SOLAR/1069-81/50
(DE81027253)

Solar Project Description

LANDURA CORPORATION
SINGLE-FAMILY RESIDENCE
Stayton, Oregon
July 24, 1981

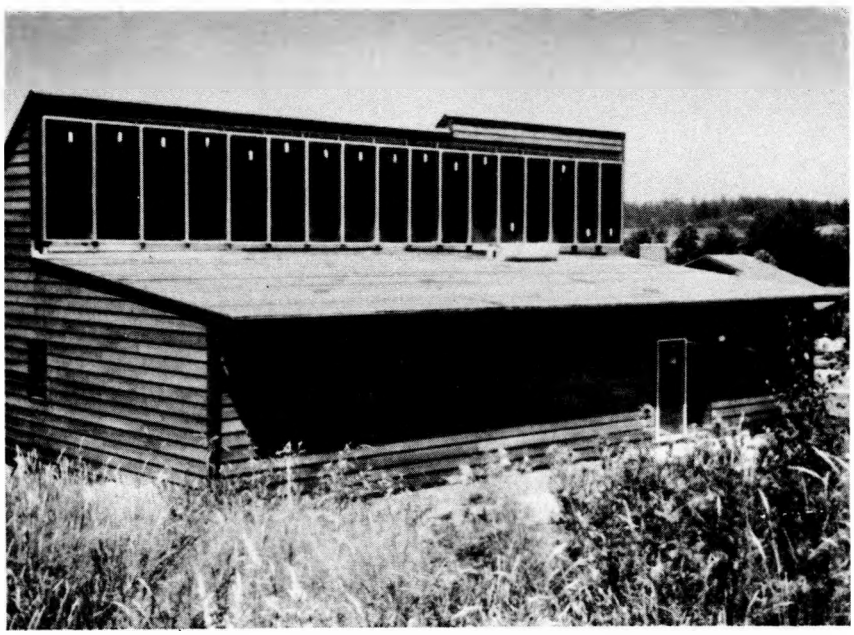
U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1069-81/50
(DE81027253)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
LANDURA CORPORATION
SINGLE FAMILY RESIDENCE - STAYTON, OREGON



Department of Housing and Urban Development

Under Contract Number

H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

The Boeing Company
David Beers, Program Manager

DISCLAIMER

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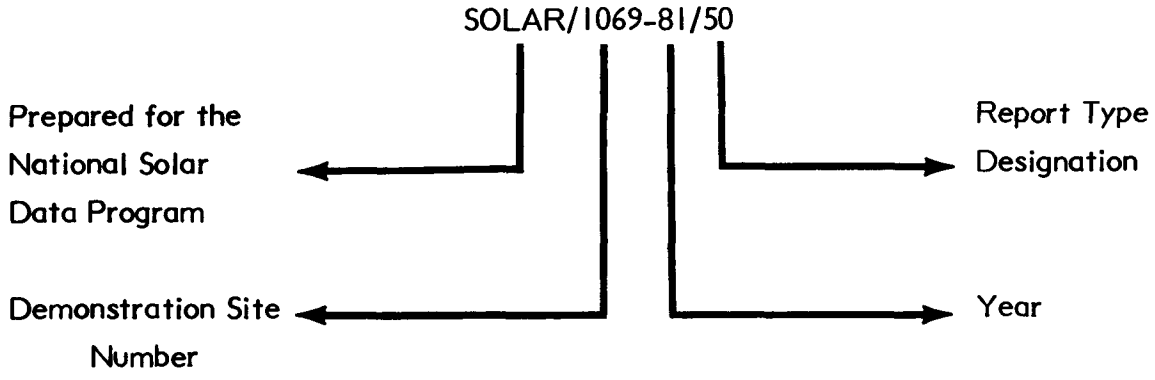
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Landura Corporation's project site is designated as SOLAR/1069-81/50. The elements of this designation are explained in the following illustration:



Demonstration Site Number: Each project has its own discrete number - 1000 through 1999 for residential sites and 2000 through 2999 for commercial sites.

Report Type Designation:
This number identifies the type of report, e.g.,

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

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

I. FOREWORD

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy (DOE) as mandated by the Solar Heating and Cooling Demonstration Act of 1974. The Department of Housing & Urban Development is responsible to DOE for the Solar Residential Demonstration Program. The overall goal of the Federal Demonstration Program is to assist in the establishment of a viable solar industry and to achieve a substantial reduction in fossil fuel use through widespread use of solar heating and cooling applications. An analysis and synthesis of the information gathered through this program will be disseminated in site-specific reports and summary documents as products of the National Solar Data Program. These reports will cover topics such as:

- Solar Project Description.
- Operational Experience.
- System Performance Evaluation.
- Monthly Performance Reports.

Information contained herein for this Solar Project Description report has been extracted from data collected during site visits and from reference documents such as the project proposal, designer specifications, grantee submittals, manufacturer literature, photographs, specific "as-built" data and other project documentation available. The remaining reports in this series will utilize the Solar Project Description for supporting reference.

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type -- Liquid active, flat plate
- o Freeze Protection -- Drain down (air bleed)
- o Application -- Space heat and DHW
- o Storage -- Two 1250 gallon tanks
- o New or Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- Reflective surface on roof

The Landura Corporation (Grant H-8200) site is a single-family residence in Stayton, Oregon. The house has approximately 1500 square feet of conditioned space. Solar energy is used for space heating the home and preheating domestic hot water (DHW).

The solar energy system has an array of flat-plate collectors with a gross area of 357 square feet. However, the roof beneath the collector array is designed as a reflector surface and increases the effective collector area to 1072 square feet. The collector array faces south at an angle of 90 degrees to the horizontal. Water is the transfer medium that delivers solar energy from the collector array to storage and to the space heating and hot water loads. Solar energy is stored above ground in two 1250-gallon tanks.

Supply water is preheated in a heat exchanger coil in storage tank 1 and supplied, on demand, to a conventional 65-gallon DHW tank. When solar energy is insufficient to satisfy the space heating load, a heat exchanger/heat pump and an electrical heating element in the air-handling unit provide auxiliary energy. Similarly, an electrical heating element in the DHW tank provides auxiliary energy for water heating.

The dwelling has been fully instrumented for performance evaluation since October 1977 and the data is integrated into the National Solar Data Network.

Original cost estimates for provisioning and installation of the solar system are given in section VI of this report. However, the final solar system cost and the cost of its instrumentation are not included in this report.

III. GENERAL CHARACTERISTICS (See figure III-1. Site Plan)

The Landura Corporation's solar energy system provides space heating and domestic hot water for a single family dwelling unit of approximately 1500 sq. ft. The 357 sq. ft. collector unit consists of 17 Sunworks, Inc. liquid flat plate panels, mounted due south at a 90 degree tilt from horizontal. To increase the incident radiation, the roof below the collectors is offset 10 degrees from the horizontal and acts as a reflector surface, increasing the efficiency equivalent to 1072 ft^2 of collectors.

The storage subsystem consists of two 1250 gallon tanks, one of which is normally bypassed from the solar system operation during the summer months.

- Building type - Single family detached
- Latitude - 45^o
- Longitude - 123^o
- Altitude - 195 ft

HEATING DESIGN TEMPERATURES

- Outdoor - 23^o F DB
- Indoor - 68^o F DB

BUILDING

- Building faces - N
- Average stories above ground - 1.5
- Average stories below ground - 0.5
- Height above grade - 23 ft
- Conditioned floor area - 1500 ft^2
- Roof type - Sloped 10^o pitch angle

DESIGN HEAT LOSS/LOAD

- Heat Loss - 26,077 Btu/hr
- Heat gain - 10,262 Btu/hr

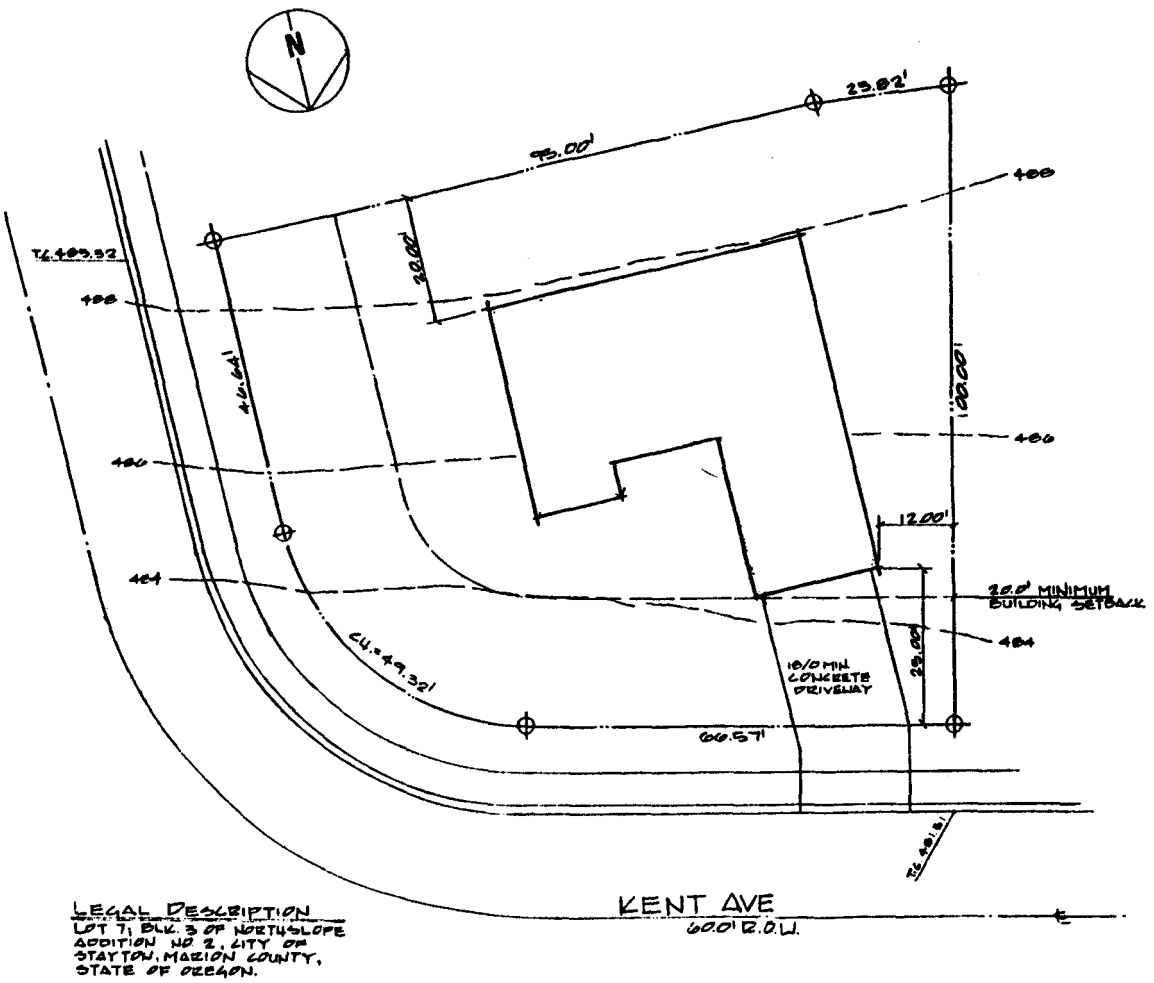


Figure III-1. Site Plan

- Shading
  - Heating season - 84 ft^2
- Appliance, lighting and equipment load - 1425 Btu/hr
- Average horizontal insolation
  - January - 332 Btu/ft^2 - day
  - July - 2142 Btu/ft^2 - day
- Annual degree days
  - Heating - 4852
  - Data location - Salem, Oregon
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

MECHANICAL SYSTEM

- Heating
  - Solar - Liquid flat plate, active
  - Auxiliary - Heat Exchanger/Heat Pump
  - Distribution - Air ducts

DOMESTIC HOT WATER

- Daily water demand - 80 gallons
- Solar - Liquid active flat plate collectors
- Auxiliary - Electrical heating element in DWH-1

GENERAL DATA

- Manufacturer - Sunworks, Inc.
- Model name/number - Solector
- Type of system - Liquid, active

SYSTEM AND COMPONENT SUMMARY

- Collector types - COL-1
- Circulation loops - 4

- Thermal storage units - 2 (TSU-1, TSU-2)
- Operational modes - 4
- Pumps - 3
- Valves - 3 (Types)
- Blowers - 1 (BL-1, Part of Heat Exchanger/Heat Pump)
- Sensors - 8
- Fail safe controls - 2

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (Landura Corporation Grant H-8200) located at Stayton, Oregon is a liquid active system utilized for space heat and DHW. A heat pump is used for auxiliary energy for space heating and an electrical element in DWH-1 is used as auxiliary energy should solar energy be insufficient.

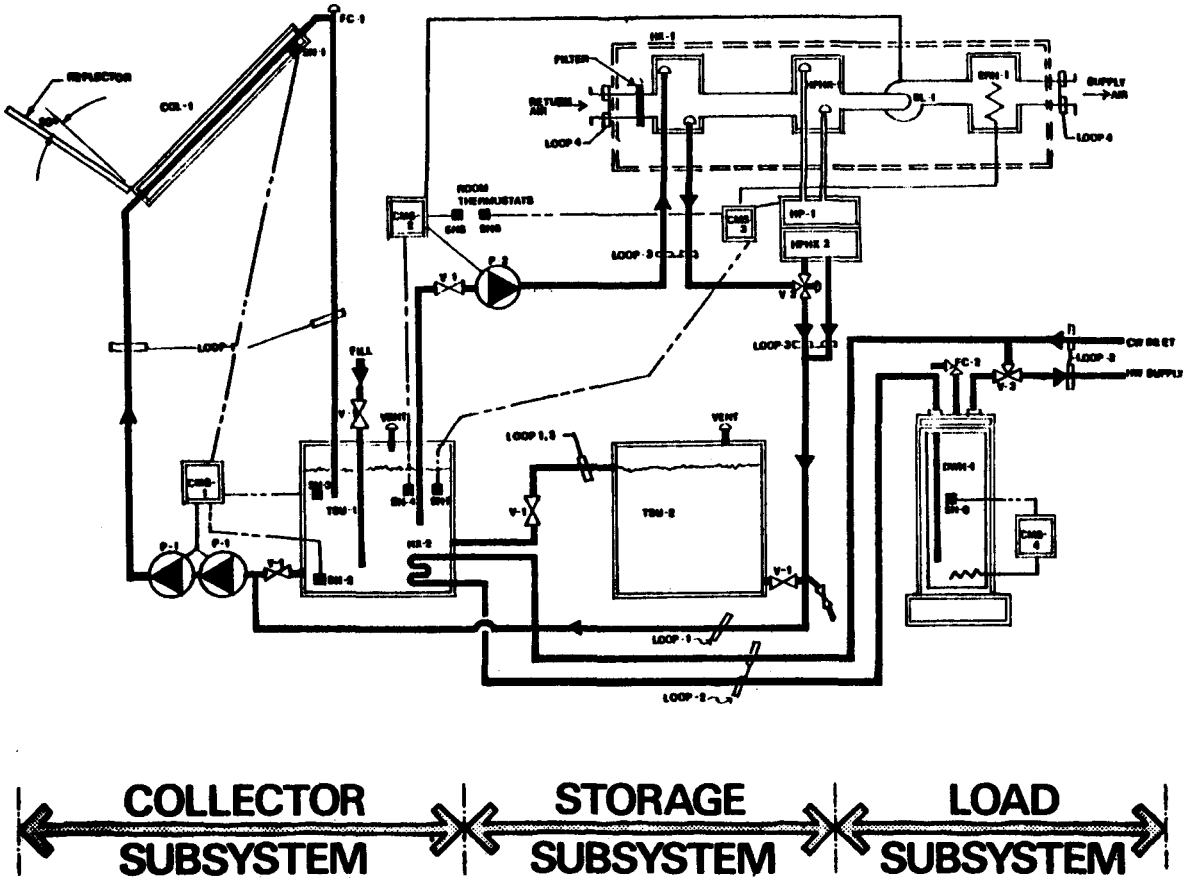


Figure IV-A-1. General Overview

Subsequent sections describe the collector, storage, energy-to-load, and auxiliary subsystem. Specific details of the operating modes and controls are described in the final section. Figure IV-A-1 is a system schematic diagram.

B. Collector Subsystem (See figure IV-B-1)

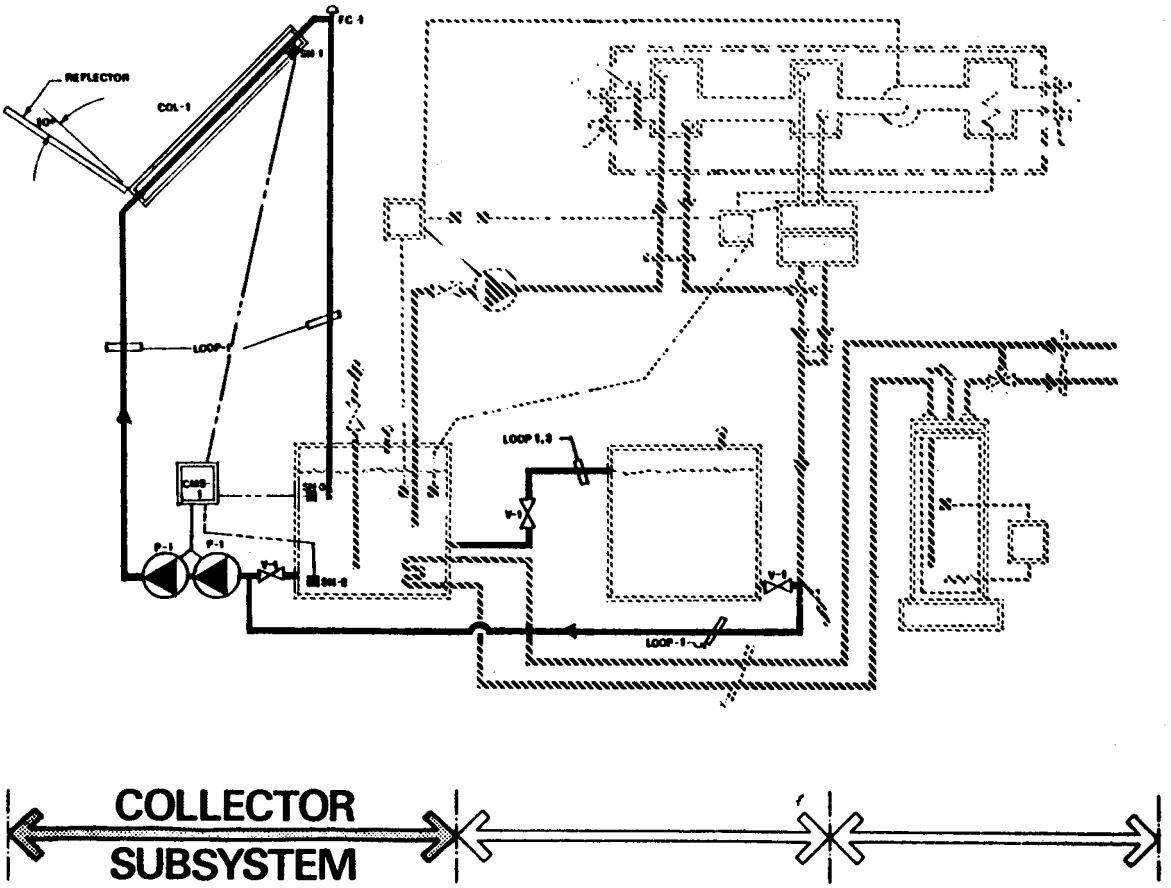
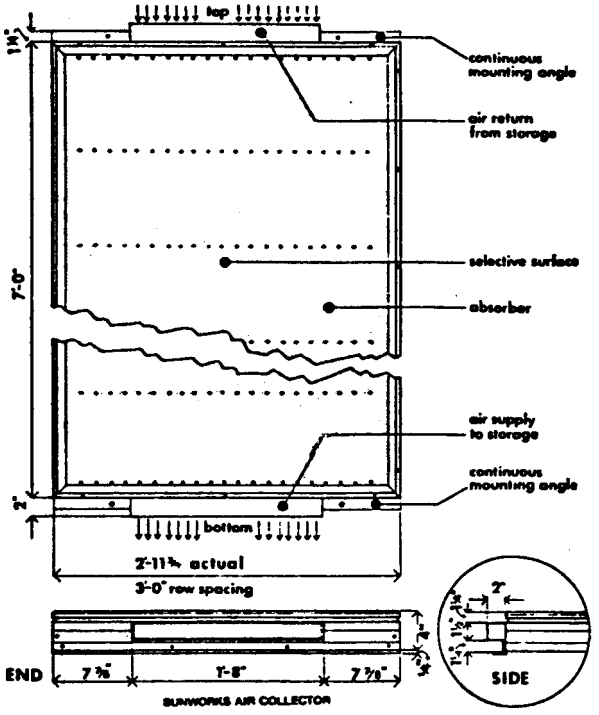


Figure IV-B-1. Collector Subsystem

Collector array system consists of 17 (357 ft^2) liquid flat plate collector panels. Freeze protection is by drain down-air bleed.

COLLECTOR (COL-1) (See figure IV-B-2)

- Manufacturer - Sunworks, Inc.
- Model name/number - Solector
- Type - Liquid flat plate, tube and plate
- Location - Roof
- Orientation - 0^{o} E of S
- Tilt angle - 90^{o} from horizontal
- Collector characteristics
  - Number of panels - 17
  - Total gross area of array - 357 ft^2
  - Net aperture area - 318 ft^2
  - Net absorber area - 318 ft^2
  - Weight per panel, empty - 111 lb
  - Weight per panel, full - 114 lb
  - Weight of filled array and support structure - 1938 lb
  - Panel length - 84.0 in
  - Panel width - 35.5 in
  - Frame depth - 4.0 in
  - Standoff height - 0
- Built-in collector - Yes
- Collector shading -
  - Area shaded in June - 0%
  - Area shaded in December - 10%
  - Maximum shade during functional season - 5% of aperture
- Cover plates
  - Number of cover plates - One



TECHNICAL DATA ON *SOLECTOR SOLAR ENERGY COLLECTORS (LIQUID-TYPE AND AIR-TYPE)****

Cover: single glass, 3/16 in. tempered, edges swiped, 92% solar transmittance
Absorber container: sides, aluminum extrusion; rear, aluminum sheet 0.05 in. thickness
Air space between cover and absorber: approximately 1 in.
Gasketing material: neoprene "U" gasket
Weatherproofing: this module can be placed out in the weather without need for further weatherproofing
Finish on aluminum sides of container: standard mill finish. Anodized clear or black finish available at extra cost
Dimensions of surface-mounted module:
- —outside dimensions overall: 36 in. wide x 84 in. long x 4 in. thick (add 1-3/8 in. each end for continuous mounting bracket)
- —effective absorber area = 18.56 ft^2
- —ratio of usable absorber area to total surface covered: 0.884
- —glass area: 18.96 ft^2

Method of anchoring: continuous mounting bracket is fastened to each end of frame for anchoring; four predrilled holes are provided for anchor bolt or screw connections; additional holes may be drilled by installer if required.
Solector solar energy collectors can be mounted end-to-end for series flow or side-by-side for parallel flow. It is recommended that no more than three collectors be connected in series. The *Solector* solar energy collector modules for both liquid and air are identical in size, 3 ft. wide and 4 in. thick and are available in two lengths, 5'4" long or 7'0" long.

DATA ON AIR *SOLECTOR* SOLAR ENERGY COLLECTORS

Absorber:
- —copper sheet: 0.016 in. thick (12 oz.)
- —selective black: minimum absorptivity .90; maximum emissivity .12; applied by Enthone, Inc., durable to 400°F.
- —air chamber: 7/8 in. high, mechanical bond to absorber
- —connection to external duct: 1½ in. x 20 in. duct stub extending 2 in. beyond end of collector envelope
- —distribution pattern: parallel top to bottom, behind absorber

Insulation behind absorber: 1 in. thick fiberglass plus 1 in. urethane: R = 10
Weight per module: 111 lb.
Recommended flow rate through collector: 3 cfm/ft^2 of collector (flow resistance at this rate is negligible)
NOTE: Manufacturer reserves right to change specifications and dimensions without notice.

*Trademark of Enthone, Inc. **Patents Pending

Figure IV-B-2. Solar Collector

- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer - Amerda
  - Product name/number - No Iron
  - Material - Glass tempered
  - Thickness - 0.188 in
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	92%	
- Reflectance -		
- Emittance -		

  - Edge or surface treatment, other than coating - Swiped
  - Coating on cover plate material - None
- Absorber
  - Manufacturer - Sunworks, Inc.
  - Model name/number - Solector
  - Material - Copper
  - Substrate material dimension
    - Thickness - 0.010 in
    - Length - 84.0 in
    - Width - 35.0 in
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - Sunworks, Inc.
  - Coating material - Copper Oxide on copper
  -

	(solar region)	(infrared region)
Absorptance -	87%	
Reflectance -	7%	
Emittance -		

- Heat transfer fluid passages
  - Location - On absorber
  - Pattern - Grid
  - Materials - Copper, Type L
  - Wall thickness - Unknown
  - Internal diameter - 0.250 in
  - Maximum operating conditions
    - Temperature - 400° F
    - Pressure - 250 psi
  - Fluid passage bond to substrate - Soldering
  - Protective coating inside fluid passage - None
- Insulation
  - Layer one - side
    - Manufacturer - Sunworks, Inc.
    - Product name/number - Glass Fiber
    - Material - Glass Fiber
    - Thermal resistance - R-10
  - Layer two-sides
    - Material - Glass Fiber
    - Thermal resistance - R-10
  - Layer one-back
    - Material - Glass Fiber
    - Thermal resistance - R-10
  - Layer two-back
    - Material - Glass Fiber
    - Thermal resistance - R-10

- Gaskets and sealants
  - Inner cover - EPDM U Gasket
- Frame
  - Manufacturer - Sunworks, Inc.
  - Product name/number - Solector
  - Material - Aluminum
  - Protective coating - None
  - Standoffs used - No
  - Number of structure attach points per module to building - 6
  - Built-in collector - No
- Reflectors - Yes, built in on roof with 10^{o} slope
- Substrate material - Unknown
- Reflective coating - Unknown
- Protective coating - Unknown
- Physical dimensions
  - Length - Unknown
  - Thickness - Unknown
  - Width - Unknown
  - Shape - Unknown
  - Desiccant - No
  - Freeze protection - Drain down (air bleed)
  - Overheating protection - Oversized thermal storage

- Collector performance - DATA NOT AVAILABLE
  - Method of evaluation -
  - y intercept $F_R (\tau\alpha)_n$ -
  - Slope - $F_R U_L$
- Point Number 1 2 3 4
  - n = Collector thermal efficiency (%) -
  - t_i or t_f = collector inlet temperature (^{o} F) -
  - t_a = ambient air temperature (^{o} F) -
  - I_t = insolation intensity Btu/hr ft^2 -
  - ASHRAE $(t_i-t_a)/I_t$ -

Where

- η = collector thermal efficiency
- U_L = collector heat loss factor
- F_R = collector heat removal factor
- t_a = ambient air temperature, ^{o} F
- $(\tau\alpha)$ = Transmissivity-absorptivity product at normal incidence
- t_i = collector inlet temperature, ^{o} F
- t_f = average fluid temperature
- I_t = radiation (insolation) intensity on collector, Btu/hr.ft^2
  - Test flow rate -
  - Heat loss coefficient
  - Test wind speed -
  - Test collector area
    - Gross - 21 ft^2
    - Net - 18.56 ft^2
  - Fluid specific heat - 1.00 Btu/lb/^{o}F
  - Test fluid medium - Water

LIQUID CIRCULATION LOOP NO. 1 (COL-1 TO TSU-1/TSU-2)

- Maximum design operating temperature - 175° F
- Maximum design operating pressure - 9 psi
- Heating design liquid flow -
  - Maximum 11.5 gpm
  - Minimum 7.0 gpm
- Heat transfer medium -
  - Volume of liquid in loop - 2445 gallons
  - Anticipated liquid temperatures -
    - Maximum 175° F
    - Minimum 50° F
  - Provisions for expansion - Vacuum Breakers
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Recommended use temperature -
    - Maximum 175° F
    - Minimum 50° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Components within circulation loop
  - Pump(s) - P-1

- Thermal storage unit(s) - TSU-1, TSU-2
- Collector(s) - COL-1
- Valve(s) - V-1
- Other(s) - Strainer

- Piping
  - Rigid - Copper, Type L
  - Maximum operating
    - Temperature - 250° F
    - Pressure - 400 psi
  - Insulation Type -
    - Manufacturer - Armstrong
    - Product name/number - AFT Armaflex
    - Thermal resistance - R-3
  - Location - Above grade
  - Exterior Finish - None
  - Filters and Strainers -
    - Filter(s) - None
    - Strainer(s) - Copper, 0.01 mesh
  - Getters - No
- Circulator pump (P-1)
  - Manufacturer - Grundfos
  - Model name/number - UP-25-42SF
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 5 psi
    - Temperature - 200° F
  - Material exposed to heat transfer fluid - Stainless Steel

- Motor size - 0.05 hp; 115 V; 1 phase; 60 Hz
- Maximum motor speed - 2620 rpm
- Drive - Direct
- Speed - Single
- Pump speed - 2620 rpm
- Circulating volume -

  Low head mode - 11.5 gpm

  High head mode - 7.0 gpm
- Operating head (dynamic) -

  Low head mode - 5.4 psi

  High head mode - 9.1 psi
- Motor operation - 0.05 bhp

- Distribution Valve (V-1)
  - Manufacturer - Bell and Gossett
  - Model name/number - Unknown
  - Function - Flow, adjusting
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Bronze

Control Mode Selector (CMS-1)

- Manufacturer - Unknown
- Model name/number - Unknown
- Modes controlled
  - Collector to storage
    - ON - (SN-1) > (SN-2) + 15° F
    - OFF - (SN-1) < (SN-3) + 1.5° F or (SN-2) > 175° F

- Sensors (SN-1) and (SN-2)
  - Manufacturer - Delta T
  - Model name/number - DIT 3413
  - Type - Thermister
- Fail Safe Control (FC-1)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Vacuum Relief Valve

C. Storage Subsystem (See figure IV-C-1)

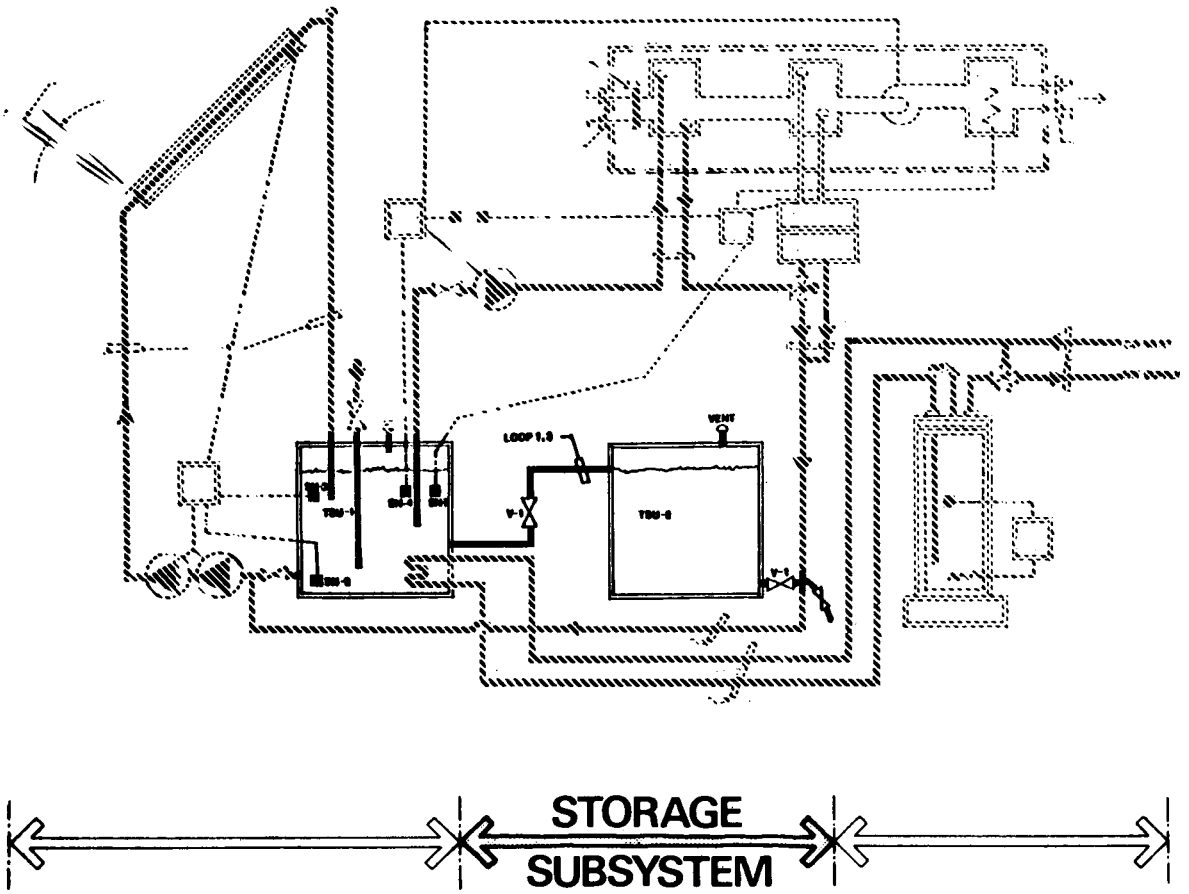


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by two 1250-gallon storage tanks. These tanks are made of Glass Fiber with Hetron lining. They measure 6.5 ft in height by 5.7 ft in diameter with Fiberglas and Urethane insulation.

THERMAL STORAGE UNIT (TSU-1 and TSU-2)

- Manufacturer - Hoffman Fiberglas
- Model name/number - Solar Heat Tanks
- Total storage volume per container - 166 ft^3
- Volume of storage medium - 1250 gallon each
  - Height - 6.5 ft
  - Diameter - 5.7 ft
- Maximum rated operating conditions
  - Temperature - 185° F
- Storage medium
  - Design heating operating temperatures
    - Maximum 175° F
    - Minimum 50° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F
- Medium manufacturers recommended use of temperature:
  - Maximum - 175° F
  - Minimum - 50° F
- Toxicity - Potable
- pH Factor - 7.0
- Inhibitor - No

- Container construction
  - Type - Glass fiber (Hoffman Fiberglas)
  - Interior lining - Hetron 197-P
  - Location - In basement
  - Auxiliary heaters - No
  - Insulation - Fiberglas/Urethane w/Foil
  - Exterior finish - Fiberglas
  - Filters - No
  - Getters - No

D. Energy To Load Subsystem (See figures IV-D-1 and IV-D-2)

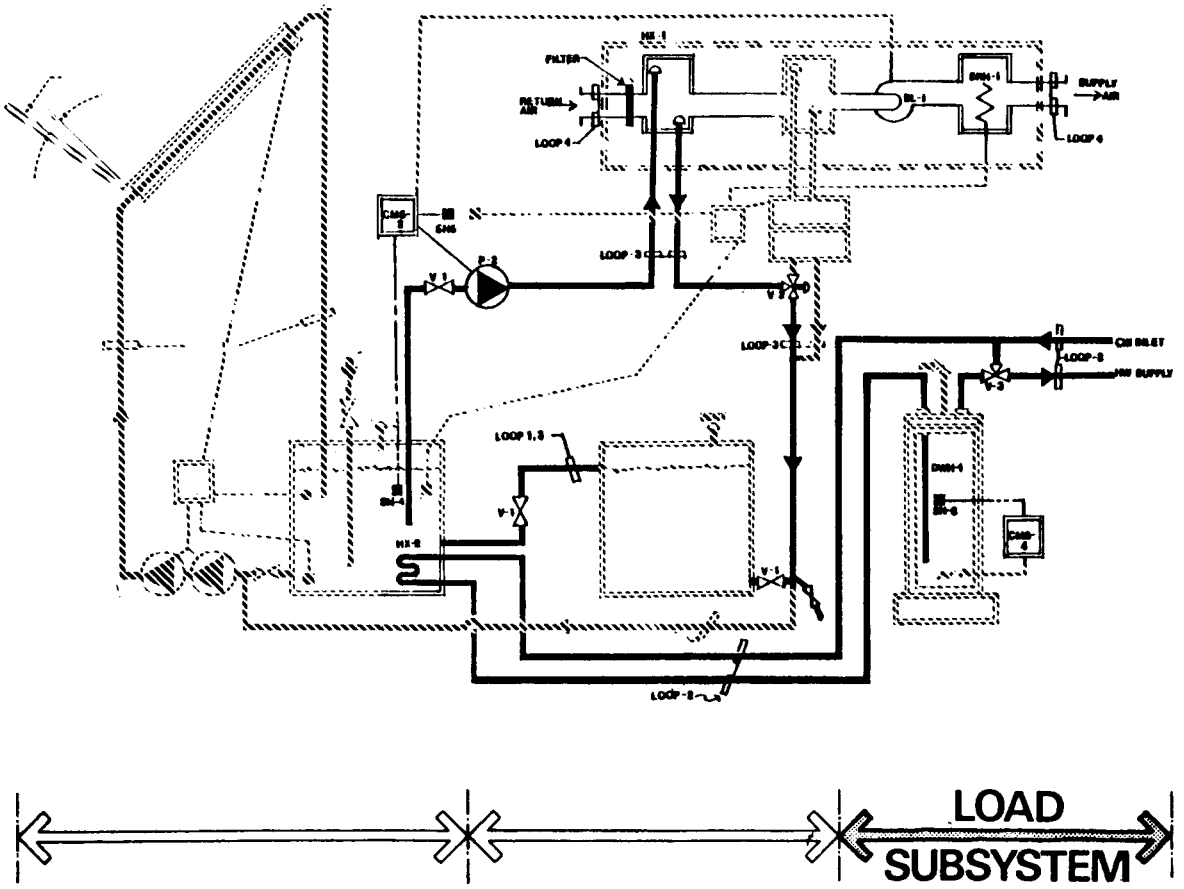


Figure IV-D-1. Energy-to-Load Subsystem, Solar Only

Solar energy stored in TSU-1 and TSU-2 storage tanks is used to meet the space heating demands by circulating it through a hydronic coil in the air distribution heating duct. This mode activates on demand when the temperature in the storage tank is higher than 90^{o} F.

Cold water is preheated in the storage tank (TSU-1) before going to a 52-gallon water heater (DWH-1). An electric element in DWH-1 provides auxiliary energy for the hot water.

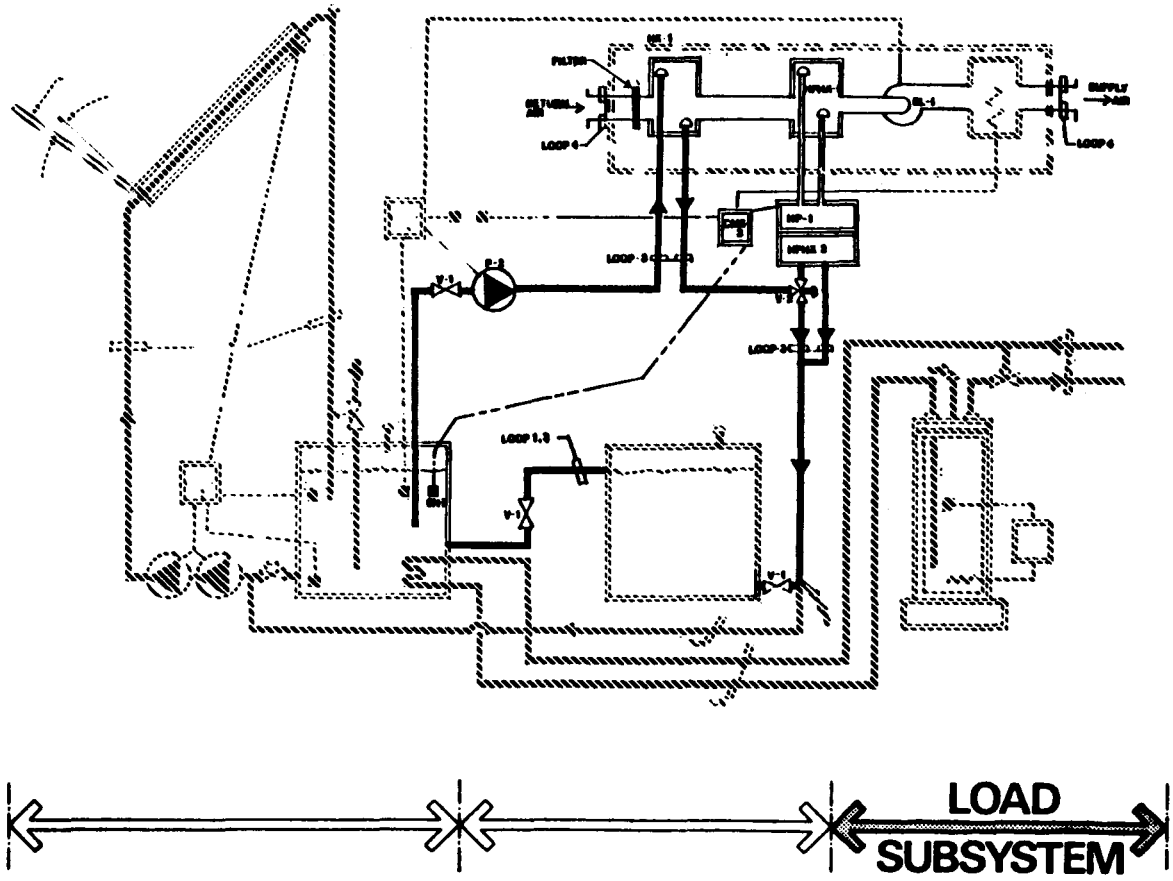


Figure IV-D-2. Energy-to-Load Subsystem, Solar Plus Heat Pump

This mode activates on demand when the water temperature in the storage tank is higher than 50° F but lower than 90° F. Solar heated water circulates through the heat exchanger assisting the heat pump operation.

LIQUID CIRCULATION LOOP NO. 2 (CW TO HW SUPPLY)

- Design operating temperature - 150° F
- Design operating pressure - 150 psi
- Heating
  - Design liquid flow -
    - Maximum 3.0 gpm
    - Minimum 0 gpm
- Heat transfer medium:
  - Volume of liquid in loop - 54 gal (incl DHW-1)
  - Anticipated liquid temperatures -
    - Maximum 140° F
    - Minimum 55° F
  - Provisions for expansion - None
  - Medium - Water (100%)
  - Specific heat - 1.0 Btu/lb/°F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Medium manufacturer's recommended use temperature:
    - Maximum - 140° F
    - Minimum - 50° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - No
  - Inhibitor - No

- Components within circulation loop:
  - Domestic water heater(s) - DWH-1
  - Heat exchanger(s) - HX-2
  - Thermal storage unit(s) - TSU-1
  - Valve(s) - V-3
  - Other(s) - FC-2
- Piping
  - Rigid - Copper
  - Maximum operating
    - Temperature - 250° F
    - Pressure - 400 psi
  - Insulation - Armaflex (Armstrong)
  - Location - Above grade
  - Exterior finish - Unfinished
  - Filters - No
  - Getters - No
- Heat Exchanger (HX-2)
  - Manufacturer - Broad/McClung
  - Model name/number - Unknown
  - Type of flow - Cross
  - Heat exchanger design - Inside tank without fins
  - Number of separations - Unknown
  - External exposed surface - 19.6 ft^2

	Side One	Side Two
o Convection:	Forced	Forced
o Located in:	TSU-I	TSU-I
o Part of circulation loop:	2	2
o Maximum manufacturer's rated:		
- Temperature -	250° F	150 psi
- Pressure -	150 psi	150 psi
o Heat transfer area		

o Description

	Side One	Side Two
o Length of tubing without fins -	120 ft	
o Diameter of tubing -	Unknown	Unknown
o Fins N/A	N/A	
o Material	Copper	Copper

o Heating

- o Design heating capacity - 110,600 Btu/hr
- o Effectiveness - Unknown

	Side One	Side Two
o Design flow rate -	3 gpm	
o Related pump no. -	P-I	
o Liquid temperatures:		
- Entering -	55.0° F	
- Leaving -	110.0° F	

o Distribution Valve (V-3)

- o Manufacturer - Bell and Gossett
- o Model name/number - Unknown
- o Function - 3 way, mixing

- Operation - Manual
- Type - Gate
- Material exposed to heat transfer fluid - Bronze

- Fail Safe Control (FC-2)
  - Manufacturer - Unknown
  - Product name/number - Unknown
  - Type - Pressure Relief Valve

LIQUID CIRCULATION LOOP 3 (TSU-1/TSU-2 TO HX-1 TO HPHX2 TO TSU-2)

- Design maximum operation temperature - 175° F
- Design maximum operation pressure - 30 psi
- Heating
  - Design liquid flow - 8.0 gpm
  - Design pump speed - At maximum
- Heat transfer medium
  - Volume of liquid in loop - 2432 gallon
  - Anticipated liquid temperatures
    - Maximum - 175°F
    - Minimum - 50° F
  - Provisions for expansion - Air pocket at tops of TSU-1 and TSU-2
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F

- Medium manufacturer's recommended use temperature -
  - Maximum - 175° F
  - Minimum - 50° F
- Toxicity - Potable
- pH Factor - 7.0
- Chemical feeder to maintain pH factor - No
- Inhibitor - No

- Components within circulation loop
  - Pump(s) - P-2
  - Heat exchanger(s) - HX-1, HPHX-2
  - Thermal storage unit(s) - TSU-1, TSU-2
  - Valve(s) - V1, V-2
  - Other(s) - Strainer, CMS-2, CMS-3

- Piping
  - Rigid - Copper, Type L
  - Maximum Operating
    - Temperature - 250° F
    - Pressure - 400 psi
  - Insulation - Aft Armaflex (Armstrong)
  - Location - Above grade
  - Strainer - Copper (mesh 0.01)

- Circulator pump - P-2
  - Manufacturer - Grundfos
  - Model name/number - UP26-64F
  - Type - Centrifugal

- Maximum operating conditions
  - Dynamic pressure - 2.9 psi
  - Temperature - 200° F
- Material exposed to heat transfer fluid - Stainless Steel
- Motor size - 0.08 hp; 115 V; 1 phase; 60 Hz
- Maximum motor speed - 3100 rpm
- Drive - Direct
- Speed - Single
- Pump speed - 3100 rpm
- Circulating volume - Low head mode - 8.0 gpm
- Operating head (dynamic) - Low head mode - 2.9 psi
- Motor operation - 0.08 bhp

- Distribution Valve - V-2
  - Manufacturer - Bell and Gossett
  - Model name/number - Modumate VD 1184
  - Function - Flow switching/3-way diverting
  - Operation - Automatic, motorized
  - Type - Gate
  - Pressure - 125 psi
  - Material exposed to transfer fluid - Bronze
- Heat Exchanger (HX-1) Liquid to Air
  - Manufacturer - Command-Aire
  - Model name/number - SWP 150
  - Type of flow - Cross
  - Heat exchanger design - Fin Coil
  - External exposed surface - Unknown

	Air Side	Liquid Side
o Convection:	Forced	Forced
o Part of circulation loop:	4	3
o Maximum manufacturer's rated:		
- Temperature -	Unknown	Unknown
- Pressure -	Unknown	Unknown
o Heat transfer area		
- Rows -	3	
- Fins per inch -	12	
- Face area -	2.0 ft^2	

o Description

o Material - Aluminum | Copper, Type L

o Heating

o Design heating capacity - 25,500 Btu/hr

o Effectiveness - 75%

	Air Side	Liquid Side
o Design flow quality -	750 cfm	8 gpm
o Related circulator -	BL-1	P-3
o Temperatures -		
- Entering -	65° F	98° F
- Leaving -	90° F	92° F

o Blower (BL-1) - Part of HP-1

o Manufacturer - Command-Aire

o Model name/number - SWP 150

o Type - Squirrel cage

o Motor size - 0.125 hp; 208 V; 1 phase; 60 Hz

- Maximum motor speed - 1075 rpm
- Drive - Direct
- Blower speed - Single

- Design conditions
  - At single speed
    - Impeller - 1075 rpm
    - Circulating volume - 750 cfm
    - External static pressure - 0.33 in. wg
    - Motor operation - 0.125 bhp

AIR CIRCULATION LOOP NO. 4 (Air Circulation)

- Heating
  - Maximum design operating temperature - 95° F
  - Pressure - 1.09 in wg
  - Heating design air flow - 700 cfm
- Components within circulation loop
  - Blower(s) - BL-1 (Part of HP-1)
  - Heat exchanger(s) - HX-1, HPHX-1
  - Other(s) - ERH-1 (Part of HP-1)
- Ducting
  - Type - Steel galvanized
  - Location - Above grade
  - Maximum operating temperature - 95° F
  - Interior Insulation - Line acoustic glass fiber (Johns Manville)
  - Exterior Insulation - Fiberglas (Owens Corning)
  - Exterior finish- Aluminum foil
  - Filter - Fiberglas (Owens Corning)

- Location - Return duct
- Face area - 2 ft^2

CONTROL MODE SELECTOR (CMS-2)

- Modes controlled
  - Storage to space -
    - ON - (SN-5)< 65^{o} F and (SN-4) > 98^{o} F
    - OFF - (SN-4)< 98^{o} F
- Sensors (SN-4) and (SN-5)
  - Characteristics unknown

CONTROL MODE SELECTOR (CMS-3)

- Storage to auxiliary to space
  - ON - (SN-6) < 65^{o} F and (SN-7) > 50^{o} F
  - OFF - (SN-7)< 50^{o}, ERH-1 ON
- Sensors (SN-6) and (SN-7)
  - Characteristics unknown

CONTROL MODE SELECTOR (CMS-4)

- Storage to DWH-1
  - ON - (SN-8) < 135^{o} F
  - OFF - (SN-08) > 135^{o} F
- Sensor (SN-8)
  - Characteristics unknown

E. Auxiliary Subsystems (See figure IV-E-1)

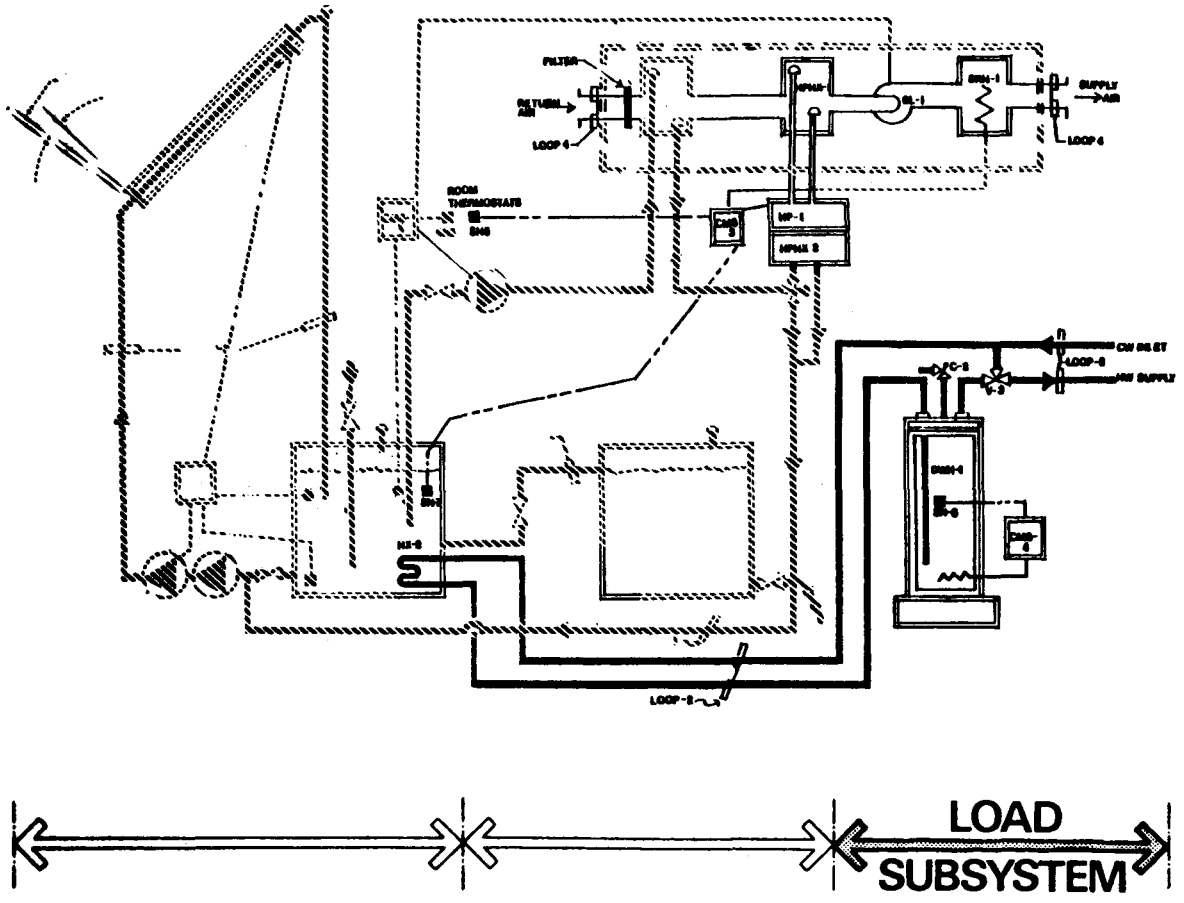


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystems, DWH-1 and HP-1 mentioned in the foregoing Energy to Load Subsystem have been grouped in this section for descriptive purposes, their function and purpose have been previously described.

AUXILIARY LOADS

- Domestic Water Heater (DWH-1)
  - Manufacturer - Rheem
  - Model - 666 H-52D
  - Energy source - Electric; 240 V; 1 phase; 60 Hz
  - Manufacturer's rating:
    - Tank size - 52 gallon
    - Energy input - 13,652 Btu/hr
    - Energy output - 12,300 Btu/hr
    - Maximum pressure rating - 300 psi
    - Maximum temperature rating - 140° F
    - Design operating pressure - 30 psi
    - Heating stages - 2
    - Maximum recovery rate - 19 gal/hr
    - Yearly average inlet temperature - 55° F
    - Design output temperature - 135° F
    - Thermal resistance - R-4
    - Standby heat loss - 2% per hr
    - Corrosion protection anodes - No
    - Burner ignition method - Electric
    - Flue vent - No
- Electric Resistance Heater (ERH-1)
  - Manufacturer - Lennox
  - Model name/number - ED-7-816-4.8-2C
  - Energy source - Electric; 4.8 kW; 240 V; 1 phase; 60 Hz

- Heat Pump (HP-1)
  - Manufacturer - Command-Aire
  - Model name/number - 150
  - Type - Vapor compression
  - Fluid - Refrigerant, R-12
  - Power within refrigeration machine
    - Electrical motor size - 1.5 hp; 230 V; 1 phase; 60 Hz
    - Blower - BL-1
- Heat Pump Heat Exchanger (HPHX-1)
  - Manufacturer- Command-Aire
  - Model name/number - 150
  - Type of flow - Counter
  - Heat exchanger design - Continuous fin coil wrapped inside shell
  - Number of separations - Unknown
  - External exposed surface - Unknown

	Liquid Side	Refrig. Side
o Convection:	Forced	Forced
o Located in:	HP-1	
o Part of circulation loop:	3	
o Maximum manufacturer's rated:		1.5 HP
- Temperature -	Unknown	Unknown
- Pressure -	Unknown	Unknown
o Material -	Copper/Aluminum	Copper/Aluminum

F. Modes of Operation (See figure IV-F-1)

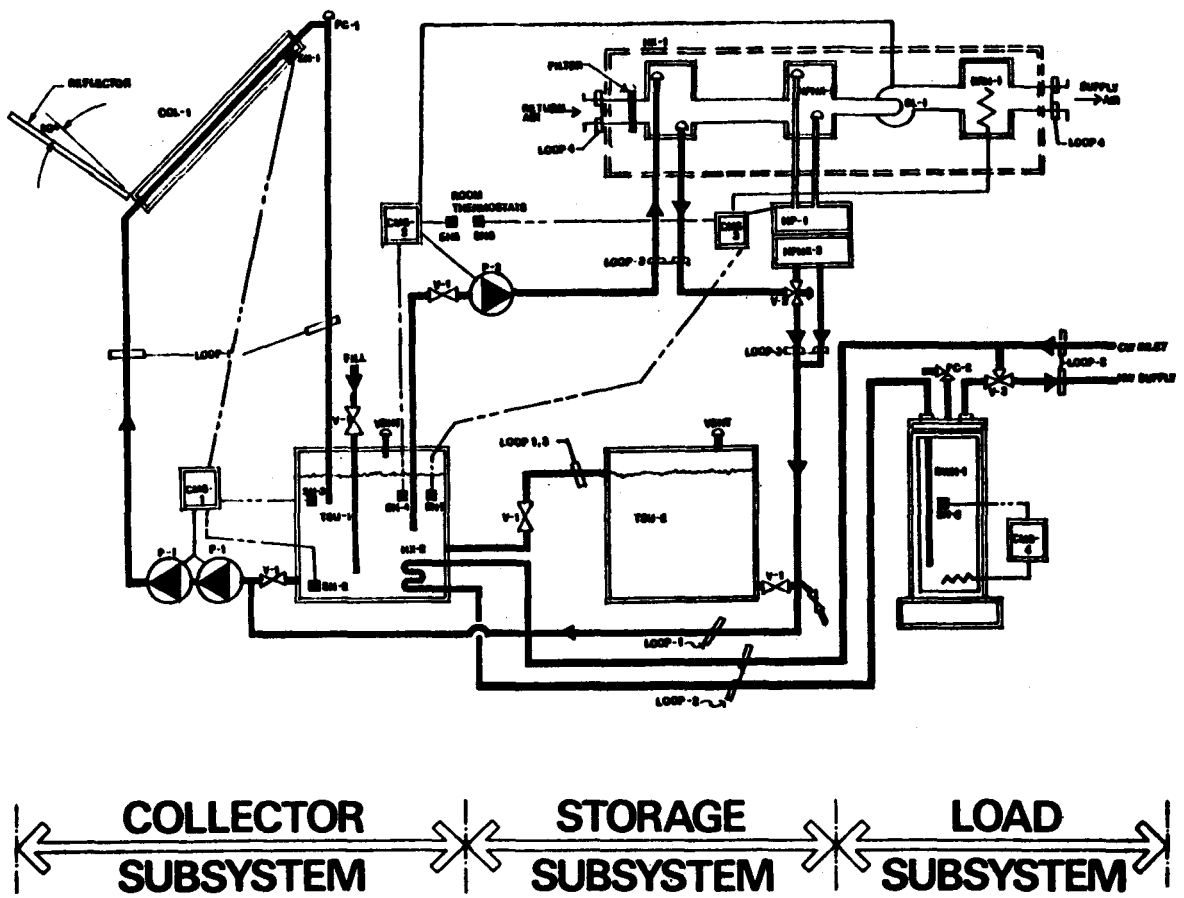


Figure IV-F-1. Controls Diagram

The Landura solar system is shown on figure IV-F-1. The system consists of the following four subsystems: a) Collector, b) storage, c) load (space heat and DHW), d) auxiliary loads subsystems.

Operation of the solar system and the auxiliary subsystems may involve one or more of the four modes of operations described below.

Mode 1 - Collector-to-Storage:

This mode is activated when temperature sensors in the collector array obtain a temperature differential 9^{o} F higher than the average temperature in the storage tank. The collector loop pump then turns on and circulates water through the collector array and the storage tanks.

Mode 2 - Storage-to-Space Heating - Solar Only:

This mode activates when there is a demand for heating and the temperature in the storage tank is higher than 90^{o} F. Hot water is circulated through the hydronic coil in the air supply duct.

Mode 3 - Storage-to-Space Heating - Solar Plus Heat Pump:

This mode activates when there is a demand for space heating and the temperature in the storage tank is higher than 50^{o} F but lower than 90^{o} F. Control Valve D401 opens, allowing the hot water to circulate through the heat exchanger and assist the heat pump operation before returning to storage.

Mode 4 - Storage-to-DHW Tank:

This mode activates when there is a demand for hot water as measured by flow through W300. Supply water is preheated by passing through the heat exchanger coil in storage tank 1 and then flows to the conventional DHW tank where auxiliary energy will heat it to the demand temperature.

V. PERFORMANCE EVALUATION INSTRUMENTATION

A. The National Solar Data Network

The National Solar Data Network (see figure V-A-1) has been developed for the Department of Energy to process data collected from specific residential demonstration sites which were selected for thermal performance evaluation. The data flow in the Network includes monthly and seasonal system performance reports describing the thermal performance of the solar energy system and subsystems.

The performance evaluation instrumentation at each selected demonstration site is part of a comprehensive data collection system that allows for valid analyses of the solar system performance. Collected data are both applicable and practical in calculating thermal performance factors that describe the behavior of the solar system (see NBSIR 76-1137), National Bureau of Standards. Additional instrumentation may also be included as a result of site-specific requirements. Typically, the instrumentation includes sensors that monitor the following:

- Total insolation in the plane of the collector array
- Ambient temperature
- Collector subsystem flow rate and temperatures
- Storage inlet flow rate and temperatures
- Storage outlet flow rate and temperatures
- Storage temperature
- Storage-to-load subsystem flow rate and temperatures
- Auxiliary fuel flow rates

Site data are recorded automatically at prescribed intervals by the Site Data Acquisition System (SDAS). The recorded data are transmitted daily to the Communications Processor in the Central Data Processing System (CDPS). The communications link between every SDAS and the CDPS consists of voice-grade telephone lines and telephone data couplers. A reading is transmitted from the SDAS internal timer with every data sample to ensure that the data are time-tagged correctly.

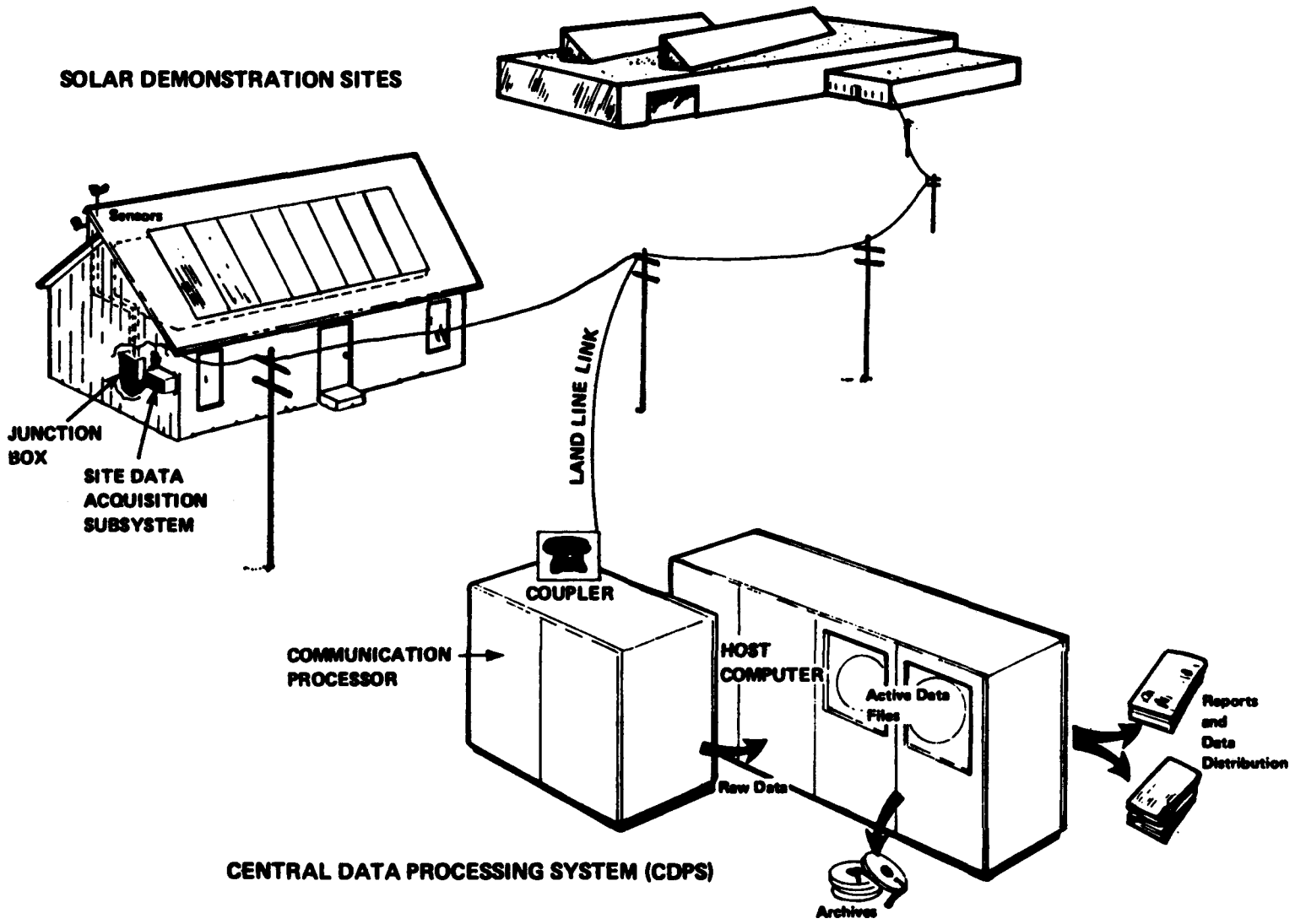


Figure V-A-1. The National Solar Data Network

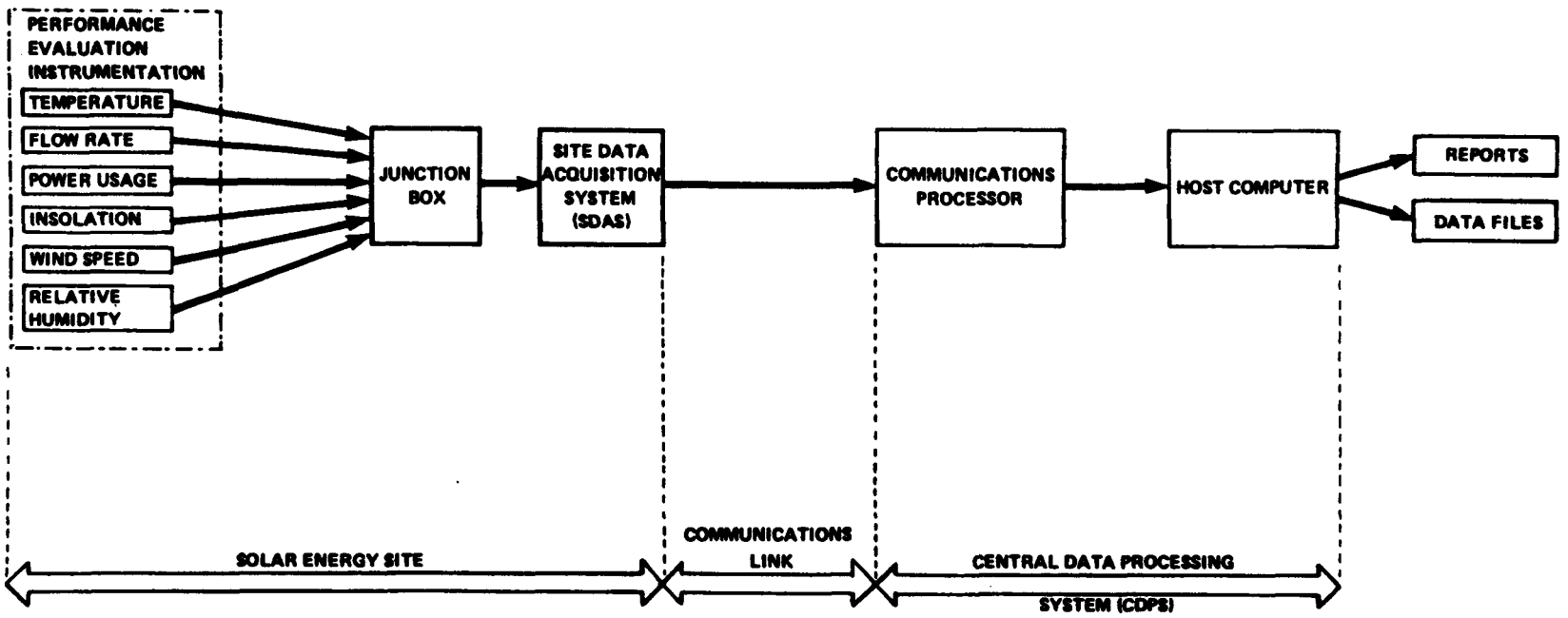


Figure V-A-2. Data Flow Path for the National Solar Data Network

The Communications Processor scans the receiving data to identify any apparent transmission errors and verifies correct site contact by checking the address code transmitted by the SDAS. Data is stored temporarily in the Communications Processor and processed by the Host Computer. The processing includes measurement checking to ensure that the data are reasonable; that is, that they are not beyond the known instrument limits and that they are not erratic. Data which appear questionable are discarded and are not used in the solar system preformance analyses.

Appropriate equations were formulated and programmed to define desired performance factors for the solar energy systems at each selected demonstration site. A performance factor is a number that describes either the efficiency or the quantity of energy lost, gained, or converted by a solar energy system or by a component. All valid data are processed using these performance factor equations to generate hourly performance factors. Hourly performance factors are integrated into daily and monthly performance factors. These hourly, daily, and monthly performance factors are stored in data files in the CDPS. These data files also include measurement data, expressed in engineering units; numerical and textual site identification; and specific site data used in generating the performance factors.

B. On-Site Instrumentation

The on-site instrumentation includes sensors to monitor the various parameters of the solar energy system, a junction box, and a Site Data Acquisition System that stores and transmits data to the Host Computer (see figure V-A-1 and V-A-2). Specific information for temperature, flow, power and miscellaneous sensors are presented in tabular form. Sensor locations are shown in figure V-B-1.

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Insolation, total	Eppley PSP
T001	Temperature, outside ambient	S53P-60
T100	Temperature, collector inlet manifold	S53P-60
T101	Temperature, collector output manifold	S53P-60
W-100	Flow rate, collector loop	MKV-1-1.0-10.0
EP-100	Power, collector loop pumps P1 & P2	PC5-106
T-102	Temperature, collector/storage input to tank T2	S53P-60
T-103	Temperature, collector/storage output from tank T2	S53P-60
T-104	Temperature, collector/storage input to tank T1	S53P-60
T-105	Temperature, collector/storage output from tank T1	S53P-60
T-400	Temperature, storage, space heating output from tank T1	S53P-60
T-200	Temperature, tank T1 storage medium, top	S53P-386
T-201	Temperature, tank T1 storage medium, center	S53P-386
T-202	Temperature, tank T1 storage medium, bottom	S53P-386
T-203	Temperature, outer most surface, storage tank T1	S32B
T-204	Temperature, tank T2 storage medium, top	S53P-386
T-205	Temperature, tank T2 storage medium, center	S53P-386
T-206	Temperature, tank T2 storage medium, bottom	S53P-386
T-207	Temperature, outer most surface, storage tank T2	S32B
T-300	Temperature, cold water supply to DHW preheat coil	S53P-60
T-301	Temperature, DHW preheat coil output manifold	S53P-60
W-300	Flow Totalizer, cold water supply to DHW tank	Hersey #430
T-302	Temperature, DHW tank output	S57P-100
T-303	Temperature, outer most surface of the DHW tank	S32B
EP-300	Power; consumed by DHW tank electric heater	PC5-29 (2 passes)

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
T-401	Temperature, input to solar heat coil	S53P-60
T-402	Temperature, output from solar heat coil	S53P-60
W-400	Flow rate, space heating loop	MKV-1-1.0-10.0
T-403	Temperature, input to heat pump HX (HX-1)	S53P-60
T-404	Temperature, output from heat pump HX (HX-1)	S53P-60
S-401	Operation mode, space heating	W88ACPX-3
T-405	Temperature, return air to heat pump	S53P-100
T-406	Temperature, air flow between the solar heating coil and heat pump coil	S53P-100
T-407	Temperature, air flow between the heat pump coil and aux. electric duct heater	S53P-100
T-408	Temperature, air supply available for space heating	S53P-100
W-401	Flow rate, return air to heat pump	Kurz 430-DC
EP-400	Power, consumed by heat pump blower	PC5-107
EP-401	Power, consumed by electric duct heater	PC5-29 (2 passes)
EP-402	Power, consumed by heat pump compressor	PC5-20
EP-403	Power, consumed by space heating loop pump P3	PC5-103
T-600	Temperature, heated space	S53P-28
I-002	Solar Insolation	Eppley PSP
T-106	Temperature, collector/storage loop output from tank T1. (Summer mode only)	S53P-60

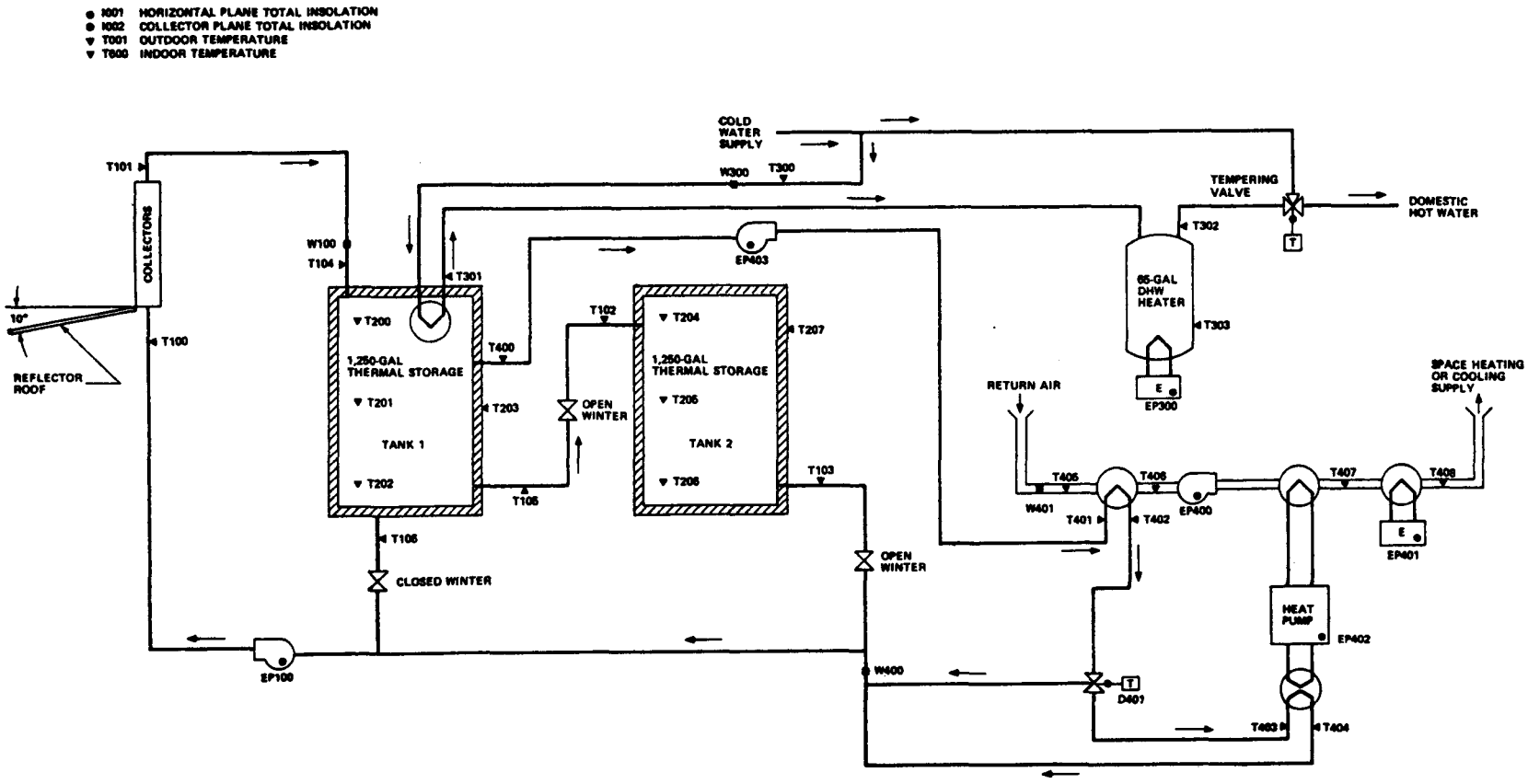


Figure V-B-1. Sensor and Control Diagram

VI. COST DATA

A. General

The following cost data depicts only solar energy portion of the construction costs. Costs of instrumentation are not included since it is not part of the construction effort.

B. Construction Grant Funds

Solar Subsystem	Applicants Request	Construction Grant
Collectors	$3705	$
Energy Storage	680	
Distribution and Controls	3716	
Installation	1584	
Other		
Total	$9,685	$9,685

C. Construction Period: August 1977 through November 1977

VII. APPENDIX

A. Glossary

ABSORBER PLATE - The surface in a flat plate collector that absorbs incident solar radiation and transfers the absorbed energy to a heat transfer fluid.
ABSORPTANCE - The ratio of absorbed radiation by a surface to the total incident radiation on that surface.
ABSORPTION SUBSYSTEM - The mechanical equipment that conditions indoor air by an absorption process.
ACTIVE SOLAR SYSTEM - An integrated solar energy system, consisting of collector, storage, solar energy-to-load subsystems, that can condition indoor air or preheat domestic hot water in a controlled manner.
AIR-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which air is the heat transfer fluid.
AIR CONDITIONING - The process of treating indoor air by controlling the temperature, humidity, and distribution to specified comfort settings as set by the occupants in the conditioned space.
AMBIENT AIR - A term for outdoor air, and may be brought into a building to be conditioned or circulated.
ANTI-FREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses additives or solutions to the heat transfer medium, which depresses its freezing point sufficiently to prevent possible water freeze in the solar collectors and the exterior piping.
AUXILIARY ENERGY SUBSYSTEM - The equipment, utilizing conventional energy sources, used to supplement the output provided by a solar energy system and used to provide a full backup system when the solar system is inoperable.
BACKFLOW - The reversal of flow in a distribution system.
BACKFLOW PREVENTOR - A device or means to stop backflow.
BEAM RADIATION - Solar radiation which is not scattered and may be concentrated.
BRITISH THERMAL UNIT (Btu) - A unit of energy that is required to heat one pound of water from 59° F to 60° F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

CLIMATE - The prevailing or average weather conditions of a specific geographic region as described by temperature and other meteorological data.

COLLECTOR MANIFOLD - The piping that connects the absorber tubes in a collector plate.

COLLECTOR PLATE - A term used for an absorber plate.

COLLECTOR SUBSYSTEM - The assembly that absorbes solar radiation and transfers the absorbed thermal energy to a heat transfer fluid.

COMBINED COLLECTORS - An assembly that both collects solar radiation and stores the thermal energy in the same unit.

CONCENTRATING SOLAR COLLECTOR - A solar collector which focuses beam radiation onto an absorber in order to obtain higher energy fluxes than can normally be achieved by flat plate solar collectors.

CONCENTRATOR - A reflective surface or refracting lens used in directing insolation onto an absorber.

CONDITIONED SPACE - The space in a building where the air is conditioned by heating or cooling.

CONTROL SUBSYSTEM - The assembly of electric, pneumatic, and hydraulic actuated sensing devices used in regulating the solar energy system and the auxiliary energy subsystems.

COOLING TOWER - A heat exchanger that transfers waste heat from an absorption cooling system to ambient air.

DIFFUSE RADIATION - Solar radiation which is scattered by air molecules, dust, or other substances suspended in the air.

DRAIN-DOWN FREEZE PROTECTION SYSTEM - A freeze protection system that prevents potential water freeze-up within the collector and exterior piping by automatically draining and replacing the water with a non-freezing medium such as air, nitrogen, etc.

DUCT HEATING COIL - A liquid-to-air heat exchanger in the duct distribution system used to heat air by passing a hot fluid through a coil in the air system.

EQUIVALENT FULL LOAD COOLING HOURS - The seasonal cooling load for a building described as the total number of hours that the air conditioning system will operate under full load conditions to meet the required cooling load.

EMITTANCE - The ratio of energy radiated by a body to the energy radiated by a black body at the same temperature.

EXPANSION TANK - A tank which will permit water to expand whenever it is heated to prevent excessive pressures on the other system components.

FIXED COLLECTOR - A solar collector that is permanently oriented towards the sun and cannot track the sun nor be adjusted for seasonal variations.

FLAT PLATE COLLECTOR - A basic heat collection device used in solar heating systems, which consists of an absorber plate, with insulated bottom and sides, and covered by one or more transparent covers. There are no concentrators or focusing aids in a flat plate collector.

FOCUSING COLLECTOR - A solar collector using a parabolic mirror, fresnel lens, or other type of focusing device to concentrate solar radiation onto an absorber.

FRESNEL COLLECTOR - A concentrating solar collector which uses a fresnel lens to focus beam radiation onto an absorber.

GLAZING - The transparent cover(s) on a solar collector used to reduce the energy losses from the top of the collector.

HEAT TRANSFER FLUID - The fluid that transfers solar energy from the solar collector to the storage subsystem or to the load.

INCIDENCE ANGLE - The angle in which the insolation strikes a surface and the normal for that surface.

INSOLATION - The total amount of solar radiation on a surface in a given unit of time.

LAMINATED GLASS - A glazing consisting of multiple glass sheets bonded together by intervening layer or layers of plastic.

LANGLEY - The standard unit of insolation defined as 1 langley = 1 cal/cm^2, (1 Langley = 3.69 Btu/ft^2).

LIQUID-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which either water or an antifreeze solution is the heat transfer fluid.

LOAD - The total space conditioning or domestic water heating requirements that are supplied by both the solar energy system and the auxiliary energy subsystem.

NOCTURNAL RADIATION - The loss of thermal energy by the solar collectors to the sky at night.

NO-FLOW CONDITION - The condition obtained when the heat transfer fluid is not flowing through the collector array due to a shutdown or a malfunction.

OPAQUE - A surface that is not transparent, thus solar radiation is either reflected or absorbed.

OUTGASSING - The emission of gases by materials and components, usually during exposure to elevated temperature, or reduced pressure.

PACKAGE AIR-CONDITIONING UNIT - A factory-made assembly consisting of an indoor coil, a compressor, an outdoor coil, and other components needed for space cooling operations. This unit may also include additional components to heat the condition space.

PARABOLIC FOCUSING COLLECTOR - A concentrating collector which focuses beam radiation by a parabolic reflector.

PASSIVE SOLAR SYSTEM - An integrated solar energy system that can provide for space heating needs without the use of any other energy source other than the sun.

REFLECTANCE - The ratio of radiation reflected by a surface to the total incident radiation on the surface.

REFLECTED RADIATION - Insolation which is reflected from a surface, such as the ground, and is incident on the solar collector.

ROCK BED - A storage tank using uniform-sized rocks to store solar energy in air-based solar collector systems.

SELECTIVE SURFACE - A surface which has a high absorptance for solar radiation and a low emittance for thermal radiation.

SOLAR CONDITIONED SPACE - The area in a building that depends on solar energy to provide for a fraction of the heating and cooling needs.

SOLAR HEATING SYSTEM - An integrated assembly of collector, storage, solar energy-to-load, and control subsystems required to convert solar energy into thermal energy for space heating requirements, as well as the addition of an auxiliary backup system.

SOLAR RETROFIT - The addition of a solar energy system to an existing structure.

STORAGE SUBSYSTEM - The components used to store solar energy so that the stored energy can be used for heating, cooling, or heating water during periods of low insolation.

STRATIFICATION - The horizontal layering in a medium due to temperature differentials, commonly noticed in storage tanks filled with water.

THERMOSTAT - A temperature sensing device which controls the heating and cooling systems for space conditioning or the hot water heater.

TILT ANGLE FROM HORIZONTAL - Angle between the horizontal plane and the plane of collector.

TON OF REFRIGERATION - A unit of refrigeration which is equivalent to 12,000 Btu/hr.

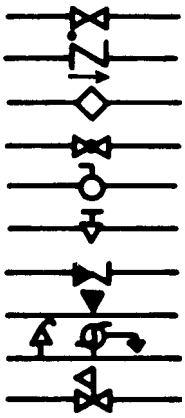
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

VAPOR BARRIER - A material which is used to reduce the transmission of water vapor.

ZONE - A portion of a conditioned space which use a common control because of their similar heating and cooling requirements.

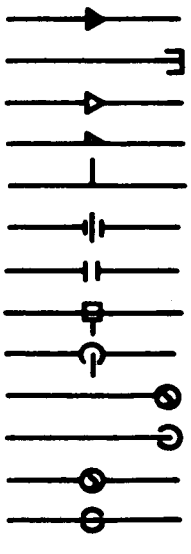
B. Legend For Solar System Schematics

VALVES



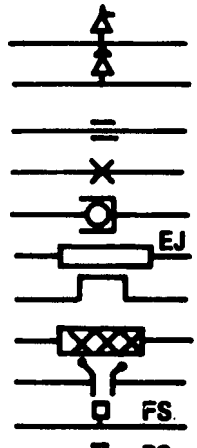
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS

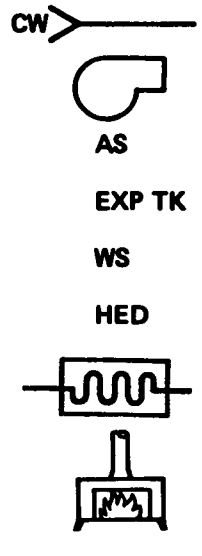


DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

PIPING SPECIALITIES



AUTOMATIC AIR VENT
MANUAL AIR VENT
ALIGNMENT GUIDE
ANCHOR
BALL JOINT
EXPANSION JOINT
EXPANSION LOOP
FLEXIBLE CONNECTION
FLOWMETER FITTING
FLOW SWITCH
PRESSURE SWITCH
PRESSURE GAUGE
PUMP
PIPE SLOPE
STRAINER
STRAINER, W/BLOW OFF
TRAP
CONTROL SENSOR
INSTRUMENTATION SENSOR
THERMOMETER
THERMOMETER WELL ONLY



COLD WATER SUPPLY
BLOWER
AS — AIR SEPARATOR
EXP TK — EXPANSION TANK
WS — WATER SOFTENER
HED — HOSE END DRAIN
HEAT EXCHANGER
STOVE (FRANKLIN TYPE)

* U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2264