE, FRACTION
68,     .1000E+00
$ MORTGAGE INTEREST RATE, PERCENT/YEAR
72,     .7000E-02
$ BUILDING FIRE INSURANCE RATE, (FRACTION OF I.C.)
73,     0.
$ PROPERTY TAX RATE, FRACTION OF INITIAL COST
74,     .3000E+00
$ INCOME TAX RATE, (FRACTION)
82,     .1000E+00
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .1420E+00 .1500E+02 .4200E-01 .5000E+02 .4300E-01 .1200E+03
     .3600E-01 .1000E+05 .1000E+00 *
$ ENERGY COST SCHEDULE-ELECTRICITY
190,     1
$ FLAG TO EXECUTE SUBSYSTEM SELECTION/SIZING ROUTINES
191,     1
$ FLAG FOR COUNTERFLOW LIQ-LIQ HX IN COLLECTION LOOP
192,     1
$ FLAG FOR CROSSFLOW AIR-LQ (OR LQ-AIR) HX IN COL LOOP
193,     1
$ FLAG TO INCLUDE COMPONENTS IN SYSTEM COSTS
204,     .6500E+02
$ TOTAL PIPE OR DUCT LENGTH IN COLLECTION LOOP
RUN

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Figure D-4. SOLCOST Output for the Air System Subcomponent Sizing Example

TITLE: AIR SYSTEM COMPONENT SIZING EXAMPLE

Figure D-4. (Cont.)

TITLE: AIR SYSTEM COMPONENT SIZING EXAMPLE

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --DENVER,CO LATITUDE = 39.8 TILT ANGLE 55.0
 AIR SOLAR SYSTEM WITH 50.0 LBS OF ROCK STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .49
 COL. EFFIC. = .12 AT DEL T/FLUX = .5 HR T 90 FT/DTU
 INPUT SPACE HEAT U-VALUE = 7.10 BTU/(F-DAY-SQ FT) FLOOR AREA= 1500. SQ FT
 INPUT SER. HOT WATER LOAD= .090 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	0.00	0.00
INITIAL COST,	\$/SQ FT	45.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	20.0	20.0
INTEREST RATE,	%	10.0	10.0
DISCOUNT RATE,	%	10.0	10.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.7	.7
MAINTENANCE RATE,	% OF IN COST	.6	.5
GEN INFLATION,	% PER YEAR	10.0	10.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	7	7	7	7	7	7	7	7	7	7	7	7
TRANSPORT EFFIC.	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
COL. INLET TEMP.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.	70.
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DAILY LOAD-MIL BTU	.46	.43	.39	.28	.18	.12	.09	.09	.13	.23	.36	.43
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	48.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	78.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	60.	60.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.	1127.	1530.	1879.	2135.	2351.	2273.	2044.	1727.	1301.	884.	732.
HEATING DEG. DAYS	1088.	902.	868.	525.	253.	80.	0.	0.	120.	408.	748.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA	
ELECTRIC	\$.142 PER UNIT FOR FIRST 15.0 UNITS
ELECTRIC	\$.062 PER UNIT FOR NEXT 50.0 UNITS
ELECTRIC	\$.043 PER UNIT FOR NEXT 120. UNITS
ELECTRIC	\$.036 PER UNIT FOR NEXT .100E+05 UNITS
ESCALATION RATE =	10.00 PERCENT

Figure D-4. (Cont.)

+++++DUCT AND FAN INPUT SUMMARY FOR AN AIR SYSTEM

COLLECTOR FLOW RATE	2.00 SCFM/SQFT-COL
COLLECTOR HEAD LOSS	.50 INCHES OF WATER
DUCT DESIGN AIR VELOCITY	700.00 FEET/MINUTE
MAXIMUM DUCT HEAD LOSS	.08000 IN/H2O/100FT
HEIGHT OF ROCKS IN ROCK BED	5.00 FEET
DENSITY OF THE BED ROCK	100.00 LBM/FT**3
POUNDS IF ROCK PER SQFT OF COLLECTOR	50.00 LBM/FT**2
ROCK BED HEAD LOSS	.15 INCHES OF WATER
CROSS FLOW HEAT EXCHANGER HEAD LOSS	.20 INCHES OF WATER
TOTAL DUCT LENGTH	65.00 FEET
DUCT COST	4.00 DOLLARS PER FOOT
INSULATION FRICTION FACTOR	1.15
SITE ELEVATION	3000.00 FEET
NUMBER OF DAMPERS	4
NUMBER OF TURNS	6
COST OF A DAMPER	25.00 DOLLARS
COST OF A TURN	25.00 DOLLARS
EQUIVALENT DUCT LENGTH AT D=12IN-DAMPERS	.75 FEET
EQUIVALENT DUCT LENGTH AT D=12IN-TURNS	.50 FEET

FAN TABLE			
NUMBER	FAN HEAD(IN OF WATER)	FLOW RATE(CFM)	COST(\$)
1	0.00	140.00	25.00
1	.20	135.00	25.00
1	.40	121.00	25.00
1	.50	114.00	25.00
1	1.04	0.00	25.00
2	0.00	525.00	55.00
2	.20	475.00	55.00
2	.40	415.00	55.00
2	.50	387.00	55.00
2	1.15	0.00	55.00
3	.30	865.00	60.00
3	.40	825.00	60.00
3	.50	760.00	60.00
3	.60	660.00	60.00
3	.70	520.00	60.00
4	1.00	291.00	80.00
4	2.00	231.00	80.00
4	3.00	156.00	80.00
4	4.00	0.00	80.00
5	1.00	530.00	85.00
5	2.00	475.00	85.00
5	3.00	415.00	85.00
5	4.00	335.00	85.00
5	5.00	160.00	85.00
6	.13	1100.00	100.00
6	.25	1000.00	100.00
6	.38	890.00	100.00
6	.50	800.00	100.00
6	.75	475.00	100.00
6	1.00	0.00	100.00
7	1.50	1840.00	175.00
7	1.75	1735.00	175.00
7	2.00	1610.00	175.00
7	2.25	1457.00	175.00
7	2.50	1288.00	175.00
7	2.75	1047.00	175.00
8	.50	2100.00	180.00
8	.75	1980.00	180.00
8	1.00	1460.00	180.00
9	1.00	1200.00	210.00
9	2.00	1137.00	210.00
9	3.00	1069.00	210.00
9	4.00	1011.00	210.00
9	4.50	937.00	210.00
10	1.00	2137.00	330.00
10	3.00	1927.00	330.00
10	5.00	1711.00	330.00

Figure D-4. (Cont.)

+++++INPUT SUMMARY FOR CROSS FLOW HEAT EXCHANGER
(AS USED IN THE AIR HEATING SYSTEM)

CROSS FLOW HEAT EXCHANGER UA VS COST TABLE		
NUMBER----	UA(BTU/HR-DEGF)----	COST(\$)
1	197.00	45.00
2	295.50	50.00
3	394.00	55.00
4	492.50	63.00
5	591.00	77.00
6	700.00	84.00
7	886.50	85.00
8	985.00	100.00
9	1773.00	128.00
10	1940.00	140.00
11	3546.00	192.00

AIR COLLECTOR MANIFOLD SIZING FOR A 60.000 SQUARE FEET COLLECTOR
 MODULE SIZE = 20.000 SQUARE FEET
 NUMBER OF MODULES PER BRANCH = 1
 NUMBER OF BRANCHES = 3

BRANCH TAKEOFF ROUND DUCT DIAMETER = 5.00 IN
 BRANCH TAKEOFF SQUARE DUCT SIDE = 3.38 IN
 MAIN SUPPLY AND RETURN DUCT DIAMETER = 7.00 IN
 MAIN DUCT SIDE = 5.75 IN
 MAIN DUCT FLOW RATE = 143.75 ACFM

SIZING FOR BRANCH NUMBER 1

FLOW RATE EXITING BRANCH = 97.04 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 6.00 IN
 SQUARE MANIFOLD SIDE = 4.75 IN

SIZING FOR BRANCH NUMBER 2

FLOW RATE EXITING BRANCH = 40.92 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 5.00 IN
 SQUARE MANIFOLD SIDE = 3.38 IN

AIR COLLECTOR MANIFOLD SIZING FOR A 120.00 SQUARE FEET COLLECTOR
 MODULE SIZE = 20.000 SQUARE FEET
 NUMBER OF MODULES PER BRANCH = 1
 NUMBER OF BRANCHES = 6

BRANCH TAKEOFF ROUND DUCT DIAMETER = 5.00 IN
 BRANCH TAKEOFF SQUARE DUCT SIDE = 3.38 IN
 MAIN SUPPLY AND RETURN DUCT DIAMETER = 9.00 IN
 MAIN DUCT SIDE = 8.13 IN
 MAIN DUCT FLOW RATE = 293.51 ACFM

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 1

FLOW RATE EXITING BRANCH = 244.59 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 9.00 IN
 SQUARE MANIFOLD SIDE = 7.38 IN

SIZING FOR BRANCH NUMBER 2

FLOW RATE EXITING BRANCH = 195.67 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 8.00 IN
 SQUARE MANIFOLD SIDE = 6.63 IN

SIZING FOR BRANCH NUMBER 3

FLOW RATE EXITING BRANCH = 146.75 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 7.00 IN
 SQUARE MANIFOLD SIDE = 5.75 IN

SIZING FOR BRANCH NUMBER 4

FLOW RATE EXITING BRANCH = 97.84 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 6.00 IN
 SQUARE MANIFOLD SIDE = 4.75 IN

SIZING FOR BRANCH NUMBER 5

FLOW RATE EXITING BRANCH = 48.92 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 5.00 IN
 SQUARE MANIFOLD SIDE = 3.38 IN

AIR COLLECTOR MANIFOLD SIZING FOR A 100.00 SQUARE FEET COLLECTOR
 MODULE SIZE = 20.000 SQUARE FEET
 NUMBER OF MODULES PER BRANCH = 5
 NUMBER OF BRANCHES = 9

BRANCH TAKEOFF ROUND DUCT DIAMETER = 5.00 IN
 BRANCH TAKEOFF SQUARE DUCT SIDE = 3.38 IN

MAIN SUPPLY AND RETURN DUCT DIAMETER = 11.00 IN
 MAIN DUCT SIDE = 9.88 IN
 MAIN DUCT FLOW RATE = 440.26 ACFM

SIZING FOR BRANCH NUMBER 1

FLOW RATE EXITING BRANCH = 391.34 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 11.00 IN
 SQUARE MANIFOLD SIDE = 9.38 IN

SIZING FOR BRANCH NUMBER 2

FLOW RATE EXITING BRANCH = 342.42 ACFM

MANIFOLD DIAMETER AFTER BRANCH = 10.00 IN
 SQUARE MANIFOLD SIDE = 8.75 IN

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 3	
FLOW RATE EXITING BRANCH =	293.51 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	9.00 IN
SQUARE MANIFOLD SIDE =	9.13 IN
SIZING FOR BRANCH NUMBER 4	
FLOW RATE EXITING BRANCH =	244.59 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	9.00 IN
SQUARE MANIFOLD SIDE =	7.38 IN
SIZING FOR BRANCH NUMBER 5	
FLOW RATE EXITING BRANCH =	195.67 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	8.00 IN
SQUARE MANIFOLD SIDE =	6.63 IN
SIZING FOR BRANCH NUMBER 6	
FLOW RATE EXITING BRANCH =	146.75 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	7.00 IN
SQUARE MANIFOLD SIDE =	5.75 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	97.84 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	6.00 IN
SQUARE MANIFOLD SIDE =	4.75 IN
SIZING FOR BRANCH NUMBER 8	
FLOW RATE EXITING BRANCH =	48.92 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	5.00 IN
SQUARE MANIFOLD SIDE =	3.38 IN
AIR COLLECTOR MANIFOLD SIZING FOR A 240.00 SQUARE FEET COLLECTOR	
MODULE SIZE = 20 000 SQUARE FEET	
NUMBER OF MODULES PER BRANCH =	2
NUMBER OF BRANCHES =	6
BRANCH TAKEOFF ROUND DUCT DIAMETER =	6.00 IN
BRANCH TAKEOFF SQUARE DUCT SIDE =	4.75 IN
MAIN SUPPLY AND RETURN DUCT DIAMETER =	13.00 IN
MAIN DUCT SIDE =	11.38 IN
MAIN DUCT FLOW RATE =	587.01 ACFM

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 1

FLOW RATE EXITING BRANCH = 489.18 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 12.00 IN
 SQUARE MANIFOLD SIDE = 10.38 IN

SIZING FOR BRANCH NUMBER 2

FLOW RATE EXITING BRANCH = 391.34 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 11.00 IN
 SQUARE MANIFOLD SIDE = 9.38 IN

SIZING FOR BRANCH NUMBER 3

FLOW RATE EXITING BRANCH = 293.51 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 9.00 IN
 SQUARE MANIFOLD SIDE = 8.13 IN

SIZING FOR BRANCH NUMBER 4

FLOW RATE EXITING BRANCH = 195.67 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 8.00 IN
 SQUARE MANIFOLD SIDE = 6.63 IN

SIZING FOR BRANCH NUMBER 5

FLOW RATE EXITING BRANCH = 97.84 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 6.00 IN
 SQUARE MANIFOLD SIDE = 4.75 IN

AIR COLLECTOR MANIFOLD SIZING FOR A 300.00 SQUARE FEET COLLECTOR
 MODULE SIZE = 20.000 SQUARE FEET
 NUMBER OF MODULES PER BRANCH = 2
 NUMBER OF BRANCHES = 8
 BRANCH TAKEOFF ROUND DUCT DIAMETER = 6.00 IN
 BRANCH TAKEOFF SQUARE DUCT SIDE = 4.75 IN
 MAIN SUPPLY AND RETURN DUCT DIAMETER = 14.00 IN
 MAIN DUCT SIDE = 12.75 IN
 MAIN DUCT FLOW RATE = 233.77 ACFM

SIZING FOR BRANCH NUMBER 1

FLOW RATE EXITING BRANCH = 635.93 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 13.00 IN
 SQUARE MANIFOLD SIDE = 11.88 IN

SIZING FOR BRANCH NUMBER 2

FLOW RATE EXITING BRANCH = 538.10 ACFM
 MANIFOLD DIAMETER AFTER BRANCH = 12.00 IN
 SQUARE MANIFOLD SIDE = 10.88 IN

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 3	
FLOW RATE EXITING BRANCH =	440.26 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	11.00 IN
SQUARE MANIFOLD SIDE =	9.88 IN
SIZING FOR BRANCH NUMBER 4	
FLOW RATE EXITING BRANCH =	342.42 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	10.00 IN
SQUARE MANIFOLD SIDE =	8.75 IN
SIZING FOR BRANCH NUMBER 5	
FLOW RATE EXITING BRANCH =	244.59 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	9.00 IN
SQUARE MANIFOLD SIDE =	7.38 IN
SIZING FOR BRANCH NUMBER 6	
FLOW RATE EXITING BRANCH =	146.75 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	7.00 IN
SQUARE MANIFOLD SIDE =	5.75 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	48.92 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	5.00 IN
SQUARE MANIFOLD SIDE =	3.38 IN
AIR COLLECTOR MANIFOLD SIZING FOR A 360.00 SQUARE FEET COLLECTOR	
MODULE SIZE = 20.000 SQUARE FEET	
NUMBER OF MODULES PER BRANCH =	2
NUMBER OF BRANCHES =	9
BRANCH TAKEOFF ROUND DUCT DIAMETER =	6.00 IN
BRANCH TAKEOFF SQUARE DUCT SIDE =	4.75 IN
MAIN SUPPLY AND RETURN DUCT DIAMETER =	16.00 IN
MAIN DUCT SIDE =	14.00 IN
MAIN DUCT FLOW RATE =	880.52 ACFM
SIZING FOR BRANCH NUMBER 1	
FLOW RATE EXITING BRANCH =	782.69 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	15.00 IN
SQUARE MANIFOLD SIDE =	13.13 IN

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 2	
FLOW RATE EXITING BRANCH =	404.05 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	14.00 IN
SQUARE MANIFOLD SIDE =	12.38 IN
SIZING FOR BRANCH NUMBER 3	
FLOW RATE EXITING BRANCH =	507.01 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	13.00 IN
SQUARE MANIFOLD SIDE =	11.38 IN
SIZING FOR BRANCH NUMBER 4	
FLOW RATE EXITING BRANCH =	409.18 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	12.00 IN
SQUARE MANIFOLD SIDE =	10.38 IN
SIZING FOR BRANCH NUMBER 5	
FLOW RATE EXITING BRANCH =	391.34 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	11.00 IN
SQUARE MANIFOLD SIDE =	9.38 IN
SIZING FOR BRANCH NUMBER 6	
FLOW RATE EXITING BRANCH =	293.51 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	9.00 IN
SQUARE MANIFOLD SIDE =	8.13 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	195.67 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	8.00 IN
SQUARE MANIFOLD SIDE =	6.63 IN
SIZING FOR BRANCH NUMBER 8	
FLOW RATE EXITING BRANCH =	97.84 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	6.00 IN
SQUARE MANIFOLD SIDE =	4.75 IN
AIR COLLECTOR MANIFOLD SIZING FOR A 440.00 SQUARE FEET COLLECTOR	
MODULE SIZE = 20.000 SQUARE FEET	3
NUMBER OF MODULES PER BRANCH =	8
NUMBER OF BRANCHES =	
BRANCH TAKEOFF ROUND DUCT DIAMETER =	7.00 IN
BRANCH TAKEOFF SQUARE DUCT SIDE =	5.75 IN
MAIN SUPPLY AND RETURN DUCT DIAMETER =	17.00 IN
MAIN DUCT SIDE =	15.38 IN
MAIN DUCT FLOW RATE =	1076.19 ACFM

Figure D-4. (Cont.)

SIZING FOR BRANCH NUMBER 1	
FLOW RATE EXITING BRANCH =	929.44 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	14.00 IN
SQUARE MANIFOLD SIDE =	14.38 IN
SIZING FOR BRANCH NUMBER 2	
FLOW RATE EXITING BRANCH =	782.69 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	15.00 IN
SQUARE MANIFOLD SIDE =	13.13 IN
SIZING FOR BRANCH NUMBER 3	
FLOW RATE EXITING BRANCH =	635.93 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	13.00 IN
SQUARE MANIFOLD SIDE =	11.88 IN
SIZING FOR BRANCH NUMBER 4	
FLOW RATE EXITING BRANCH =	489.18 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	12.00 IN
SQUARE MANIFOLD SIDE =	10.30 IN
SIZING FOR BRANCH NUMBER 5	
FLOW RATE EXITING BRANCH =	342.42 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	10.00 IN
SQUARE MANIFOLD SIDE =	8.75 IN
SIZING FOR BRANCH NUMBER 6	
FLOW RATE EXITING BRANCH =	195.67 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	8.00 IN
SQUARE MANIFOLD SIDE =	6.63 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	40.92 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	5.00 IN
SQUARE MANIFOLD SIDE =	3.30 IN

Figure D-4. (Cont.)

AIR COLLECTOR MANIFOLD SIZING FOR A 500.00 SQUARE FEET COLLECTOR	
MODULE SIZE = 20.000	SQUARE FEET
NUMBER OF MODULES PER BRANCH =	3
NUMBER OF BRANCHES =	9
BRANCH TAKEOFF ROUND DUCT DIAMETER =	7.00 IN
BRANCH TAKEOFF SQUARE DUCT SIDE =	5.75 IN
MAIN SUPPLY AND RETURN DUCT DIAMETER =	18.00 IN
MAIN DUCT SIDE =	16.50 IN
MAIN DUCT FLOW RATE =	1222.95 ACFM
SIZING FOR BRANCH NUMBER 1	
FLOW RATE EXITING BRANCH =	1076.19 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	17.00 IN
SQUARE MANIFOLD SIDE =	15.38 IN
SIZING FOR BRANCH NUMBER 2	
FLOW RATE EXITING BRANCH =	929.44 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	16.00 IN
SQUARE MANIFOLD SIDE =	14.38 IN
SIZING FOR BRANCH NUMBER 3	
FLOW RATE EXITING BRANCH =	782.69 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	15.00 IN
SQUARE MANIFOLD SIDE =	13.13 IN
SIZING FOR BRANCH NUMBER 4	
FLOW RATE EXITING BRANCH =	635.93 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	13.00 IN
SQUARE MANIFOLD SIDE =	11.88 IN
SIZING FOR BRANCH NUMBER 5	
FLOW RATE EXITING BRANCH =	489.18 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	12.00 IN
SQUARE MANIFOLD SIDE =	10.38 IN
SIZING FOR BRANCH NUMBER 6	
FLOW RATE EXITING BRANCH =	342.42 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	10.00 IN
SQUARE MANIFOLD SIDE =	8.75 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	195.67 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	8.00 IN
SQUARE MANIFOLD SIDE =	6.63 IN
SIZING FOR BRANCH NUMBER 8	
FLOW RATE EXITING BRANCH =	40.92 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	5.00 IN
SQUARE MANIFOLD SIDE =	3.38 IN

Figure D-4. (Cont.)
n-29

AIR COLLECTOR MANIFOLD SIZING FOR A 560.00		SQUARE FEET COLLECTOR
MODULE SIZE =	20.000	SQUARE FEET
NUMBER OF MODULES PER BRANCH =		3
NUMBER OF BRANCHES =		10
BRANCH TAKEOFF ROUND DUCT DIAMETER =		7.00 IN
BRANCH TAKEOFF SQUARE DUCT SIDE =		9.75 IN
MAIN SUPPLY AND RETURN DUCT DIAMETER =		19.00 IN
MAIN DUCT SIDE =		17.38 IN
MAIN DUCT FLOW RATE =		1369.70 ACFM
SIZING FOR BRANCH NUMBER 1		
FLOW RATE EXITING BRANCH =		1222.95 ACFM
MANIFOLD DIAMETER AFTER BRANCH =		18.00 IN
SQUARE MANIFOLD SIDE =		16.50 IN
SIZING FOR BRANCH NUMBER 2		
FLOW RATE EXITING BRANCH =		1076.19 ACFM
MANIFOLD DIAMETER AFTER BRANCH =		17.00 IN
SQUARE MANIFOLD SIDE =		15.38 IN
SIZING FOR BRANCH NUMBER 3		
FLOW RATE EXITING BRANCH =		929.44 ACFM
MANIFOLD DIAMETER AFTER BRANCH =		16.00 IN
SQUARE MANIFOLD SIDE =		14.38 IN
SIZING FOR BRANCH NUMBER 4		
FLOW RATE EXITING BRANCH =		782.69 ACFM
MANIFOLD DIAMETER AFTER BRANCH =		15.00 IN
SQUARE MANIFOLD SIDE =		13.13 IN
SIZING FOR BRANCH NUMBER 5		
FLOW RATE EXITING BRANCH =		635.93 ACFM
MANIFOLD DIAMETER AFTER BRANCH =		13.00 IN
SQUARE MANIFOLD SIDE =		11.00 IN
SIZING FOR BRANCH NUMBER 6		

Figure D-4. (Cont.)

FLOW RATE EXITING BRANCH =	489.18 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	12.00 IN
SQUARE MANIFOLD SIDE =	10.38 IN
SIZING FOR BRANCH NUMBER 7	
FLOW RATE EXITING BRANCH =	342.42 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	10.00 IN
SQUARE MANIFOLD SIDE =	8.75 IN
SIZING FOR BRANCH NUMBER 8	
FLOW RATE EXITING BRANCH =	195.67 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	8.00 IN
SQUARE MANIFOLD SIDE =	6.63 IN
SIZING FOR BRANCH NUMBER 9	
FLOW RATE EXITING BRANCH =	40.92 ACFM
MANIFOLD DIAMETER AFTER BRANCH =	5.00 IN
SQUARE MANIFOLD SIDE =	3.38 IN

Figure D-4. (Cont.)

+++++THIS IS AN AIR SYSTEM

COLLECTOR AREA	60.	120.	180.	240.	300.	360.	440.	500.	560.
DUCT DIAMETER (INCHES)	7.00	9.00	11.00	13.00	14.00	16.00	17.00	18.00	19.00
SQUARE DUCT SIDE (IN)	5.75	8.13	9.88	11.38	12.75	14.00	15.38	16.50	17.38
ROCK BOX CROSS SECTION AREA	6.0	12.0	18.0	24.0	30.0	36.0	44.0	50.0	56.0
SYSTEM HEAD LOSS (INCHES)	.90	.90	.89	.88	.88	.87	.87	.87	.87
SUBCOMPONENT COST	760.	1060.	1360.	1660.	1960.	2260.	2560.	2860.	3160.
FAN COST (DOLLARS)	55.	85.	85.	175.	175.	175.	175.	330.	180.
FAN SELECTION (NUMBER)	2	5	5	7	7	7	7	10	8
CROSS FLOW HX UA (BTU/DEG-F-HR)	53.	105.	159.	212.	266.	321.	394.	450.	505.
CROSS FLOW HX COST (\$)	45.	45.	45.	50.	50.	55.	63.	63.	77.
CROSS FLOW HX EFFECTIVENESS	.300	.300	.300	.300	.300	.300	.300	.300	.300
CROSS FLOW HX SELECTION	1	1	1	2	2	3	4	4	5

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	60.	120.	180.	240.	300.	360.	440.	500.	560.
STORAGE SIZE	2.	3.	5.	6.	8.	9.	11.	13.	14.
COMPONENT COSTS	860.	1190.	1490.	1805.	2105.	2390.	2680.	2950.	3217.
STORAGE COSTS	75.	150.	225.	300.	375.	450.	525.	600.	675.
COLLECTOR COSTS	2700.	5400.	8100.	10800.	13500.	16200.	19000.	22500.	25200.
FIXED COSTS	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL COSTS	3635.	6740.	9815.	12305.	15360.	18240.	21040.	24070.	27617.

Figure D-4. (Cont.)

TITLE: AIR SYSTEM COMPONENT SIZING EXAMPLE

SYSTEM PERFORMANCE AND COST SUMMARY FOR 55.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
60.0	.175	3635.00	55.6	276.23	1758.21
120.0	.334	6740.00	26.0	696.61	4159.41
180.0	.453	9815.00	13.7	322.39	4047.15
240.0	.557	12385.00	7.8	-339.88	3741.32
300.0	.639	15360.00	1.6	-1002.12	1023.89
360.0	.713	18240.00	0.0	-3526.45	-2003.50
440.0	.790	21848.00	0.0	-5604.44	-6205.12
500.0	.858	24078.00	0.0	-7746.92	-10601.81
560.0	.915	27617.00	0.0	-9444.28	-13977.73

ENERGY BALANCE BY MONTH FOR 120.0 SQ. FT. COLLECTOR

MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.162	626.8	2.33	12.05	14.38
2	.193	695.0	2.34	9.79	12.13
3	.221	714.4	2.66	9.30	12.03
4	.320	736.3	2.65	5.64	8.29
5	.508	748.8	2.79	2.70	5.48
6	.847	836.2	3.01	.54	3.55
7	1.000	911.8	2.79	0.00	2.79
8	1.000	932.9	2.79	0.00	2.79
9	.853	942.6	3.39	.58	3.98
10	.450	863.5	3.21	3.92	7.14
11	.220	663.5	2.39	8.49	10.88
12	.162	588.9	2.19	11.29	13.48
ANNUAL	.336		32.54	64.39	96.92

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR CORROSION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 10.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure D-4. (Cont.)

TITLE: AIR SYSTEM COMPONENT SIZING EXAMPLE

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 35. DEGREES IS 120. SQ. FT.
COLLECTOR TYPE = WATER DEFINED, AIR TYPE
FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	351.	88.	0.	607.	1730.	713.	-674.
2	386.	96.	0.	596.	179.	713.	-243.
3	425.	106.	0.	584.	175.	713.	-218.
4	467.	117.	0.	572.	171.	713.	-190.
5	514.	128.	0.	557.	167.	713.	-159.
6	565.	141.	0.	542.	163.	713.	-125.
7	622.	155.	0.	525.	157.	713.	-88.
8	684.	171.	0.	506.	152.	713.	-47.
9	752.	188.	0.	485.	146.	713.	-1.
10	827.	207.	0.	463.	139.	713.	47.
11	910.	227.	0.	438.	131.	713.	102.
12	1001.	250.	0.	410.	123.	713.	162.
13	1101.	275.	0.	380.	114.	713.	228.
14	1211.	302.	0.	347.	104.	713.	301.
15	1333.	333.	0.	310.	93.	713.	380.
16	1466.	366.	0.	270.	81.	713.	460.
17	1612.	403.	0.	226.	68.	713.	565.
18	1774.	443.	0.	177.	53.	713.	671.
19	1951.	487.	0.	124.	37.	713.	788.
20	2146.	536.	0.	65.	19.	713.	917.
TOTALS	20098.	5019.	0.	8184.	4002.	14260.	4165.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 1540.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 11.2 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT5 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS 696.61 DOLLARS

RATE OF RETURN ON NET CASH FLOW 27.0 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 33.6 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 32.5 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure D-4. (Cont.)

APPENDIX E. COMBINED OPTIMIZATION OF SPACE HEATING LOADS FOR WINDOWS, INSULATION, DOORS, ETC. AND THE SOLAR COLLECTOR AREA

Introduction

When load variables such as windows and insulation types are included in the optimization of a conventional or solar space heating system, the overall solar cost is lower than that resulting from optimization of a heat supply system for a fixed load system. This appendix presents a simple, straightforward algorithm for optimizing the trade off between construction and fuel costs in a conventional heating system or between construction, fuel and collector costs in active solar systems. The methodology which follows was developed by C. Dennis Barley and was implemented on small handheld calculators for easy use by the engineering and/or design community. When Mr. Barley developed this procedure, he assumed continuity and uniformity in some of the parameters which are not continuously defined in the SOLCOST program; one of these assumptions is that the fuel cost per unit is constant. SOLCOST allows for the user to define the fuel costs in a piecewise linear fashion. That is, the average fuel cost per unit may be different for different loads. Also inherent in Mr. Barley's development is the assumption that non-modular collector areas could be considered to be optimum. These assumptions have been removed to make the following development more general. A cost was paid since this development is more general. An iterative procedure must be used if the cost of fuel is not constant, or the collector area must be an integer multiple of the module size.

The design heat load (UA) of a building may be defined by Equation E-1. This equation adds up all of the conductances through the enclosure shell increments, that is, walls, windows and/or doors and then includes parameters for infiltration losses through cracks in the walls and around windows and doors, etc. This UA value is used to calculate the design load of a building and can be easily modified using ASHRAE techniques to represent the average UA value. For those segments of the external shell which have associated infiltration rates with them, the U_i can be transformed to an effective U' value as shown in Eqn. E-2.

$$UA = \underbrace{\sum_{i=1}^N U_i A_i}_{\text{conduction}} + \underbrace{\rho C_p \sum_{j=1}^M V_j}_{\text{infiltration}} \quad (E-1)$$

U_i = conductance of i^{th} element

A_i = area of i^{th} element

ρ = density of air

C_p = specific heat of air

V_j = leakage rate of j^{th} leak

$$U_i' = U_i + \frac{V_i \rho C_p}{A_i} \quad (E-2)$$

This effective U_i' value would remain the same as shown in (Eqn.) E-3 for segments of the shell such as walls.

$$U_i' = U_i \quad (E-3)$$

The individual U_i' 's and V_j 's to be considered for the optimization process are the heat load contributing elements of the shell. That is, should R3, R7, R9 or R16 and so on be considered, or should single-pane, double-pane, or triple-pane windows be considered and similarly for doors; a foam core, solid wood, no core, etc. Equation E-4 shows the resultant UA as modified to incorporate those sections of the shell which have associated infiltration rates.

$$UA = \underbrace{\sum_{i=1}^N U_i' A_i}_{\text{conduction}} + \underbrace{\rho C_p \sum_{j=1}^M V_j}_{\text{infiltration}} \quad (E-4)$$

The cost of building this shell is given by A-5; this particular cost is not the total cost of the external portions of the building. It is the cost only of those candidate pieces which are to be considered in the optimization process. E-6 gives the total cost for the thermal system (C_T) in present worth form.

$$C_e = \underbrace{\sum_{i=1}^N A_i C_{u_i}}_{\text{surface costs}} + \underbrace{\sum_{j=1}^M C_{v_j}}_{\text{infiltration costs}} \quad (E-5)$$

A_i = area of i^{th} segment

C_{u_i} = cost of i^{th} shell portion for conduction

C_{v_j} = cost of j^{th} shell portion for infiltration

$$C_T = \left(C_e + \frac{C_h}{\text{cost of furnace}} \right) E_1 + \frac{L C_f}{\text{fuel costs}} E_4 \quad (E-6)$$

C_h = space heating system fixed costs

L = heating load

C_f = cost of fuel per unit

E_1 and E_4 are multipliers to bring all of these costs to present worth. The inputs to generate these economic multipliers are discount rates, inflation rates, etc., and are currently in the SOLCOST program. No further explanation will be given as to how to generate them in this development. By combining E-5 and E-6, equation E-7 is generated. It has been reorganized to indicate the various contributions to total thermal system cost expressed in present worth.

$$\begin{aligned}
 C_T = & \frac{\sum_{i=1}^N [A_i (U_i \text{ DD } C_f E_4 + C_{u_i} E_1)]}{\text{conduction and shell costs}} \\
 & + \frac{\sum_{j=1}^M [U_j \rho C_p \text{ DD } C_f E_4 + C_{v_j} E_1]}{\text{infiltration costs}} \\
 & + \frac{C_h E_1}{\text{auxiliary fixed costs}}
 \end{aligned}
 \tag{E-7}$$

DD = number of degree days for heating.

To optimize the choice of insulation, windows or doors and also the choice of infiltration lessening features, it is desired to minimize C_T as shown mathematically in E-8. That is, select the individual u 's and v 's from each subsection choice or select the door and select the appropriate insulation and select the appropriate windows that will minimize the function C_T . This is further simplified if the user is willing to assume a fixed fuel cost; i.e., the fuel cost per unit does not vary as the fuel requirements are increased. A simplification results. The individual minimization selection of the insulation can be done independently of the cost minimization to select the doors and so on and so forth and finally the minimization to select the infiltration conserving features.

Min (C_T); $u = 1, 2, 3, \dots$, $v = 1, 2, 3, \dots$

u, v

if $C_f = \text{Constant}$

Min (C_T) = MIN (C_T , windows)

u, v

+ Min (C_T , doors)

+ Min (C_T , insulation)

+

.

.

+ Min (C_T , infiltration)

v

If the fuel cost per unit is not a constant and is a function of the amount consumed, this separation is no longer possible. An iterative procedure can be contrived, however, that allows one to assume a fixed fuel rate, do the minimizations separately for the windows, doors and so on; then calculate the effective fuel cost based on the total fuel requirements, and repeat the whole procedure again and then keep repeating it until the load or the total amount of required energy converges. Since in the neighborhood of the fuel utilization, fuel costs are fairly constant, this iterative procedure should converge rapidly (see Figure E-1).

For a solar system, the thermal cost in present worth (C_{Ts}) is shown in E-9.

$$\begin{aligned}
 C_{Ts} = & \frac{(C_b + A_c C_a) E_1}{\text{solar system costs}} + \frac{(C_b + A_c C_a) C_I E_2}{\text{solar system insurance costs}} \\
 & + \frac{(C_b + A_c C_a) C_m E_3}{\text{solar system maintenance, operating costs}} + \frac{L C_f E_4 (1-F)}{\text{auxiliary fuel costs}} + \frac{C_e E_1}{\text{shell costs}} \\
 & + \frac{(C_h) E_1}{\text{auxiliary installation costs}}
 \end{aligned} \quad (E-9)$$

$$L = UA(DD)$$

where

C_b = solar system fixed costs

C_a = solar system variable costs

A_c = collector area

C_m = solar system operating and maintenance costs (fixed, fraction of C_b)

F = solar load fraction

C_I = insurance costs

L is assumed to be a function of the UA and the number of degree days (DD). To minimize this function, that is, to choose the individual u 's, v 's and the collector area, becomes a more detailed task because of the coupling of the active solar system to the thermal envelope. However, there are simplifying procedures.

If the first partial of E-9 is taken with respect to the collector area (see E-11), one can observe that it is independent of the thermal envelope cost and areas. C_e does not appear in this equation. However, L (the total load) does. Mr. Barley demonstrated in his relative areas work that in the neighborhood of a collector area, the partial of F with respect to A_c is approximately equal to a constant over the area of the collector (see E-12). If this is plugged into E-11, the optimum collector area (A_{opt}) is approximately equal to a constant multiplied by the load.

$$\frac{\partial C_{T_s}}{\partial A_c} \quad (E-10)$$

$$\frac{\partial C_{T_s}}{\partial A_c} = C_a (E_1 + C_I E_2 + C_m E_3) - L C_f E_4 \frac{\partial F}{\partial A} \quad (E-11)$$

$$\frac{\partial F}{\partial A_c} \approx \frac{\text{Constant}}{A_c} \quad (E-12)$$

$$A_{opt} \approx \frac{C L C_f E_4}{C_a (E_1 + C_I E_2 + C_m E_3)} \quad (E-13)$$

As is shown in A-14, this reduces to: optimum area divided by load is a constant;

$$\frac{A_{\text{opt}}}{L} \approx \text{Constant} \quad (\text{E-14})$$

a very valuable reduction. If the optimum area is calculated for one particular load, then it is observed that the load has changed slightly (let's say it is increased by 10%), then to get the new optimum collector area, the old area only need be multiplied by an appropriate scaling factor (in this case 1.1). If one is considering the module size in the optimum process, only candidate areas are to be considered which are integer multiples of the modular size, then it becomes necessary to check the module based collector areas in the neighborhood of the calculated optimum. The two adjacent candidate areas must be checked to see which one is optimum. It cannot be construed that either one would be optimal just because the calculated optimal area is closer to it. This reduction allows the user to, first of all, check the optimal load fraction, which is presently done automatically in the SOLCOST program* and then to use the fraction derived and to minimize E-9. Once the optimal load fraction is known, the appropriate insulation, windows, doors and infiltration conserving features can be easily determined. Once the optimal thermal shell features have been discerned, the new load can be calculated and then the optimal collector area can be scaled because the load fraction will remain virtually constant. However, this is only true if the cost of fuel is to remain a constant. If it is not to remain a constant, then the whole process becomes iterative as illustrated in Figure E-1.

This iterative procedure will save a lot of computer time because the alternative would be to, in a brute force manner, consider all of the possible combinations and then depict the one with the best economic advantage. To use the SOLCOST Program and to evaluate all possible combinations would require possibly several hundred candidate sets to be considered. For example, if nine candidate collector areas are to be considered along with five candidate insulation values, three candidate windows and three candidate doors, this would lead to 405 possible system combinations. Using the iterative procedures as described, many fewer system evaluations will be evaluated, saving a lot of time and money.

The SOLCOST Program does not employ the iterative procedure, but only calculates the total discounted lifetime savings for each system option and the derived load fraction. The normal procedure would be for the user to run the SOLCOST Program to determine the optimum load fraction and the

* The SOLCOST program can choose the optimum load fraction based on rate of return. In that case this procedure is no longer valid. The SOLCOST program also calculates the cash flow summary to be a difference between the thermal system with solar and a reference system without solar. The reference system costs are independent of collector area. Consequently, they have no impact in the optimization process when optimizing versus discounted or undiscounted cash flow: not so when considering rate of return.

heat reducing features that give the heat savings then readjust the load and costs and run the program again and repeat this procedure until convergence is achieved. A design procedure is illustrated in the following example. Review it closely, for it will give insight into the mechanisms that cannot be explained explicitly.

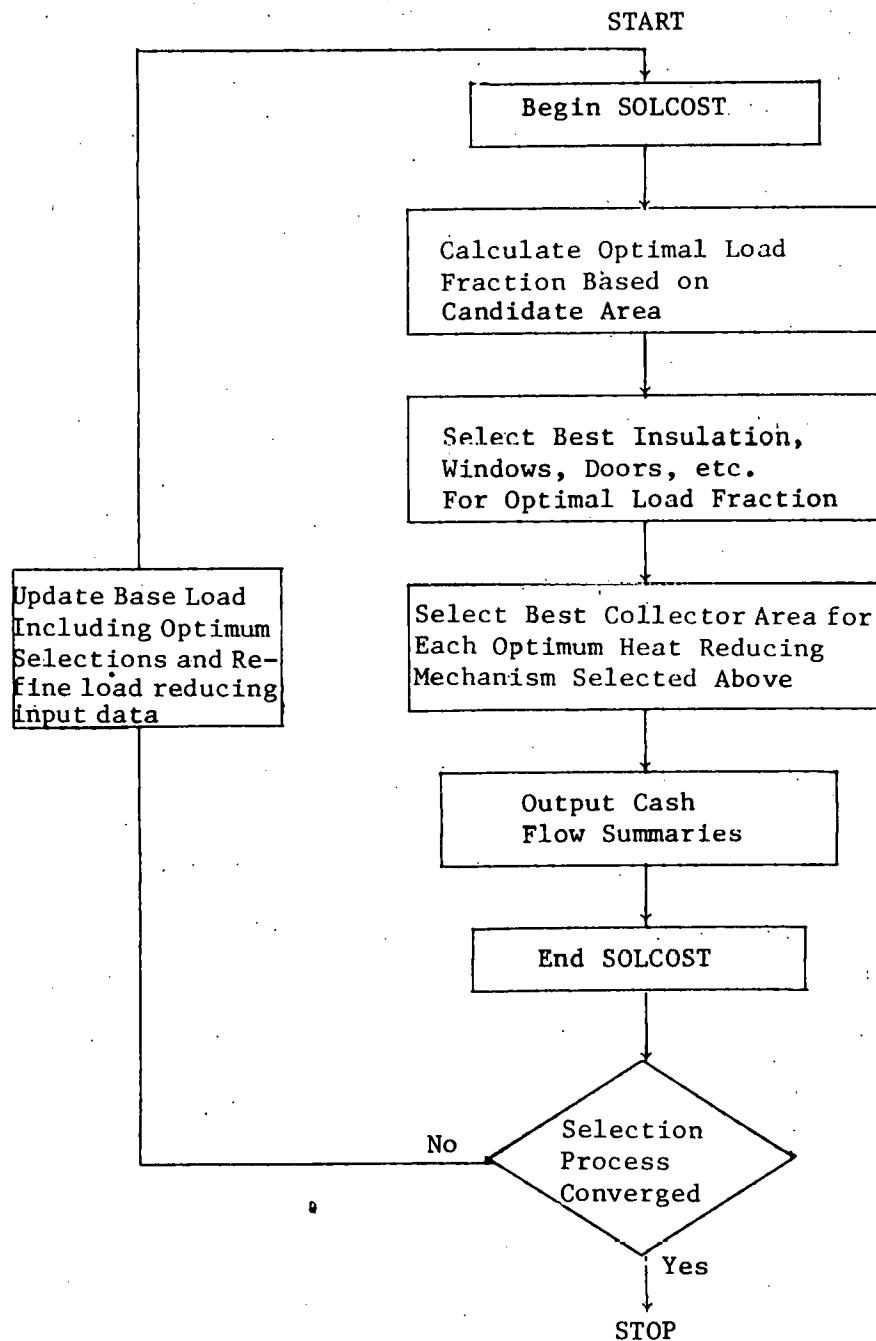


Figure E-1. Design Procedure Used When Selecting the Best Overall Solar and Conservation System.

Total Systems Optimization Example

To demonstrate the new total systems optimization methodology, an analysis was performed on a standard construction tract home with electric resistance space heat, located in Denver, Colorado. The residence was assumed to have aluminum sashed single glazed windows, standard 2 x 4 wall construction with R-11 insulation, an uninsulated floor over the crawl space, R-11 attic insulation, and built relatively tight to minimize infiltration losses. The input file for this sample problem as well as the SOLCOST output are listed in Figure E-2.

SOLCOST first analyzed and optimally sized a solar space heating system for the standard construction. Then, using the basic residence and selected solar system as a reference, several energy economizing features were considered. The expenses for each energy conservation measure were based on Denver's local retail and labor costs.

The first of these options shown in Figure E-2 was to increase the effective wall insulation value to R-19. The cost estimates for the decreased wall UA values were based on a R-5 rigid styrofoam insulation being attached externally to the sheathing rather than altering the standard 2 x 4 construction. This option proved to be uneconomically attractive having a net present worth of total lifetime costs less than the reference system.

The second and third energy conservation measures considered R-30 and R-19 blown attic insulation respectively. Again, the option examining R-30 insulation appeared less profitable than the reference system. However, the R-19 attic insulation proved nearly a breakeven choice, having a net present worth \$55 greater than the reference system.

The fourth energy economizing feature considered the effect of double glazed aluminum sashed windows in contrast to the single pane on the reference system. This option appeared to be attractive in that it had a net present worth \$727 greater than the reference system.

In the last two options considered, the residence was analyzed with double and triple glazed wooden sashed windows. These options, again proved less profitable than the reference system. In fact, to increase the net present worth of the total system, SOLCOST decreased the solar system array size reducing the initial capital costs.

The sample example illustrating the optimization methodology was repeated and shown in Figure E-3. However, the residence was assumed to have a natural gas forced air heating system, instead of electric strip heaters. Only the double glazed aluminum sashed windows appeared to be an economically viable choice, demonstrating that natural gas is still a cheap source of energy.

```

T
OPTIMIZATION SAMPLE ANALYSIS
1,      1      1      1      1      1      1      1      1
      1      1      1      1 *
$ SOLAR SYSTEM TYPE FLAGS BY MONTH
2,      .9000E+00      .9000E+00      .9000E+00      .9000E+00      .9000E+00      .9000E+00
      .9000E+00      .9000E+00      .9000E+00      .9000E+00      .9000E+00      .9000E+00 *
$ AVG MONTHLY TRANSPORT EFFIC/COP - SOLAR SYSTEM
4,      2      2      2      2      2      2      2      2
      2      2      2      2 *
$ REFERENCE SYSTEM FUEL TYPE
6,      2
$ SOLAR AUXILIARY ENERGY FLAG
10,     2
$ COLLECTOR TYPE FLAG
13,     .5500E+02 *
$ COLLECTOR TILT ANGLES, DEGREES
25,     55
$ SITE LOCATION CODE
42,     .4900E+01
$ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)
43,     .1690E+04
$ BUILDING FLOOR AREA (SQ.FT)
55,     .1000E+04
$ SOLAR SYSTEM FIXED COST, DOLLARS
56,     .3000E+02
$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT
57,     .2000E+01
$ LIQUID STORAGE COST (DOLLARS/GALLON)
65,     1
$ FINANCIAL SCENARIO FLAG(RES,BUS,NPO): 1,2, OR 3
68,     .1200E+00
$ MORTGAGE INTEREST RATE, PERCENT/YEAR
69,     .3000E+02
$ LOAN TERM, YEARS
74,     .3000E+00
$ INCOME TAX RATE, (FRACTION)
82,     .1200E+00
$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES
91,     .6000E-01      .3500E+02      .4500E-01      .4000E+02      .3080E-01      .4250E+03
      .2230E-01      .1000E+17      .1000E+00 *
$ ENERGY COST SCHEDULE-ELECTRICITY
240,    2
$ TOTAL SYSTEMS OPTIMIZATION FLAG
271,    .4750E+01      .5340E+03 *
$ PAIRS (NEW LOAD , COST) FOR WALL INSULATION
272,    .4410E+01      .5400E+03      .4600E+01      .1580E+03 *
$ PAIRS (NEW LOAD , COST) FOR CEILING INSULATION
273,    .3760E+01      .2900E+03      .3620E+01      .1792E+04      .3350E+01      .2256E+04 *
$ PAIRS (NEW LOAD , COST) FOR WINDOW INSULATION
RUN

```

Figure E-2. Total Energy System Optimization
Example for the Denver Area.

TITLE: OPTIMIZATION SAMPLE ANALYSIS

----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES----

LOCATION --DENVER,CO LATITUDE = 39.8 TILT ANGLE= 55.0
 LIQUID SOLAR SYSTEM WITH 1.5 GAL. STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .67
 COL. EFFIC. = .30 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SPACE HEAT U-VALUE = 4.90 BTU/(F-DAY-SQ FT) FLOOR AREA= 1690. SQ FT
 INPUT SER. HOT WATER LOAD= 0.000 MILLION BTUS/DAY
 AUXILIARY ENERGY IS ELECTRIC LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	1000.00	0.00
INITIAL COST,	\$/SQ FT	30.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	30.0	30.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	12.0	12.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	1	1	1	1	1	1	1	1	1	1	1	1
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC	ELEC
REF. SYSTEM EFFIC.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DAILY LOAD-MIL BTU	.29	.27	.23	.14	.07	.02	.00	.00	.03	.11	.21	.27
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	48.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	78.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	68.	68.	71.	71.	67.	65.
DAILY HOR. INSOL.	840.	1127.	1530.	1879.	2135.	2351.	2273.	2044.	1727.	1301.	884.	732.
HEATING DEG. DAYS	1088.	902.	868.	525.	253.	80.	0.	0.	120.	408.	768.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

ELECTRIC	\$.060 PER UNIT FOR FIRST	35.0	UNITS
ELECTRIC	\$.045 PER UNIT FOR NEXT	40.0	UNITS
ELECTRIC	\$.031 PER UNIT FOR NEXT	425.	UNITS
ELECTRIC	\$.022 PER UNIT FOR NEXT	1000+1/	UNITS

ESCALATION RATE = 10.00 PERCENT

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

SOLAR SYSTEM COST SUMMARY TABLE

COLLECTOR AREA	40.	100.	140.	200.	260.	300.	360.	400.	460.
STORAGE SIZE	60.	150.	210.	300.	390.	450.	540.	600.	690.
STORAGE COSTS	120.	300.	420.	600.	780.	900.	1080.	1200.	1380.
COLLECTOR COSTS	1200.	3000.	4200.	6000.	7800.	9000.	10800.	12000.	13800.
FIXED COSTS	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.
TOTAL COSTS	2320.	4300.	5620.	7600.	9580.	10900.	12880.	14200.	16180.

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

SYSTEM PERFORMANCE AND COST SUMMARY FOR 55.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
40.0	.151	2320.00	0.0	-809.64	-1941.20
100.0	.335	4300.00	0.0	-1263.00	-2641.85
140.0	.446	5420.00	0.0	-1623.79	-3270.32
200.0	.578	7600.00	0.0	-2442.71	-5021.79
260.0	.699	9580.00	0.0	-3365.59	-7064.41
300.0	.770	10900.00	0.0	-4199.77	-8759.89
360.0	.877	12880.00	0.0	-5473.49	-11162.87
400.0	.918	14200.00	0.0	-6591.64	-13533.72
460.0	.968	16180.00	0.0	-8251.10	-17039.19

ENERGY BALANCE BY MONTH FOR 40.0 SQ. FT. COLLECTOR

MONTH ---	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MIL BTU/MO)	AUXILIARY ENERGY (MIL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MIL BTU/MO)
1	.007	628.6	.78	8.23	9.01
2	.106	705.1	.79	6.68	7.47
3	.123	711.8	.88	6.31	7.19
4	.171	620.4	.74	3.60	4.35
5	.289	487.8	.60	1.49	2.10
6	.919	507.4	.61	.05	.66
7	1.000	61.2	.00	0.00	.00
8	1.000	88.5	.00	0.00	.00
9	.767	634.9	.76	.23	.99
10	.252	686.4	.85	2.53	3.38
11	.123	649.6	.78	5.58	6.36
12	.087	585.5	.73	7.59	8.31
ANNUAL	.151		7.53	42.29	49.82

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS = PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 55° DEGREES IS 40. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVERS, PAINT
FINANCIAL SCENARIO--RESIDENCE

***** CASH FLOW SUMMARY *****

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	54.	23.	0.	251.	739.	259.	-232.
2	60.	26.	0.	250.	75.	259.	511.
3	66.	29.	0.	248.	75.	259.	-150.
4	72.	33.	0.	247.	74.	259.	-147.
5	80.	37.	0.	246.	74.	259.	-144.
6	88.	41.	0.	244.	73.	259.	-141.
7	96.	46.	0.	242.	73.	259.	-138.
8	106.	51.	0.	240.	72.	259.	-135.
9	117.	57.	0.	238.	71.	259.	-132.
10	128.	64.	0.	235.	71.	259.	-128.
11	141.	72.	0.	232.	70.	259.	-124.
12	155.	81.	0.	229.	69.	259.	-120.
13	171.	90.	0.	226.	68.	259.	-115.
14	188.	101.	0.	221.	66.	259.	-110.
15	206.	113.	0.	217.	65.	259.	-105.
16	227.	127.	0.	212.	64.	259.	-100.
17	250.	142.	0.	206.	62.	259.	-94.
18	275.	159.	0.	200.	60.	259.	-89.
19	302.	178.	0.	193.	58.	259.	-83.
20	333.	200.	0.	185.	55.	259.	-76.
TOTALS	3115.	1670.	0.	4562.	2034.	5180.	-1922.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 17.4 YEARS

PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT 5 YEARS

NET PRESENT WORTH OF SOLAR SAVINGS -809.64 DOLLARS

RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT

ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 15.1 PERCENT

ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 7.5 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

NOTE *** RATE OF RETURN ON THIS SOLAR INVESTMENT IS ZERO OR LESS, I.E., NOT ECONOMICAL

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

TOTAL SYSTEM OPTIMIZATION PACKAGE

COLLECTOR AREA = 40. 50-FT
 LOAD FRACTION = .1511
 SYSTEM COST = 2320. DOLLARS

SUMMARY FOR REFERENCE SYSTEM

FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-324.	23.	0.	251.	739.	259.	-232.
2	-357.	26.	0.	250.	75.	259.	132.
3	-392.	29.	0.	248.	75.	259.	-567.
4	-432.	33.	0.	247.	74.	259.	-606.
5	-475.	37.	0.	246.	74.	259.	-449.
6	-523.	41.	0.	244.	73.	259.	-697.
7	-575.	46.	0.	242.	73.	259.	-750.
8	-633.	51.	0.	240.	72.	259.	-807.
9	-696.	57.	0.	238.	71.	259.	071.
10	-766.	64.	0.	235.	71.	259.	-941.
11	-842.	72.	0.	232.	70.	259.	-1019.
12	-927.	81.	0.	229.	69.	259.	-1104.
13	-1019.	90.	0.	226.	68.	259.	-1198.
14	-1122.	101.	0.	221.	66.	259.	-1301.
15	-1234.	113.	0.	217.	65.	259.	-1416.
16	-1357.	127.	0.	212.	64.	259.	-1541.
17	-1493.	142.	0.	206.	62.	259.	-1680.
18	-1642.	159.	0.	200.	60.	259.	-1833.
19	-1807.	178.	0.	193.	58.	259.	-2001.
20	-1988.	200.	0.	185.	55.	259.	-2187.
TOTALS	-18604.	1670.	0.	4562.	2034.	5180.	-23659.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -8414. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS WALL INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 4.75 BTU/DEG-DAY-SQFT
COST = 534. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1472
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-317.	29.	13.	308.	760.	319.	-285. 82.
2	-349.	32.	15.	307.	97.	319.	-618.
3	-384.	36.	17.	306.	97.	319.	-658.
4	-422.	40.	19.	304.	97.	319.	-703.
5	-464.	45.	21.	302.	97.	319.	-752.
6	-511.	50.	24.	300.	97.	319.	-807.
7	-562.	56.	26.	298.	97.	319.	-866.
8	-618.	63.	30.	295.	97.	319.	-933.
9	-680.	71.	33.	293.	98.	319.	-1005.
10	-749.	79.	37.	289.	98.	319.	-1086.
11	-824.	89.	41.	286.	98.	319.	-1174.
12	-906.	99.	46.	282.	98.	319.	-1272.
13	-997.	111.	52.	277.	99.	319.	-1380.
14	-1096.	125.	58.	272.	99.	319.	-1499.
15	-1206.	139.	65.	267.	100.	319.	-1630.
16	-1327.	156.	73.	261.	100.	319.	-1775.
17	-1460.	175.	82.	254.	101.	319.	-1935.
18	-1606.	196.	92.	246.	101.	319.	-2111.
19	-1766.	219.	103.	237.	102.	319.	-2306.
20	-1943.	246.	115.	227.	103.	319.	-2520.
TOTALS	-18187.	2056.	962.	5611.	2636.	6380.	-25233.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -9071. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -657. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS CEILING INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 4.41 BTU/DEG-DAY-SQFT
COST = 540. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1381
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-300.	29.	13.	309.	761.	320.	-286.
2	-330.	32.	15.	308.	97.	320.	-98.
3	-363.	36.	17.	306.	97.	320.	-600.
4	-400.	40.	19.	305.	97.	320.	-639.
5	-440.	45.	21.	303.	97.	320.	-681.
6	-484.	50.	24.	301.	97.	320.	-728.
7	-532.	56.	27.	298.	98.	320.	-780.
8	-586.	63.	30.	296.	98.	320.	-838.
9	-644.	71.	33.	293.	98.	320.	-901.
10	-709.	79.	37.	290.	98.	320.	-970.
11	-780.	89.	42.	286.	99.	320.	-1047.
12	-858.	99.	47.	282.	99.	320.	-1132.
13	-944.	111.	53.	278.	99.	320.	-1225.
14	-1039.	125.	59.	273.	100.	320.	-1328.
15	-1143.	140.	66.	267.	100.	320.	-1442.
16	-1257.	157.	74.	261.	101.	320.	-1568.
17	-1383.	175.	83.	254.	101.	320.	-1706.
18	-1521.	196.	93.	246.	102.	320.	-1859.
19	-1673.	220.	104.	238.	102.	320.	-2028.
20	-1841.	246.	116.	228.	103.	320.	-2214.
TOTALS	-17227.	2059.	973.	5622.	2644.	6400.	-24294.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -0744. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -330. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS CEILING INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 2

ADJUSTED UA = 4.60 BTU/DEG-DAY-SQFT
COST = 150. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1432
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-310.	25.	4.	268.	745.	277.	-248.
2	-341.	28.	4.	267.	81.	277.	129.
3	-375.	31.	5.	265.	81.	277.	-568.
4	-412.	35.	6.	264.	81.	277.	-607.
5	-454.	39.	6.	262.	81.	277.	-649.
6	-499.	44.	7.	261.	80.	277.	-695.
7	-549.	49.	8.	259.	80.	277.	-746.
8	-604.	55.	9.	256.	80.	277.	-803.
9	-665.	61.	10.	254.	79.	277.	-865.
10	-731.	69.	11.	251.	79.	277.	-934.
11	-804.	77.	12.	248.	78.	277.	-1009.
12	-885.	86.	14.	245.	78.	277.	-1092.
13	-974.	97.	15.	241.	77.	277.	-1184.
14	-1071.	108.	17.	237.	76.	277.	-1286.
15	-1178.	121.	19.	232.	75.	277.	-1397.
16	-1296.	136.	22.	226.	74.	277.	-1520.
17	-1426.	152.	24.	220.	73.	277.	-1656.
18	-1569.	170.	27.	213.	72.	277.	-1806.
19	-1726.	191.	30.	206.	71.	277.	-1971.
20	-1898.	213.	34.	197.	69.	277.	-2153.
TOTALS	-17767.	1787.	284.	4872.	2210.	5540.	-23413.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -8359. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION 55. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 3.76 BTU/DEG-DAY-SQFT
COST = 280. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1208
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-267.	26.	7.	281.	750.	290.	-260.
2	-294.	29.	8.	280.	06.	290.	159.
3	-323.	33.	9.	278.	86.	290.	-535.
4	-356.	37.	10.	277.	86.	290.	-569.
5	-391.	41.	11.	275.	86.	290.	-606.
6	-430.	46.	12.	273.	86.	290.	-648.
7	-474.	51.	14.	271.	86.	290.	-693.
8	-521.	57.	15.	269.	85.	290.	-744.
9	-573.	64.	17.	266.	85.	290.	-799.
10	-631.	72.	19.	264.	85.	290.	-860.
11	-694.	81.	22.	260.	85.	290.	-928.
12	-763.	90.	24.	257.	04.	290.	-1002.
13	-840.	101.	27.	253.	84.	290.	-1084.
14	-924.	113.	31.	248.	84.	290.	-1175.
15	-1016.	127.	34.	243.	83.	290.	-1275.
16	-1118.	142.	38.	237.	83.	290.	-1385.
17	-1230.	159.	43.	231.	82.	290.	-1506.
18	-1353.	179.	48.	224.	82.	290.	-1640.
19	-1488.	200.	54.	216.	81.	290.	-1788.
20	-1637.	224.	60.	207.	80.	290.	-1952.
TOTALS	-15323.	1872.	503.	5110.	2349.	5800.	-2132.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -7687. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION 727. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 2

ADJUSTED UA = 3.62 BTU/DEG-DAY-SQFT
COST = 1792. DOLLARS

COLLECTOR AREA = 20. SQ-FT
LOAD FRACTION = .2119
SYSTEM COST = 1660. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-234.	35.	45.	373.	623.	386.	-345.
2	-258.	39.	50.	371.	126.	386.	-76.
3	-283.	43.	56.	370.	128.	386.	-606.
4	-312.	48.	63.	368.	129.	386.	-641.
5	-343.	54.	70.	365.	131.	386.	-680.
6	-378.	61.	79.	363.	133.	386.	-723.
7	-415.	68.	88.	360.	135.	386.	-770.
8	-457.	76.	99.	357.	137.	386.	-823.
9	-503.	85.	111.	354.	139.	386.	-881.
10	-553.	96.	124.	350.	142.	386.	-945.
11	-609.	107.	139.	346.	145.	386.	-1017.
12	-670.	120.	156.	341.	149.	386.	-1095.
13	-737.	134.	175.	336.	153.	386.	-1182.
14	-810.	151.	195.	330.	158.	386.	-1278.
15	-892.	169.	219.	323.	163.	386.	-1385.
16	-981.	189.	245.	315.	168.	386.	-1502.
17	-1079.	212.	275.	307.	174.	386.	-1633.
18	-1187.	237.	308.	297.	181.	386.	-1777.
19	-1306.	265.	345.	287.	189.	386.	-1936.
20	-1436.	297.	386.	275.	198.	386.	-2112.
TOTALS	-13443.	2486.	3228.	6788.	3501.	7720.	-23714.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 498.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -8739. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -325. DOLLARS

Figure E-2. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 3
 ADJUSTED UA = 3.35 BTU/DEG-DAY-SQFT
 COST = 2256. DOLLARS
 COLLECTOR AREA = 20. SQ-FT
 LOAD FRACTION = .1980
 SYSTEM COST = 1660. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
							-392.
1	-223.	39.	56.	423.	642.	438.	-114.
2	-245.	44.	63.	421.	145.	438.	-645.
3	-270.	49.	71.	419.	147.	438.	-680.
4	-297.	55.	79.	417.	149.	438.	-720.
5	-327.	62.	89.	415.	151.	438.	-764.
6	-360.	69.	99.	412.	153.	438.	-812.
7	-396.	77.	111.	409.	156.	438.	-866.
8	-435.	87.	125.	405.	159.	438.	-925.
9	-479.	97.	140.	401.	162.	438.	-991.
10	-527.	109.	156.	397.	166.	438.	-1064.
11	-580.	122.	175.	392.	170.	438.	-1144.
12	-638.	136.	196.	387.	175.	438.	-1233.
13	-702.	153.	220.	381.	180.	438.	-1332.
14	-772.	171.	246.	374.	186.	438.	-1441.
15	-849.	191.	276.	366.	193.	438.	-1561.
16	-934.	214.	309.	358.	200.	438.	-1695.
17	-1028.	240.	346.	348.	208.	438.	-1843.
18	-1131.	269.	387.	337.	217.	438.	-2007.
19	-1244.	301.	434.	325.	228.	438.	-2189.
20	-1369.	337.	486.	312.	239.	438.	-2390.
TOTALS	-12808.	2822.	4064.	7699.	4026.	8760.	-24808.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 498.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -9713. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION 777. DOLLAR

Figure E-2. (Cont.)

T

OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

1,	1	1	1	1	1	1	1	1
	1	1	1	1 *				
	\$ SOLAR SYSTEM TYPE FLAG BY MONTH							
2,	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00
	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00	.9000E+00 *
	\$ AVG MONTHLY TRANSPORT EFFIC/COP SOLAR SYSTEM							
4,	1	1	1	1	1	1	1	1
	1	1	1	1 *				
	\$ REFERENCE SYSTEM FUEL TYPE							
6,	1							
	\$ SOLAR AUXILIARY ENERGY FLAG							
10,	2							
	\$ COLLECTOR TYPE FLAG							
13,	.5500E+02 *							
	\$ COLLECTOR TILT ANGLES, DEGREES							
25,	55							
	\$ SITE LOCATION CODE							
42,	.4200E+01							
	\$ BUILDING HEAT LOSS FACTOR (BTU/DEG-DAY-SQ.FT)							
43,	.1670E+04							
	\$ BUILDING FLOOR AREA (SQ.FT)							
55,	.1000E+04							
	\$ SOLAR SYSTEM FIXED COST, DOLLARS							
56,	.3000E+02							
	\$ COST OF SOLAR SYSTEM, DOLLARS /SQ.FT							
57,	.2000E+01							
	\$ LIQUID STORAGE COST (DOLLARS/GALLON)							
65,	1							
	\$ FINANCIAL SCENARIO FLAG (RES, BUS, NPO): 1, 2, OR 3							
68,	.1200E+00							
	\$ MORTGAGE INTEREST RATE, PERCENT/YEAR							
69,	.3000E+02							
	\$ LOAN TERM, YEARS							
74,	.3000E+00							
	\$ INCOME TAX RATE, (FRACTION)							
82,	.1200E+00							
	\$ INFLATION FACTOR FOR MAINT, INSUR, PROP TAXES							
90,	.2400E+01 0.	.2219E+00	.1000E+02	.1500E+00 *				
	\$ ENERGY COST SCHEDULE-NAT GAS, LAST ENTRY=ESCAL.							
260,	2							
	\$ TOTAL SYSTEMS OPTIMIZATION FLAG							
271,	.4750E+01	.5340E+03 *						
	\$ PAIRS (NEW LOAD, COST) FOR WALL INSULATION							
272,	.4410E+01	.5400E+03	.4600E+01	.1500E+03 *				
	\$ PAIRS (NEW LOAD, COST) FOR CEILING INSULATION							
273,	.3760E+01	.2800E+03	.3620E+01	.1722E+04	.3350E+01	.2256E+04 *		
	\$ PAIRS (NEW LOAD, COST) FOR WINDOW INSULATION							

RUN

Figure E-3. Total Energy System optimization with everything the same as Figure E-2 except the auxiliary fuel is natural gas. E-21

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

-----LISTING OF USER INPUTS AND SOLCOST DEFAULT VALUES-----

LOCATION --DENVER,CO LATITUDE = 39.0 TILT ANGLE 55.0
 LIQUID SOLAR SYSTEM WITH 1.5 GAL. STORAGE PER SQ FT OF COLLECTOR
 COL. EFFIC. INTERCEPT = .67
 COL. EFFIC. = .30 AT DEL T/FLUX = .5 HR-F-SQ FT/BTU
 INPUT SPACE HEAT U-VALUE = 4.90 BTU/(F-DAY-SQ FT) FLOOR AREA= 1690. SQ FT
 INPUT SER. HOT WATER LOAD= 0.000 MILLION BTUS/DAY
 AUXILIARY ENERGY IS NAT. GAS LENGTH OF ANALYSIS 20.0 YEARS

		SOLAR SYSTEM	REFERENCE SYSTEM
INITIAL COST,	\$ FIXED	1000.00	0.00
INITIAL COST,	\$/SQ FT	30.00	-----
DOWN PAYMENT,	% OF IN. COST	10.0	10.0
LOAN TERM,	YEARS	30.0	30.0
INTEREST RATE,	%	12.0	12.0
DISCOUNT RATE,	%	9.0	9.0
INCOME TAX RATE,	%	30.0	30.0
PROP. TAX RATE,	% OF IN COST	0.0	0.0
INSURANCE RATE,	% OF IN COST	.5	.5
MAINTENANCE RATE,	% OF IN COST	.5	.5
GEN INFLATION,	% PER YEAR	12.0	12.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SOLAR SYSTEM TYPE	1	1	1	1	1	1	1	1	1	1	1	1
TRANSPORT EFFIC.	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
REF. FUEL TYPE	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS	GAS
REF. SYSTEM EFFIC.	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
DAILY LOAD-MIL BTU	.29	.27	.23	.14	.07	.02	.00	.00	.03	.11	.21	.27
MEAN MIN TEMP., F	16.	19.	24.	34.	44.	52.	59.	57.	48.	37.	25.	19.
MEAN MAX TEMP., F	44.	46.	50.	61.	70.	80.	87.	86.	78.	67.	53.	46.
PERCENT POSS. SUN	67.	67.	65.	63.	61.	69.	68.	68.	71.	71.	67.	65.
DAILY HOR. INSOL.	040.1127	1530.1077	2135.2351	2273.2044	1727.1301	004.732						
HEATING DEG. DAYS	1088.	902.	868.	525.	253.	00.	0.	0.	120.	400.	760.	1004.
SUPPLY WATER, F	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.

ENERGY COST DATA

NAT. GAS	\$2.480 PER UNIT FOR FIRST	0.	UNITS
NAT. GAS	\$.222 PER UNIT FOR NEXT	1000	UNITS
ESCALATION RATE = 15.00 PERCENT			

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

SOLAR SYSTEM COST SUMMARY TABLE									
COLLECTOR AREA	40.	100.	140.	200.	260.	300.	360.	400.	460.
STORAGE SIZE	60.	150.	210.	300.	390.	450.	540.	600.	690.
STORAGE COSTS	120.	300.	420.	600.	780.	900.	1080.	1200.	1380.
COLLECTOR COSTS	1200.	3000.	4200.	6000.	7800.	9000.	10800.	12000.	13800.
FIXED COSTS	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.	1000.
TOTAL COSTS	2320.	4300.	5620.	7600.	9580.	10900.	12880.	14200.	16180.

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

SYSTEM PERFORMANCE AND COST SUMMARY FOR 55.0 TILT ANGLE

COLLECTOR AREA (SQ.FT.)	SOLAR ENERGY FRACTION	SOLAR SYSTEM COST \$	RATE OF RETURN ON EQUITY %	NET PRESENT WORTH OF SOLAR SAVINGS \$ (SEE NOTE 2)	LIFETIME COST SAVINGS (UNDISCOUNTED) \$
40.0	.151	2320.00	0.0	-1135.49	-2610.71
100.0	.335	4300.00	0.0	-1904.12	-4122.72
140.0	.446	5620.00	0.0	-2607.53	-5315.29
200.0	.578	7600.00	0.0	-3715.76	-7650.24
260.0	.699	9500.00	0.0	-4881.55	-10185.44
300.0	.770	10900.00	0.0	-5873.97	-12210.57
360.0	.877	12880.00	0.0	-7477.25	-15371.22
400.0	.918	14200.00	0.0	-8695.31	-17955.93
460.0	.968	16180.00	0.0	-10504.56	-22031.94

ENERGY BALANCE BY MONTH FOR 40.0 SQ. FT. COLLECTOR

MONTH	FRACTION BY SOLAR	AVERAGE USEFUL SOLAR PER DAY (BTU/DAY-SQ FT)	TOTAL USEFUL SOLAR ENERGY (MTL BTU/MO)	AUXILIARY ENERGY (MTL BTU/MO)	CONVENTIONAL SYSTEM ENERGY (MTL BTU/MO)
1	.087	428.6	.78	11.76	12.87
2	.106	705.1	.79	9.54	10.67
3	.123	711.8	.88	9.01	10.27
4	.171	670.4	.74	8.15	6.21
5	.289	487.8	.60	2.13	2.99
6	.919	507.4	.61	.08	.95
7	1.000	61.2	.00	0.00	.00
8	1.000	88.5	.00	0.00	.00
9	.767	634.9	.76	.33	1.42
10	.252	686.4	.85	3.61	4.83
11	.123	649.6	.78	7.97	9.09
12	.087	585.5	.73	10.84	11.88
ANNUAL	.151		7.53	60.41	71.17

NOTE 1 CONV. ENERGY AND SOLAR AUXILIARY ENERGY ARE GROSS VALUES
(I.E. THEY INCLUDE TANK INSULATION AND/OR COMBUSTION LOSS)

NOTE 2 NET PRESENT WORTH OF SOLAR SAVINGS PRESENT WORTH OF NET CASH
FLOWS (FOR A 9.0 % DISCOUNT RATE) MINUS THE DOWN PAYMENT

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

COLLECTOR SIZE OPTIMIZATION BY SOLCOST

BEST SOLAR COLLECTOR SIZE FOR TILT ANGLE OF 55. DEGREES IS 40. SQ. FT.
COLLECTOR TYPE = LIQUID, FLAT PLATE, 2 COVERS, PAINT
FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) FUEL/UTILITY SAVINGS	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	24.	23.	0.	251.	739.	259.	-232.
2	27.	26.	0.	250.	75.	259.	481.
3	32.	29.	0.	248.	75.	259.	-182.
4	36.	33.	0.	247.	74.	259.	-181.
5	42.	37.	0.	247.	74.	259.	-100.
6	48.	41.	0.	244.	73.	259.	-179.
7	55.	46.	0.	242.	73.	259.	-178.
8	63.	51.	0.	240.	72.	259.	-176.
9	73.	57.	0.	230.	71.	259.	-174.
10	84.	64.	0.	235.	71.	259.	-171.
11	97.	72.	0.	232.	70.	259.	-168.
12	111.	81.	0.	229.	69.	259.	-164.
13	120.	90.	0.	226.	68.	259.	-159.
14	147.	101.	0.	221.	66.	259.	-153.
15	169.	113.	0.	217.	64.	259.	-146.
16	194.	127.	0.	212.	62.	259.	-138.
17	223.	142.	0.	206.	60.	259.	-127.
18	257.	159.	0.	200.	58.	259.	-115.
19	295.	178.	0.	193.	55.	259.	-101.
20	340.	200.	0.	185.	50.	259.	-83.
TOTALS	2445.	1670.	0.	4562.	2034.	5180.	-2589.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

PAYBACK TIME FOR FUEL SAVINGS TO EQUAL TOTAL INVESTMENT ... 19.6 YEARS
PAYBACK TIME FOR NET CASH FLOW TO OFFSET DOWN PAYMENT5 YEARS
NET PRESENT WORTH OF SOLAR SAVINGS -1135.49 DOLLARS
RATE OF RETURN ON NET CASH FLOW 0.0 PERCENT
ANNUAL PORTION OF LOAD PROVIDED BY SOLAR ... 15.1 PERCENT
ANNUAL ENERGY SAVINGS WITH SOLAR SYSTEM 7.5 MILLION BTUS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F
ABOVE PAYBACK TIMES BASED ON UNDISCOUNTED DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS WALL INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 4.75 BTU/DEG-DAY-SQFT
COST = 534. DOLLARS

COLLECTOR AREA = 40. 30-FT
LOAD FRACTION = .1472
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. INSUR*	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-130.	29.	13.	300.	760.	319.	-285.
2	-149.	32.	15.	307.	97.	319.	-269.
3	-172.	36.	17.	306.	97.	319.	-446.
4	-198.	40.	19.	304.	97.	319.	-478.
5	-227.	45.	21.	302.	97.	319.	-515.
6	-262.	50.	24.	300.	97.	319.	-557.
7	-301.	56.	26.	298.	97.	319.	-605.
8	-346.	63.	30.	295.	97.	319.	-660.
9	-398.	71.	33.	293.	98.	319.	-723.
10	-458.	79.	37.	289.	98.	319.	-795.
11	-527.	89.	41.	286.	98.	319.	-878.
12	-606.	99.	46.	282.	98.	319.	-973.
13	-698.	111.	52.	277.	99.	319.	-1081.
14	-802.	125.	59.	272.	99.	319.	-1205.
15	-923.	139.	65.	267.	100.	319.	-1347.
16	-1061.	156.	73.	261.	100.	319.	-1509.
17	-1221.	175.	82.	254.	101.	319.	-1696.
18	-1404.	196.	92.	246.	101.	319.	-1909.
19	-1615.	219.	103.	237.	102.	319.	-2154.
20	-1857.	246.	115.	227.	103.	319.	-2434.
TOTALS	-13355.	2056.	962.	5611.	2636.	6380.	-20399.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -6079. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -690. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

TOTAL SYSTEM OPTIMIZATION PACKAGE

COLLECTOR AREA = 40. SQ-FT
 LOAD FRACTION = .1511
 SYSTEM COST = 2320. DOLLARS

SUMMARY FOR REFERENCE SYSTEM

FINANCIAL SCENARIO---RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-133.	23.	0.	251.	739.	259.	-232.
2	-153.	26.	0.	250.	75.	259.	323.
3	-176.	29.	0.	248.	75.	259.	-364.
4	-203.	33.	0.	247.	74.	259.	-390.
5	-233.	37.	0.	246.	74.	259.	-421.
6	-269.	41.	0.	244.	73.	259.	-456.
7	-309.	46.	0.	242.	73.	259.	-476.
8	-356.	51.	0.	240.	72.	259.	-541.
9	-409.	57.	0.	238.	71.	259.	-594.
10	-471.	64.	0.	235.	71.	259.	-654.
11	-541.	72.	0.	232.	70.	259.	-724.
12	-623.	81.	0.	229.	69.	259.	-803.
13	-716.	90.	0.	226.	68.	259.	-874.
14	-824.	101.	0.	221.	66.	259.	-998.
15	-948.	113.	0.	217.	65.	259.	-1118.
16	-1090.	127.	0.	212.	64.	259.	-1255.
17	-1253.	142.	0.	206.	62.	259.	-1412.
18	-1442.	159.	0.	200.	60.	259.	-1593.
19	-1658.	170.	0.	193.	58.	259.	-1800.
20	-1907.	200.	0.	185.	55.	259.	-2038.
TOTALS	-13714.	1670.	0.	4562.	2034.	5180.	-2311.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -6109. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS CEILING INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 4.41 BTU/DEG-DAY-SQFT
COST = 540. DOLLARS

COLLECTOR AREA = 40. SQ-FT

LOAD FRACTION = .1301

SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO---RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-121.	29.	13.	309.	761.	320.	-286.
2	-140.	32.	15.	300.	97.	320.	-277.
3	-161.	36.	17.	306.	97.	320.	-410.
4	-185.	40.	19.	305.	97.	320.	-436.
5	-213.	45.	21.	303.	97.	320.	-467.
6	-245.	50.	24.	301.	97.	320.	-502.
7	-282.	56.	27.	298.	98.	320.	-542.
8	-325.	63.	30.	296.	98.	320.	-587.
9	-374.	71.	33.	293.	98.	320.	-640.
10	-430.	79.	37.	290.	99.	320.	-700.
11	-495.	89.	42.	286.	99.	320.	-768.
12	-569.	99.	47.	282.	99.	320.	-846.
13	-654.	111.	53.	278.	99.	320.	-936.
14	-753.	125.	59.	273.	100.	320.	-1039.
15	-866.	140.	66.	267.	100.	320.	-1156.
16	-996.	157.	74.	261.	101.	320.	-1291.
17	-1145.	175.	83.	254.	101.	320.	-1445.
18	-1317.	196.	93.	246.	102.	320.	-1622.
19	-1515.	220.	104.	238.	102.	320.	-1824.
20	-1742.	246.	116.	229.	103.	320.	-2056.
TOTALS	-12528.	2059.	973.	5622.	2644.	6400.	-2321.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -4630. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -441. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS--NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS CEILING INSULATION

HEAT LOAD REDUCING FEATURE NUMBER 2

ADJUSTED UA = 4.30 BTU/DEG-DAY-SQ-FT
COST = 150. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1432
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. (INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-126.	25.	4.	260.	745.	277.	-240.
2	-145.	28.	4.	262.	81.	277.	-313.
3	-167.	31.	5.	265.	81.	277.	-399.
4	-192.	35.	6.	264.	81.	277.	-429.
5	-221.	39.	6.	262.	81.	277.	-463.
6	-254.	44.	7.	261.	80.	277.	-502.
7	-293.	49.	8.	259.	80.	277.	-546.
8	-337.	55.	9.	256.	80.	277.	-590.
9	-388.	61.	10.	254.	79.	277.	-656.
10	-446.	69.	11.	251.	79.	277.	-724.
11	-513.	77.	12.	248.	78.	277.	-801.
12	-590.	86.	14.	245.	78.	277.	-889.
13	-679.	97.	15.	241.	77.	277.	-991.
14	-781.	108.	17.	237.	76.	277.	-1107.
15	-890.	121.	19.	232.	75.	277.	-1240.
16	-1033.	136.	22.	226.	74.	277.	-1392.
17	-1188.	152.	24.	220.	73.	277.	-1567.
18	-1366.	170.	27.	213.	72.	277.	-1768.
19	-1571.	191.	30.	206.	71.	277.	-1998.
20	-1807.	213.	34.	197.	69.	277.	-2262.
TOTALS	-12995.	1787.	284.	4872.	2210.	5540.	-18440.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -6201. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -12. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 1

ADJUSTED UA = 3.76 BTU/DEG-DAY-SQFT
COST = 200. DOLLARS

COLLECTOR AREA = 40. SQ-FT
LOAD FRACTION = .1700
SYSTEM COST = 2320. DOLLARS

FINANCIAL SCENARIO---RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-106.	26.	7.	201.	750.	290.	-260.
2	-122.	29.	8.	200.	86.	290.	-343.
3	-140.	33.	9.	278.	86.	290.	-386.
4	-161.	37.	10.	277.	86.	290.	-412.
5	-185.	41.	11.	275.	86.	290.	-442.
6	-213.	46.	12.	273.	86.	290.	-476.
7	-245.	51.	14.	271.	86.	290.	-516.
8	-282.	57.	15.	269.	85.	290.	-561.
9	-325.	64.	17.	266.	85.	290.	-612.
10	-374.	72.	19.	264.	85.	290.	-671.
11	-430.	81.	22.	260.	85.	290.	-738.
12	-495.	90.	24.	257.	84.	290.	-816.
13	-569.	101.	27.	253.	84.	290.	-904.
14	-655.	113.	31.	248.	84.	290.	-1005.
15	-753.	127.	34.	243.	83.	290.	-1121.
16	-866.	142.	38.	237.	83.	290.	-1254.
17	-996.	159.	43.	231.	82.	290.	-1407.
18	-1146.	179.	49.	224.	82.	290.	-1551.
19	-1318.	200.	54.	216.	81.	290.	-1781.
20	-1515.	224.	60.	207.	80.	290.	-2010.
TOTALS	-10896.	1872.	505.	5110.	2349.	5800.	-16996.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 664.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -5729. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION 460. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 2

ADJUSTED UA = 3.62 BTU/DEG-DAY-SQFT
COST = 1792. DOLLARS

COLLECTOR AREA = 20. SQ-FT
LOAD FRACTION = .2119
SYSTEM COST = 1660. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

*** CASH FLOW SUMMARY ***

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-91.	35.	45.	373.	623.	386.	-345.
2	-105.	39.	50.	371.	126.	386.	-453.
3	-121.	43.	54.	370.	128.	386.	-478.
4	-139.	48.	63.	368.	129.	386.	-507.
5	-160.	54.	70.	365.	131.	386.	-540.
6	-184.	61.	79.	363.	133.	386.	-577.
7	-212.	68.	88.	360.	135.	386.	-619.
8	-244.	76.	99.	357.	137.	386.	-668.
9	-200.	85.	111.	354.	139.	386.	-723.
10	-322.	96.	124.	350.	142.	386.	-786.
11	-371.	107.	139.	346.	145.	386.	-858.
12	-427.	120.	156.	341.	149.	386.	-919.
13	-491.	134.	175.	336.	153.	386.	-1033.
14	-565.	151.	195.	330.	158.	386.	-1139.
15	-650.	169.	219.	323.	163.	386.	-1260.
16	-747.	189.	245.	315.	168.	386.	-1399.
17	-859.	212.	275.	307.	174.	386.	-1557.
18	-989.	237.	308.	297.	181.	386.	-1737.
19	-1137.	265.	345.	287.	189.	386.	-1943.
20	-1308.	297.	386.	275.	198.	386.	-2178.
TOTALS	-9402.	2486.	3228.	6780.	3501.	7720.	-19673.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 498.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)
NET CASH FLOW = A - B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -6971. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -782. DOLLARS

Figure E-3. (Cont.)

TITLE: OPTIMIZATION SAMPLE ANALYSIS-NATURAL GAS AUXILIARY

HEAT LOSS MECHANISM IS GLASS WINDOWS

HEAT LOAD REDUCING FEATURE NUMBER 3

ADJUSTED UA = 3.35 BTU/DEG-DAY-SQFT
COST = 2256. DOLLARS

COLLECTOR AREA = 20. SQ-FT
LOAD FRACTION = .1980
SYSTEM COST = 1660. DOLLARS

FINANCIAL SCENARIO--RESIDENCE

\$\$\$ CASH FLOW SUMMARY \$\$\$

YR	(A) AUXILIARY CASH FLOW	(B) MAINT. +INSUR.	(C) PROPERTY TAX	(D) ANNUAL INTEREST	(E) TAX SAVINGS	(F) LOAN PAYMENT	(G) NET CASH FLOW
1	-86.	39.	56.	423.	642.	438.	-392.
2	-92.	44.	61.	421.	145.	438.	-498.
3	-114.	49.	71.	419.	147.	438.	-524.
4	-131.	55.	79.	417.	149.	438.	-554.
5	-150.	62.	89.	415.	151.	438.	-587.
6	-173.	69.	99.	412.	153.	438.	-626.
7	-199.	77.	111.	409.	156.	438.	-669.
8	-229.	87.	125.	405.	159.	438.	-719.
9	-264.	97.	140.	401.	162.	438.	-776.
10	-304.	109.	156.	397.	166.	438.	-840.
11	-349.	122.	175.	392.	170.	438.	-913.
12	-402.	136.	196.	387.	175.	438.	-997.
13	-462.	153.	220.	381.	180.	438.	-1092.
14	-532.	171.	246.	374.	186.	438.	-1200.
15	-612.	191.	276.	366.	193.	438.	-1324.
16	-704.	214.	309.	358.	200.	438.	-1464.
17	-809.	240.	346.	348.	208.	438.	-1624.
18	-931.	269.	387.	337.	217.	438.	-1807.
19	-1071.	301.	434.	325.	228.	438.	-2015.
20	-1231.	337.	486.	312.	239.	438.	-2253.
TOTALS	-8852.	2022.	4064.	7699.	4026.	8760.	-20052.

SOLAR INCENTIVE INCLUDED IN YEAR 1 TAX SAVINGS 490.00 DOLLARS

TAX SAVINGS = INCOME TAX RATE X (C + D)

NET CASH FLOW = A + B - C + E - F

NET PRESENT WORTH OF TOTAL LIFETIME COSTS -7497. DOLLARS

SAVINGS NET PRESENT WORTH FOR OPTION -1308. DOLLARS

Figure E-3. (Cont.)

APPENDIX F. SOLCOST EXECUTION ON MMDS NOS SYSTEM

This appendix assumes that the user is familiar with the NOS system. New NOS users should refer to CDC 's NOS Version 1 Reference Manual for an introduction to the NOS system. The SOLCOST Program can be executed by use of cards or a timesharing terminal. This appendix explains how a MMDS user can execute the SOLCOST Program. There are three ways of executing the SOLCOST Program discussed in this appendix: input and execution, input, and execution.

F1. SOLCOST STATUS REPORT

In order to keep the user current on changes and new options within the SOLCOST Program, an information file is available. In order to get a listing of the information file, the user, at an interactive timesharing terminal, needs to do the following commands:

<u>COMMANDS</u>	<u>COMMENTS</u>
GET,SOLAR/UN=LIBRARY	Retrieves the file.
LNH,F=SOLAR	Lists the INFO file.

F2. SOLCOST Conversational Input Program for Timesharing Terminal Users

The conversational program interrogates the user for SOLCOST inputs and builds an input data file (NEWFILE). At the end of the conversational session the user can save NEWFILE for future runs. NEWFILE can also be sent to SOLCOST for execution. On subsequent runs, the user can bring in the saved version of NEWFILE and use the conversational program to modify the inputs. The first command should be GET,PROFILE/UN=LIBRARY, which retrieves the procedure file.

F2.1 Instructions for using the conversational program and executing SOLCOST are as follows:

F2.1.1 For new input, no existing files.

<u>COMMAND</u>	<u>COMMENT</u>
BEGIN,SOLCOIN,PROFIL,,NEWFILE,OUT.	Start the conversational program. NEWFILE is the file name you want the input data saved under. Out is the name of the output file. If you want the output to print at the terminal, enter OUTPUT. Any other name will make the output available for review and/or routing to your printer.

Comment: Thus, above commands will execute the conversational program and then execute the SOLCOST program. The input NEWFILE will then be available to either save or return to execute both programs again. If the user wishes to save the input file and quit, do one of the two following commands:

COMMAND

SAVE,NEWFILE Make NEWFILE into a permanent file.

F.2.1.2 For changing existing files.

<u>COMMAND</u>	<u>COMMENT</u>
BEGIN,SOLCOIN,PROFIL,OLDFILE,NEWFILE,OUT.	Same explanation as below.(OLDFILE)
GET,OLDFILE	OLDFILE is the name of the input file to be changed.

F2.2.1 Instruction for using the conversational program only, create new file.

<u>COMMAND</u>	<u>COMMENT</u>
BEGIN,COIN,PROFIL,,NEWFILE.	NEW is the file name where
SAVE,NEW	the conversationally created
	input file is placed.

F2.2.2 Conversational program only, modify existing file.

<u>COMMAND</u>	<u>COMMENT</u>
GET,OLDFILE	OLDFILE is the input file to
BEGIN,COIN,PROFIL,OLDFILE,NEWFILE,OUT.	be changed.

F2.3 SOLCOST - Execution for Timesharing Terminal Users

Executing SOLCOST in this manner the user should be familiar with SOLCOST and XEDIT. This method the user must build his own input file by the use of XEDIT. There are some example files available to help the user get a start in building his own input file. The input requirements and description are found in Section IV (pages IV-1 to IV-3). There are also examples shown in the manual in Section IV. The comments are optional and not required. The main requirement is to start the program with the word TITLE (for a title) or NO TITLE (for no title). These can be shortened to N or T.

<u>COMMANDS</u>	<u>COMMENTS</u>
GET,OLDFILE	A sample input file.
XEDIT	

Comment: User changes data values in file using XEDIT commands (see Table E1).

Q,filename,L or RL	To end XEDIT (See Note 1 below).
GET,PROFIL/UN=LIBRARY	
BEGIN,SOLCOST,PROFIL,NEWFILE,OUT	To execute SOLCOST.

Obviously the key to the terminal execution is knowledge of the XEDIT commands. Table E1 summarizes the important XEDIT commands needed to modify most files.

Edit can be used instead of XEDIT.

Table F1. XEDIT Commands for SOLCOST Input File Modification

Pointer Movement Commands*

BOTTOM or B	Moves pointer to last line in file
TOP or T	Moves pointer to first line in file
LOCATE/ <u>STRING</u> /	Locates the first line that contains a particular string of characters.
NEXT <u>n</u> or <u>Nn</u>	Advances the file pointer <u>n</u> lines from its current position.
PRINT <u>n</u> or <u>Pn</u>	Prints <u>n</u> lines starting at current pointer position
DELETE <u>n</u> or <u>Dn</u>	Deletes <u>n</u> lines starting with the line at the current pointer position
CHANGE/ <u>STRING1</u> / <u>String2</u> /	Replaces <u>string1</u> with <u>string2</u> in the line at the current pointer position
INSERT <u>n</u> or <u>In</u>	Insert <u>n</u> lines after line at the current pointer position
HELP, <u>command</u>	Requests information about a specific XEDIT command

*XEDIT positions a file pointer at a line in the edit file. Initially the pointer is positioned at the first line in the file. Refer to the XEDIT Manual for more detailed information of XEDIT commands.

1

The Command Q, Filename, SL causes an exit from EDIT and saves the data file as a new file under the user's ID. On later runs, the command OLD, Filename should be given in place of the OLD DHWRES command in order to access the users data file. Also, the command Q, Filename, RL can now be given to replace an old data file which was previously saved with the command Q,Filename, SL. The command Q,Filename,L causes an exit from XEDIT and makes the edit file into a local file only (not saved as a permanent file).

F3. BATCH Execution of SOLCOST (CARD INPUT)

The control cards needed to execute SOLCOST from cards are as follows: (Following cards start in Column 1)

XXXX,T40.	XXXX.JOBNAME
USER, USER NUMBER, PASSWORD, C.	
GET,PROFIL/UN=LIBRARY.	
BEGIN,SOLCOST,,INPUT.	
END-OF-RECORD CARD	(7/8/9 all punched in column 1.)
N or T	(To start the input deck.)
INPUT DECK	(The description of the input deck is found in Section IV pp. IV-1 to IV-3.)
END	(To END the input deck.)
END-OF-FILE CARD	(6/7/8/9 all punched in column 1.)

F4. Additional Option for MMDS Users

The SOLCOST program always prints the inputs just as the user supplied them. Also, SOLCOST reformats the inputs and prints them for easy reading by the user. The first listing of the inputs can be suppressed by the user by simply adding an L to the input file. This is done as follows:

L NO TITLE	(This is the first card of input file of a file with no title.)
L TITLE	(This is the first card of input file of a file with a title.)

Normally, the files start with NO TITLE or TITLE (Both can be shortened to one letter N or T) but by inserting the L in front of the N or T suppresses the listing of the file.

The suppressing of the listing reduces the number of characters transmitted and reduces the cost of a run.

F5. FILES Available to the Users

This is a list of the files available and how to attach them.

FILE

PROFIL	GET,PROFIL/UN=LIBRARY	Procedure file.
SOLAR	GET,SOLAR/UN=LIBRARY	Information file.
DHWRES	GET,DHWRES/UN=LIBRARY	Sample input file residence hot water system.
SAMPBUS	GET,SAMPBUS/UN=LIBRARY	Sample input file business hot water system.
SAMPNPO	GET,SAMPNPO,UN=LIBRARY	Sample input file non-profit organi- zation hot water system.
SAMPRES	GET,SAMPRES/UN=LIBRARY	Sample input file residence space heating system.

Any of these files can be listed if the user wants to see them by
attaching the file first and then doing one of the following commands:

LNH,F=Filename

or

LIST,F=Filename

APPENDIX G. ADDITIONAL INPUT INFORMATION

G1. Air Collector Performance Array, Line 19 - Space heating air collectors operate at nearly constant inlet temperatures throughout the day. The average collector temperature varies through the day, independent of the inlet temperature. This means that if the air collector is tested at constant inlet temperatures its performance cannot be specified as a function of the inlet temperature as with liquid collectors. Typically, these test results can be plotted in the formats shown in Figure G1.

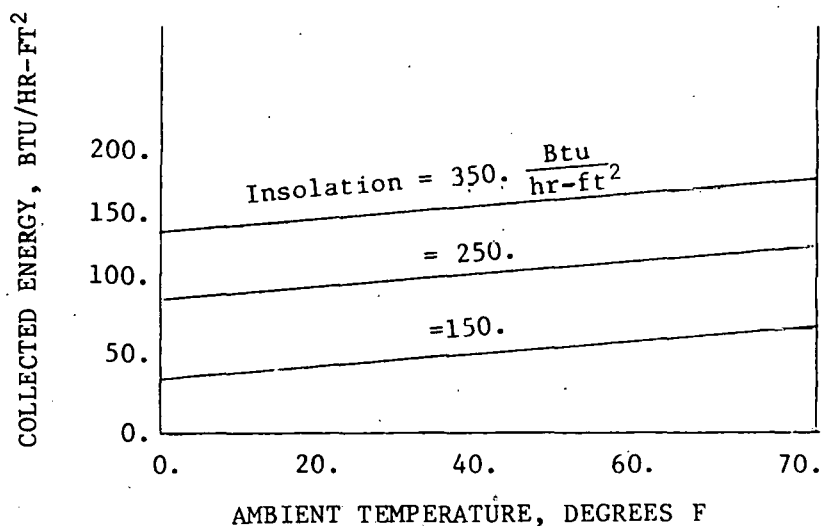


Figure G1. Air Collector Performance with Constant Inlet Temperature and Flow Rate.

SOLCOST Line 19 allows the user to input the above performance data in the following format:

19, X1, X2, Q1, Z11, Z12, Q2, Z21, Z22, Q3, Z31, Z32,*

Figure G2 defines the symbols.

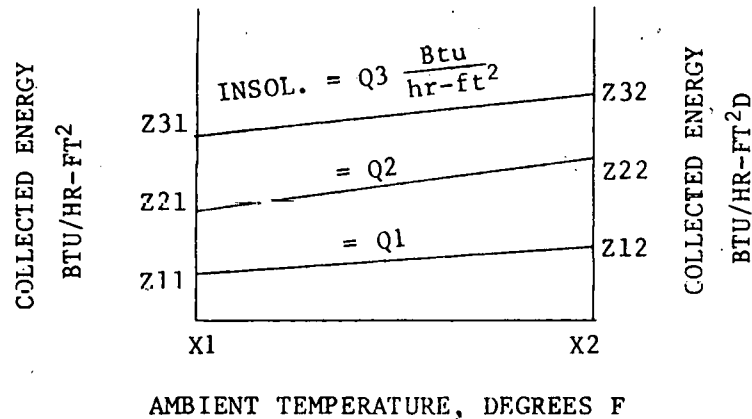


Figure G2. Input Guide for Air Collector Performance

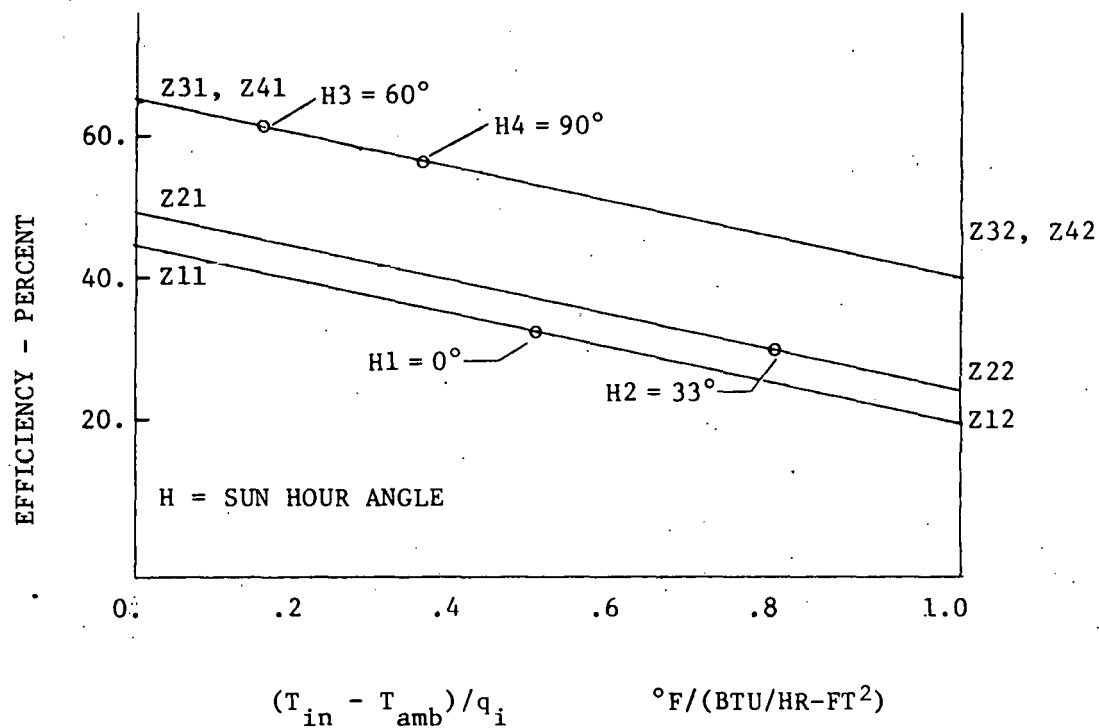
Line 19 for collector performance data specified in Figure A1 will be input as follows:

19, 0., 70., 0., 0., 0., 150., 35., 80., 250., 85., 125., 350., 135., 175., *

Note: The three initial zeros must be input to define the zero efficiency case for zero solar insolation.

G2. Evacuated Tubular Collectors, Input Line 20 - These collectors require input of multiple efficiency curves since they have different performance characteristics for each hour angle of the sun, i.e., the azimuth angle of a line from the collector to the sun. A family of efficiency curves for a typical tubular collector is shown in Figure A3. The method used to input this family of curves on Line 20 is also illustrated in the figure. If a user has curves of this type for another collector of the evacuated tubular type, he may input his data on Line 20 which will handle up to but no more than 4 separate efficiency curves.

The example in Figure G3 contains the default collector efficiency data obtained if Line 10 = 6.



Line 20 input format:

20, X1, X2, H1, Z11, Z12, H2, Z21, Z22, H3, Z31, Z32, H4, Z41, Z42, *

For example, for this set of curves:

20, 0., 1., 0., .46, .22, 33., .49, .25, 60., .62, .38, 90., .62, .38, *

Figure G3. Input Guide for Evacuated Tubular Liquid Collectors.

G3. Estimating Solar System Transport Factor - The solar system transport factor accounts for losses from collector manifolds, supply and return runs, and piping to the load distribution heat exchanger. This factor is expressed as a fraction of the useful energy output by the collector. Unfortunately, this collected energy quantity is unknown prior to the SOLCOST analysis; however, it can be initially approximated and then refined with the output of the first run.

Users are encouraged to estimate their losses prior to the first SOLCOST run. The following approach is suggested.

1. Gather the pertinent design parameters. For a first cut, estimate all unknowns, assume January temperatures. Summarize in tabular form.

	Collection Loop			To/From Load HX	Misc.
	Supply	Return	Manifolds		
Pipe Length, L					
Pipe O.D., D_1					
Insulation Conductivity, k					
Insulation O.D., D_2					
Avg. Fluid Temperature, T_f					
Avg. Ambient Temperature, T_a					
Operating Hours Per Day, N					

Note: Fluid and ambient temperatures should be average over operating hours.

2. Compute average daily piping heat loss

$$Q_{\text{loss}} = \sum_{i=1}^n (UA)_i (T_{f,i} - T_{a,i}) N \quad \text{Btu}$$

where:

$$(UA)_i = 2\pi K_i L_i / \log_n (D_2/D_1)_i \quad \text{Btu/Hr-}^\circ\text{F}$$

3. Compute transport efficiency factor for month i, repeat for temperature dependence by month. Input efficiencies on Line 2.

$$\eta_i = 1. - Q_{\text{loss}} / Q_{\text{collected}} \text{ (est.)}$$

4. Check initial η using $Q_{\text{collected}}$ computed by SOLCOST in first run. This $Q_{\text{collected}}$ term can be derived from the Average Useful Solar Per Day values listed in the Monthly Energy Balance table of the SOLCOST output.

$$Q_{\text{avg. useful solar}} = Q_{\text{collected}} - Q_{\text{stor loss}} \quad \text{Btus/Day}$$

re-arranging, we have

$$Q_{\text{collected}} = (Q_{\text{avg. useful solar}} + Q_{\text{stor loss}}) / \eta \quad \text{Btus/Day}$$

The storage loss term can be found by printing storage temperature summary table (Line 145=1), then $Q_{\text{collected}} \text{ (est.)}$ can be checked against the actual $Q_{\text{collected}}$ computed in the first run. If the differences are significant, the monthly values of η should be re-computed using the $Q_{\text{collected}}$ values from the initial run.

If the user is uncertain about the magnitude of his piping losses, he can use the defaulted system efficiencies which are reasonable for preliminary design purposes.

Note: The user can either use the above method, or input de-rated collector parameters per paragraph C-7.

Blank

G-6

APPENDIX H. SOLCOST LOADS METHODOLOGY

H1. Space Heating Loads - Four options are available for the input of space heating loads to SOLCOST. Input Line 40 is a flag to tell the program which option is being used. These options include:

Line 40 = 2 - The user must compute the design heat loss coefficient, BHLC, for his building with units of Btu/Degree-day-sq. ft. The space heating load is then computed from

$$\text{LOAD} = \text{BHLC} \times \text{DD} \times \text{AREA}$$

where

DD = Heating degree days

AREA = Floor area of heated space

Line 41 = 3 - The user must input Line 44, which is an array of building description information which allows SOLCOST to compute BHLC using the ASHRAE STD90-75 prescription for allowable U-values in the building.

Line 41 = 4 - The user must input his utility usage records on Line 45 for a retrofit installation. SOLCOST will estimate the heating load from the fuel consumption and seasonal degree days.

Line 41 = 5 - The user estimates his heating load for an average day for each month of the year. These values, in units of million Btu's per day, are input in the array of Line 46.

SOLCOST assumes that any load input by the above methods is a space heating load with the following two exceptions:

- 1) Solar system type 8 (service water heating) is specified on Line 1,
- 2) Solar system types 9 and 10 (heat pumps) are specified on Line 1 and Line 41 = 5. This allows the heat pump systems to consider any load input on Line 46 as a process load with load timing as specified in Line 150.

In the SOLCOST analysis, the space heating load is removed from the storage tank at an hourly rate which is dependent on the outside air temperature and the building skin conductance. This rate is given by:

$$LRR = (65 - T_{amb}) \frac{\text{Jan. Load} \times 1.29 \times 10^6}{\text{Jan. DD}}$$

where

LRR = Load Removal Rate, Btu/hr

Jan. Load = January Load, Million Btus/day

Jan. DD = January Degree Days, °F-Day

H2. Service or Domestic Water Heating Loads - Five options are available for the input of water heating loads. Input Line 41 is a flag to tell the program which option is being used. The options include:

Line 41 = 1 - This option requires input of Line 47 so SOLCOST can compute the hot water load using typical residential hot water usage levels.

Line 41 = 2 - This option requires input of Line 48 so SOLCOST can compute the hot water load from historical fuel usage records.

Line 41 = 3 - For this option the user has computed his hot water load for direct input to SOLCOST. Units are millions of Btus per day. This load is assumed to be constant throughout the year.

Line 41 = 4 - This option requires input of the daily water usage in gallons on Line 154. This load varies by month to account for supply temperature (input on the Line 153 array).

Line 41 = 5 - This option allows the user to enter a monthly water heating load in the Line 47 array. Setting Line 41 = 5 causes SOLCOST to apply time dependent load fractions in Line 150 to the load input via Line 46.

H3. Combined DHW and Space Heating Systems - For space heating systems which also provide domestic or service hot water, SOLCOST assumes that the space heating storage tank pre-heats the incoming city water. The program internally adds the hot water load to the space heating load. However, in the system thermal analysis, the hot water load is applied with the time dependent function input on Line 150. In the winter months this load effect is usually overwhelmed by the space heating load removal rate from storage.