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SOLAR/1047-81/50
(DE81028120)

D. 6326

Solar Project Description

FIRST MANUFACTURED HOMES (LOT 219) SINGLE FAMILY RESIDENCE

Lubbock, Texas

August 21, 1981

U.S. Department of Energy

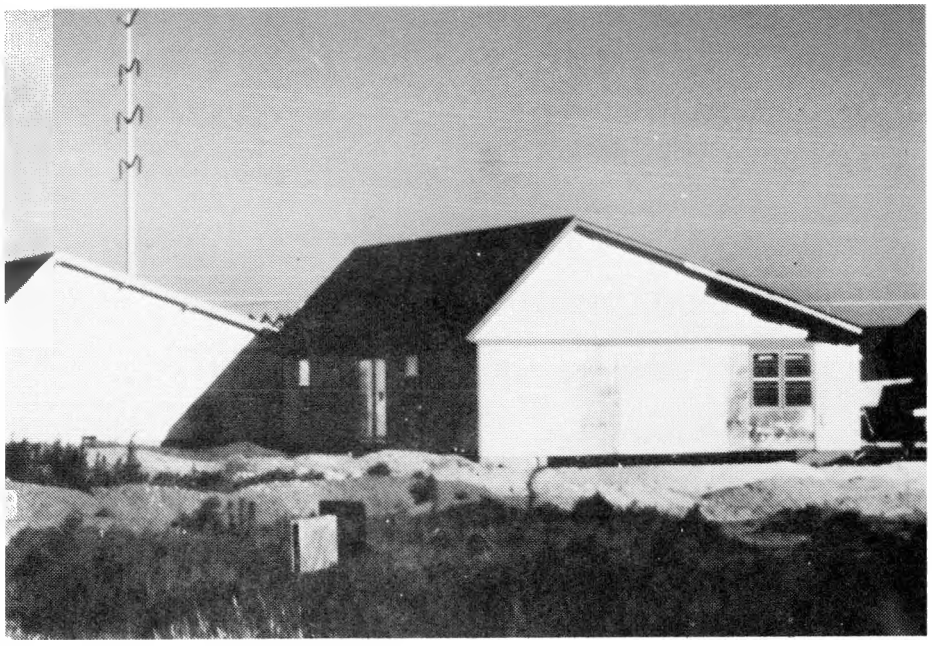
National Solar Heating and Cooling Demonstration Program

National Solar Data Program

DISCLAIMER

SOLAR/1047-81/50
(DE81028120)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
FIRST MANUFACTURED HOMES, LOT 219
SINGLE FAMILY RESIDENCE; LUBBOCK, TEXAS



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

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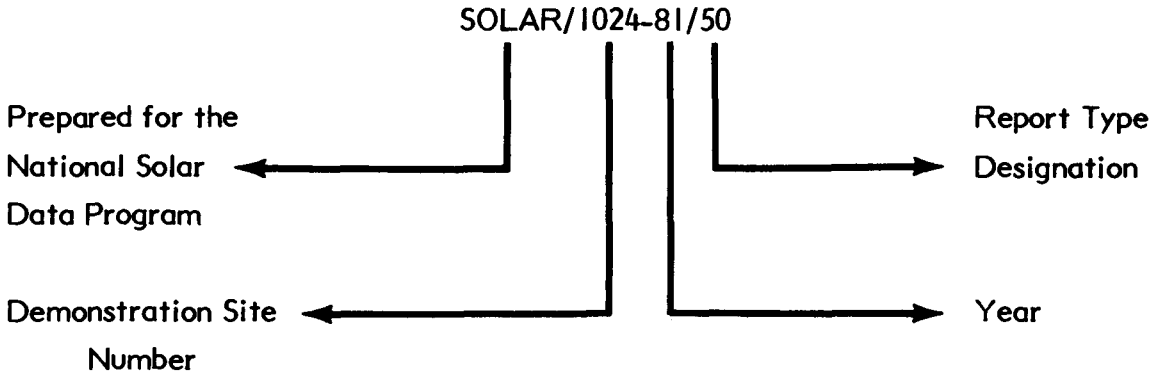
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the First Manufactured Homes project site is designated as SOLAR/1024-81/50. 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:

- o Solar Project Description.
- o Operational Experience.
- o System Performance Evaluation.
- o 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 -- Air
- o Freeze Protection -- Not required
- o Application -- Heating and domestic hot water
- o Storage -- Bin containing rock
- o New or Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- None

First Manufactured Homes, Lot 219 solar energy system (Grant H-8441) is installed in a single-family residence located in Lubbock, Texas. The system is designed to provide solar energy for space heating and to preheat domestic hot water.

Solar energy is collected by an array of nine Payne flat-plate collectors with a gross area of 288 square feet. The collector array is mounted on the roof of the house and faces due south at an angle of 45 degrees to the horizontal.

The collectors use air to collect and deliver solar energy to a storage bin containing 20,250 pounds of rock.

Space heating demands are met by circulating air through the rock and distributing the warmed air through the ductwork by means of a blower. Direct solar-to-space heating is provided by use of air directors (controller) to bypass the rock storage. Auxiliary space heating is provided by a heat pump and electric resistance heaters.

An air-to-liquid heat exchanger, located near the collector array outlet is used to heat domestic water in an 82-gallon preheat tank.

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 following are the general characteristics of First Manufactured Homes, Lot 219.

- Building type - Single-family detached
- Latitude - 33^{o}
- Longitude - 102^{o}
- Altitude - 3600 ft

HEATING DESIGN TEMPERATURES

- Outdoor - 15^{o} F DB
- Indoor - 70^{o} F DB

BUILDING

- Front of building faces - North
- Average stories above ground - 1
- Average stories below ground - 0
- Height above grade - 18 ft
- Conditioned floor area - 1280 ft^2
- Roof type - Sloped (45^{o} pitch)

DESIGN HEAT LOSS/LOAD

- Heat Loss - 24,485 Btu/hr
- Heat gain - Unknown
- Shading
  - Heating season - None
  - Cooling season - None

NOT AVAILABLE

Figure III-1. Site Plan

- Appliance, lighting and equipment load - 1200 Btu/hr
- Average horizontal insolation
  - January - 1021 Btu/ft^2-day
  - July - 2356 Btu/ft^2-day
- Annual degree days
  - Heating - 3580
  - Data source - ASHRAE

MECHANICAL SYSTEM

- Heating
  - Solar - Collector air
  - Auxiliary - Electric
  - Distribution - Ductwork
- Cooling (Non-Solar)
  - Auxiliary - Air conditioning
  - Distribution - Ductwork

DOMESTIC HOT WATER

- Daily water demand - 80 gallons per day
- Solar - Collector hot air to heat exchanger/storage
- Auxiliary - Electric water heater

GENERAL DATA

- Manufacturer - B.D. Payne Co.
- Model name/number - Solar Energy System
- Type of system - Air, active-heating

SYSTEM AND COMPONENT SUMMARY

- Collector types - 1 array
- Circulation loops - 2 air, 1 water

- Thermal storage units - 1 air, 1 water
- Operational modes - 5
- Pumps - 1
- Valves - 5
- Blowers - 2
- Dampers - 8
- Sensors - 4
- Flow regulators - 2 air directors
- Pressure regulators - none
- Fail safe controls - 1

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (First Manufactured Homes, Lot 220, Grant H-8441) located at Lubbock, Texas is an active air system utilized for heating space and domestic hot water. Auxiliary units are provided for space heating and domestic hot water.

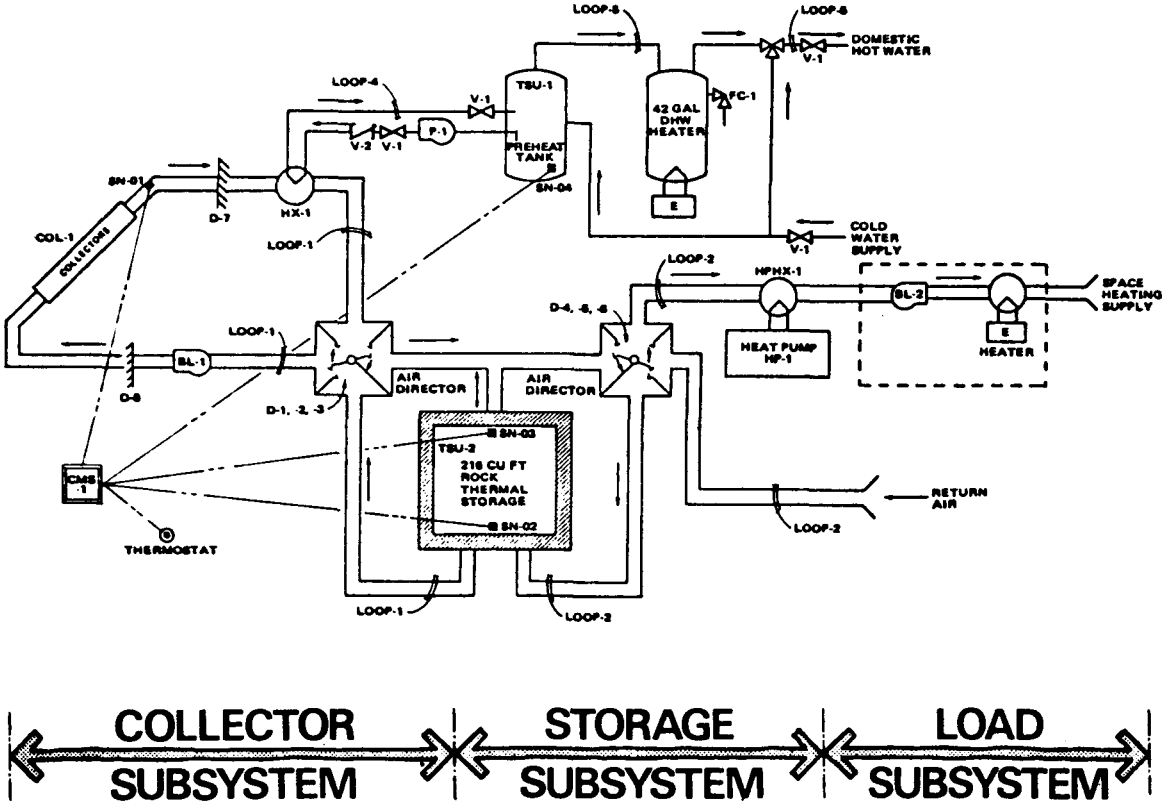


Figure IV-A-1. General Overview

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 figures IV-B-1 and IV-B-2)

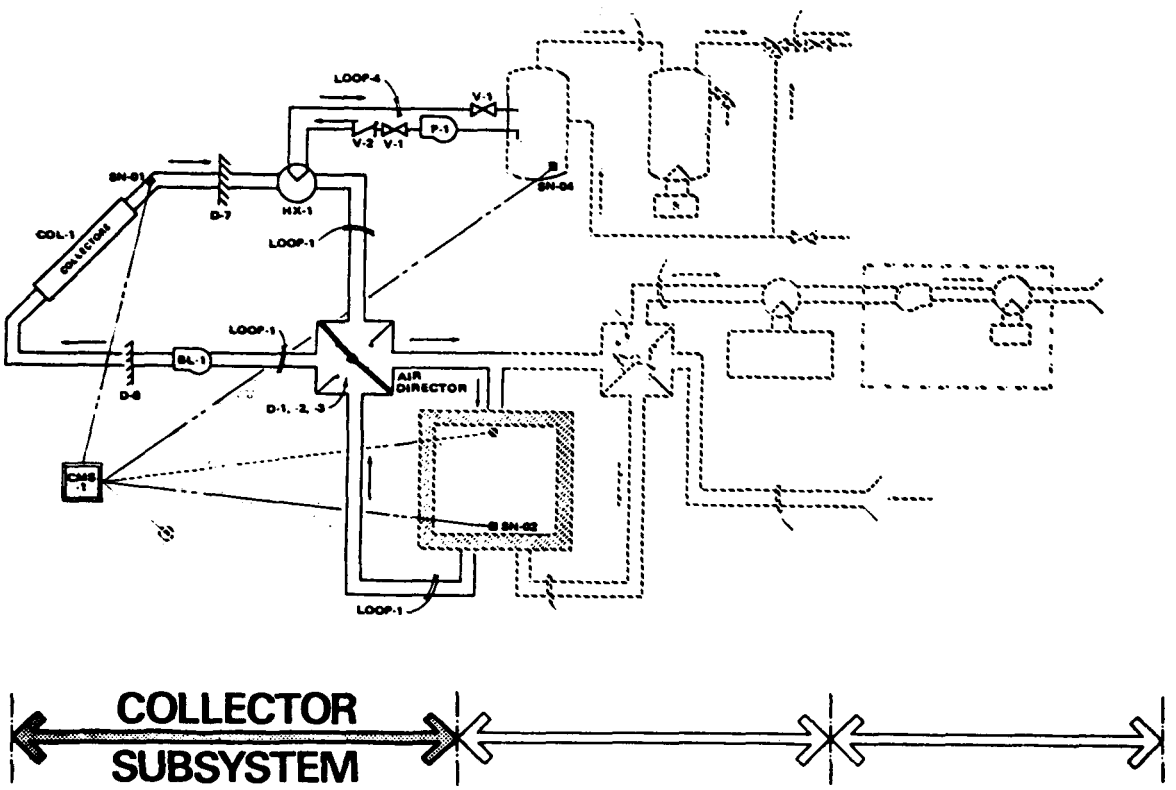


Figure IV-B-1. Collector Subsystem

Collector array system consists of nine air flat plate collector panels. The total gross area of the array is 288 ft^2.

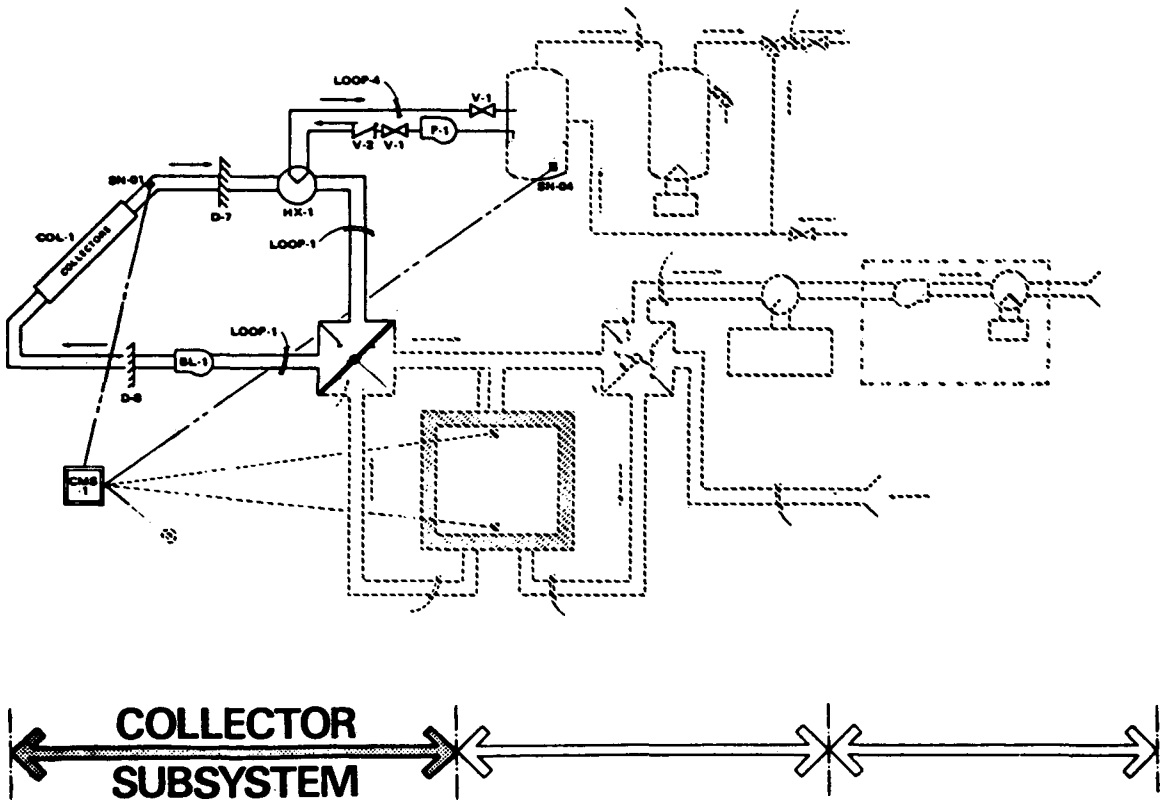


Figure IV-B-2. Collector Subsystem - Hot Water Preheat, Summer Mode

This mode can be activated during the summer when there is no need to add solar energy to the rock storage bin.

COLLECTOR (COL-1) (See figure IV-B-3)

- Manufacturer - B.D. Payne Co
- Model name/number - 175A408SCS
- Type - Air flat plate, corrugated
- Location - Roof
- Orientation - Fixed at 0^{o} W of S
- Tilt angle - 45^{o} from horizontal
- Number of collector panels - 9
- Array configuration - One row of panels side by side

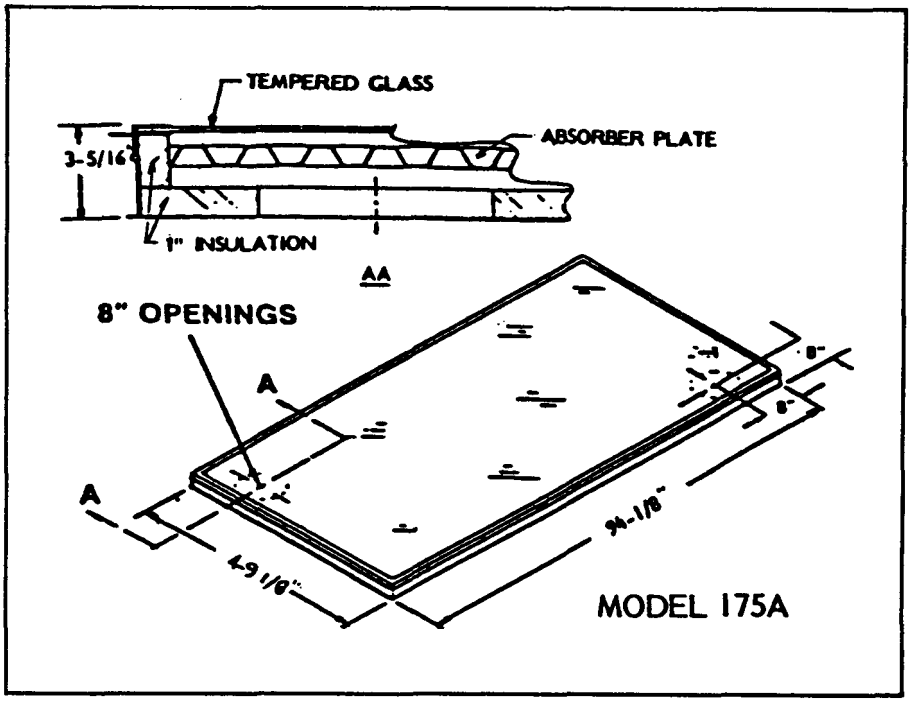


Figure IV-B-3. Solar Collector

- Collector characteristics
  - Number of panels - 9
  - Total gross area of array - 288ft^2
  - Net aperture area - 270 ft^2
  - Net absorber area - 270 ft^2
  - Weight per panel, empty - Unknown
  - Weight per panel, full - Unknown
  - Panel length - 94-1/8"
  - Panel width - 49-1/8"
  - Frame depth - 3-5/16"
  - Standoff height - None
- Built-in collector - Built into roof
- Collector shading -
  - Area shaded in June - 0%
  - Area shaded in December -0%
  - Maximum shade during functional season - 0%
- Cover plates
  - Manufacturer - B.D. Payne Co
  - Product name/number - 175A408SCS
  - Number of cover plates - 1
  - Location - Outer layer
  - Material - Glass, tempered, low iron
  - Thickness - 0.188 inch
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	90%	-
- Reflectance -	8%	-
- Emittance -	97%	-

- Edge or surface treatment, other than coating - None
- Coating on cover plate material - None

- Absorber
  - Manufacturer - B.D. Payne Co
  - Model name/number - 175A408SCS
  - Material - Metal, corrugated
  - Number of absorbers per collector - 1
- Heat transfer fluid passages
  - Location - Beneath absorber
  - Pattern - Parallel
  - Materials - Aluminum - insulation
  - Maximum rated conditions
    - Temperature - 310° F
    - Pressure - N/A
- Other information
  - Dessicant - None
  - Freeze protection - None required (air system)
- Frame
  - Material - Extruded aluminum
  - Number of structure attach points per module to building - Continuous
- Collector performance
  - Method of evaluation - $\frac{t_i - t_a}{I_t}$ NBS
  - y intercept $F_R(\tau\alpha)_\eta = 0.70 \frac{(^\circ F.hr.ft^2)}{Btu}$
  - Slope - $F_R U_L = 1.27$

- Point Number 1 2 3 4
  - η = collector thermal efficiency (η %) -
  - t_i or t_f = collector inlet temperature (^{o} F) - NOT
  - t_a = ambient air temperature (^{o} F) - AVAILABLE
  - 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, ^{o} F
- I_t = radiation (insolation) intensity on collector, Btu/hr.ft^2
  - Test flow rate - Not available
  - Heat loss coefficient - Not available
  - Test wind speed - Not available
  - Test collector area
    - Gross - Not available
    - Net - Not available
  - Fluid specific heat - 1.00 Btu/lb/^{o} F
  - Test fluid medium - Water 100%

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

- Maximum design operating temperature - 180^o F
- Maximum design operating pressure - 0.8 in wg
- Heating design air flow - 890 cfm

- Components within circulation loop
  - Blower - BL-1
  - Heat exchanger - HX-1
  - Thermal storage unit(s) - TSU-2
  - Collector - COL-1
  - Flow director (damper) - D1, D2, and D3,
  - Distribution dampers - D7, and D8
- Blower - BL-1
  - Manufacturer - B.D. Payne Co
  - Circulating volume - 890 cfm
- Flow director and dampers
  - Manufacturer - B.D. Payne Co
  - Model name/number - Unknown
- Ducting
  - Manufacturer - Johns Manville
  - Type - Fiberglas ductboard
  - Location - Above grade
  - Exterior insulation - Fiberglas blanket
  - Exterior finish - Vinyl

LIQUID CIRCULATION LOOP NO. 4 (HX-1 TO TSU-1 HOT WATER PREHEAT)

- Design maximum operation temperature - 140° F
- Design maximum operation pressure - 150 psi
- Heating
  - Design heating capacity - 21,000 Btu/hr
- Heat transfer medium
  - Design pump circulating volume - 2 gpm @ 1.3 psi
  - Design flow, maximum - 3 gpm

- Design pump speed - 3100 rpm
- Volume of liquid in loop - 130 gallons
- Anticipated liquid temperatures
  - Maximum - 140° F
  - Minimum - 55° F
- Medium - Water (100%)
- Specific heat - 1.00 Btu/lb/° F
- Density - 62.4 lb/ft^3
- Boiling point - 212° F
- Freezing point - 32° F
- Toxicity - Potable
- pH factor - 7.0
- Chemical feeder to maintain pH factor - No
- Inhibitor - No

- Components within circulation loop
  - Pump - 1, (P-1)
  - Heat exchanger - 1, (HX-1)
  - Thermal storage unit - 1, (TSU-1)
  - Valve(s) - V-1, three total
  - Check valve - V-2, one total
- Piping
  - Rigid - Copper tubing
  - Interior coating - None
  - Insulation - Cellular rubber, vinyl covered
  - Location - Above grade in building
  - Filters - None
  - Getters - None

- Circulator pump (P-1)
  - Manufacturer - Grundfos
  - Model name/number - UP2664F
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 150 psi
    - Temperature - 140° F
  - Material exposed to heat transfer fluid - Bronze
  - Motor size - 1/12 hp
  - Maximum motor speed - 3100 rpm
  - Drive - Direct
  - Speed - Yes
  - Pump speed - 3100 rpm
  - Circulating volume - Low head mode - 2 gpm
  - Operating head (dynamic) - Low head mode - 1.3 psi
- Distribution Valve - V-1
  - Manufacturer - Nibco
  - Model name/number - 725
  - Function - On-Off
  - Operation - Manual
  - Type - Globe, 125 psi, 200° F
  - Material exposed to heat transfer fluid - Bronze
- Distribution Valve - V-2
  - Manufacturer - Nibco
  - Model name/number - 3/4" B
  - Function - check valve

- Operation - Automatic, non-motorized
- Type - Swing, 125 psi, 200° F
- Materials exposed to heat transfer fluid - Bronze

- Heat Exchanger, HX-1
  - Manufacturer - B.D. Payne Co.
  - Model name/number - 414B048CCW
  - Type of flow - Cross
  - Heat exchanger design - Fin coil

	Air Side	Liquid Side
o Convection:	Forced	Forced
o Circulation Loop:	1	4
o Maximum manufacturers rated		
- Temperature -	200° F	200° F
- Pressure -	-	300 psi
o Heat transfer/surface area		
- Rows -	3	
- Fins/inch -	13	
- Face area -	3.6 ft^2	
o Material types		
- Tubes -	Copper	Copper
- Fins -	Aluminum	-
- Exposed to fluid -	-	Copper
o Heating		
- Capacity -	-	21,000 Btu/hr
- Air flow rate -	890 cfm	3 gpm
Temperature		
- Entering -	180° F DB	55° F
- Leaving -	-	70° F

Control Mode Selector (CMS-1)

- Manufacturer - B.D. Payne Co
- Model name/number - 851BSSC
- Modes controlled
  - Collector to storage
    - ON - (SN-01) > (SN-02) + 25°F
    - OFF (SN-01) < (SN-02) + 10°F
  - Collector to hot water
    - ON - (SN-01) > (SN-04) + 25°F
    - OFF - (SN-01) < (SN-04) + 10°F or (SN-04) >140°F
- Sensors (SN-1) through (SN-4)
  - Manufacturer - B.D. Payne Co
  - Model name/number - 303009-101
  - Type - Temperature, thermistor

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

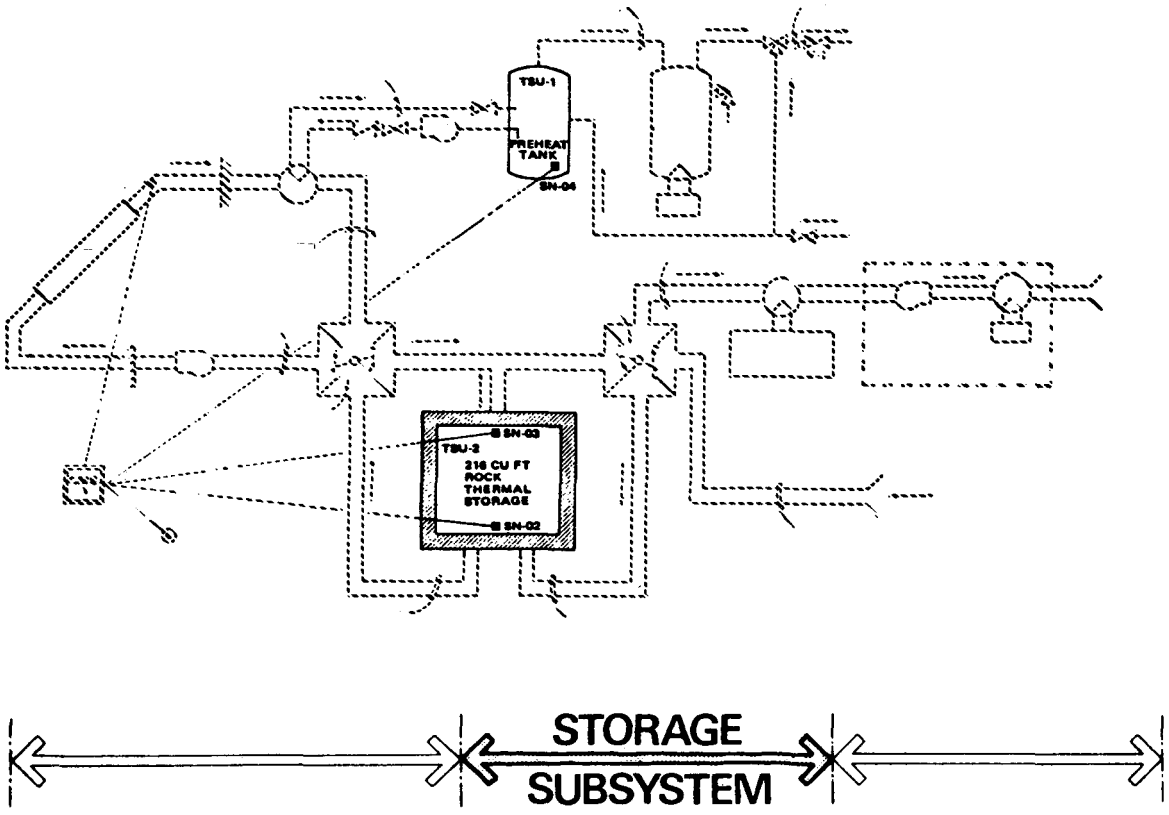


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by a bin containing 20,520 pounds of rock located within the house. This bin is constructed of 2' x 4' studs lined with gypsum board. It measures 7.5' x 7.7' high and has a volume of 234 ft^3 and is insulated with fiberglas batts and polystyrene insulation board.

The solar energy is distributed by a blower (BL-2) through a flow director and ductwork to the building space. When solar energy is insufficient, a heat pump (HP-1) provides space heating.

THERMAL STORAGE UNIT (TSU-2)

- Manufacturer - Site built
- Total storage bin volume - 278 ft^3
- Volume of storage medium - 234 ft^3
  - Length - 7.5 ft
  - Width - 7.7 ft
  - Height - Unknown
- Maximum rated operating conditions
  - Temperature - Not rated
  - Pressure - Not rated
- Storage medium
  - Design operating temperatures
    - Heating - 200° F
    - Cooling - N/A
  - Medium - Smooth surfaced stone 1.5 inch to 2 inch size
  - Specific heat - 0.205 Btu/lb/° F
  - Density - 100 lb/ft^3
  - Heat capacity - 20 $Btu/ft^3/°$ F
- Bin air pressure drop - 0.18 in wg
- Bin construction
  - 2" x 4" studding 16" oc
  - ½" plywood sheathing
  - ½" gypsum board lining
  - Fiberglass batts (R-11, R-19) between studs
  - Polystyrene insulation board on exterior
  - Location - In building on floor slab

- Thermal Storage Unit (TSU-1)
  - Manufacturer - State Industries Inc.
  - Total storage container volume - 11 ft^3
  - Volume of storage medium - 11 ft^3
    - Height - 5.2 ft
  - Diameter - 2.0 ft (outside)
  - Maximum rated operating conditions
    - Temperature - 210° F
    - Pressure - 300 psi
  - Storage medium -
    - Design operating temperatures
      - Maximum - 140° F
      - Minimum - 55° F
    - Medium - Potable water (100%)
    - Design pressure drop - 0.41 in wg
    - Lining - Vitrified glass
    - Auxiliary heater in unit - None
    - Finish - Enamel
    - Insulation - Fiberglas

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

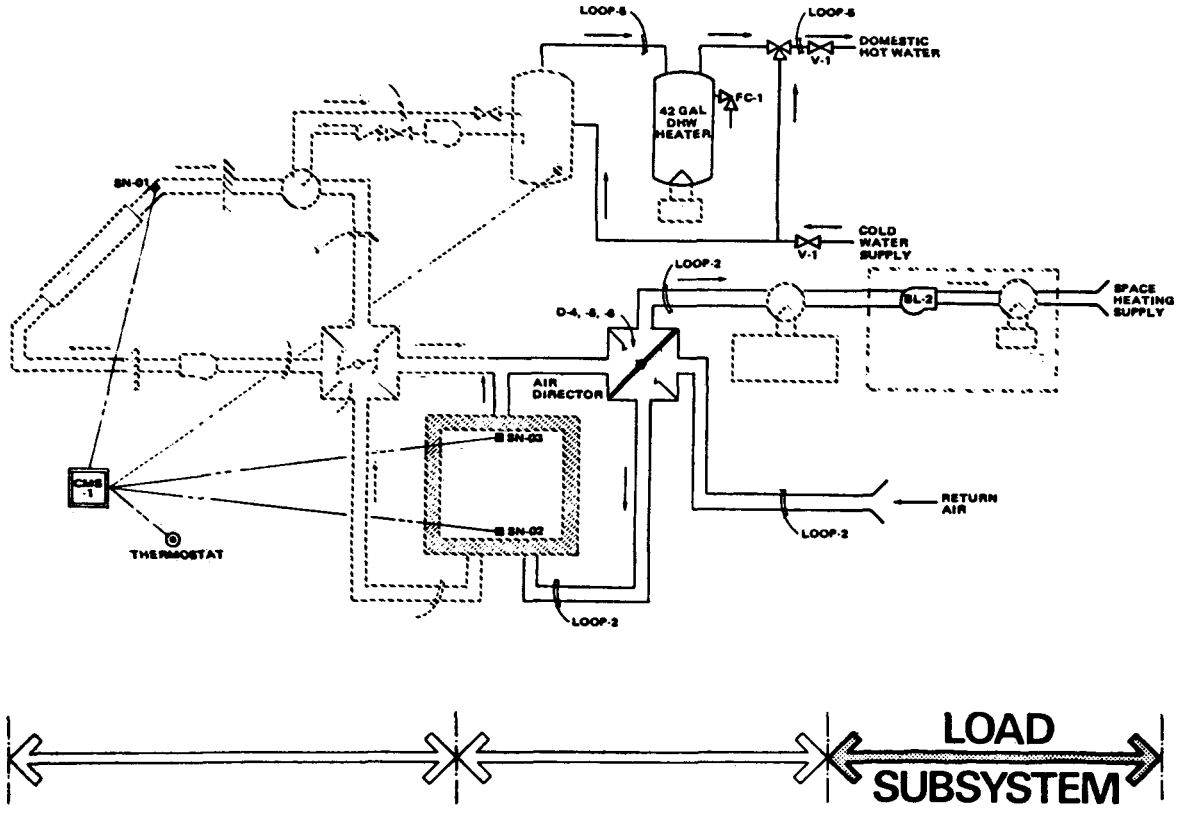


Figure IV-D-1. Energy-to-Load Subsystem, Storage to Space

Solar energy is used for space heating and preheating domestic hot water. Air is the transfer medium that delivers solar energy to storage, space heating and for preheating city water. Solar energy heated rocks are stored in the above ground bin (TSU-2). Space heating is provided by circulating air through the bin by means of the air distribution system. Auxiliary space heating is available from a heat pump and electric heating coils installed in the air system. Space cooling is provided by a heat pump/air conditioning unit.

Preheated city water is stored in an 11 ft^3 tank (TSU-1) and supplied on demand from a conventional 40-gallon DHW tank.

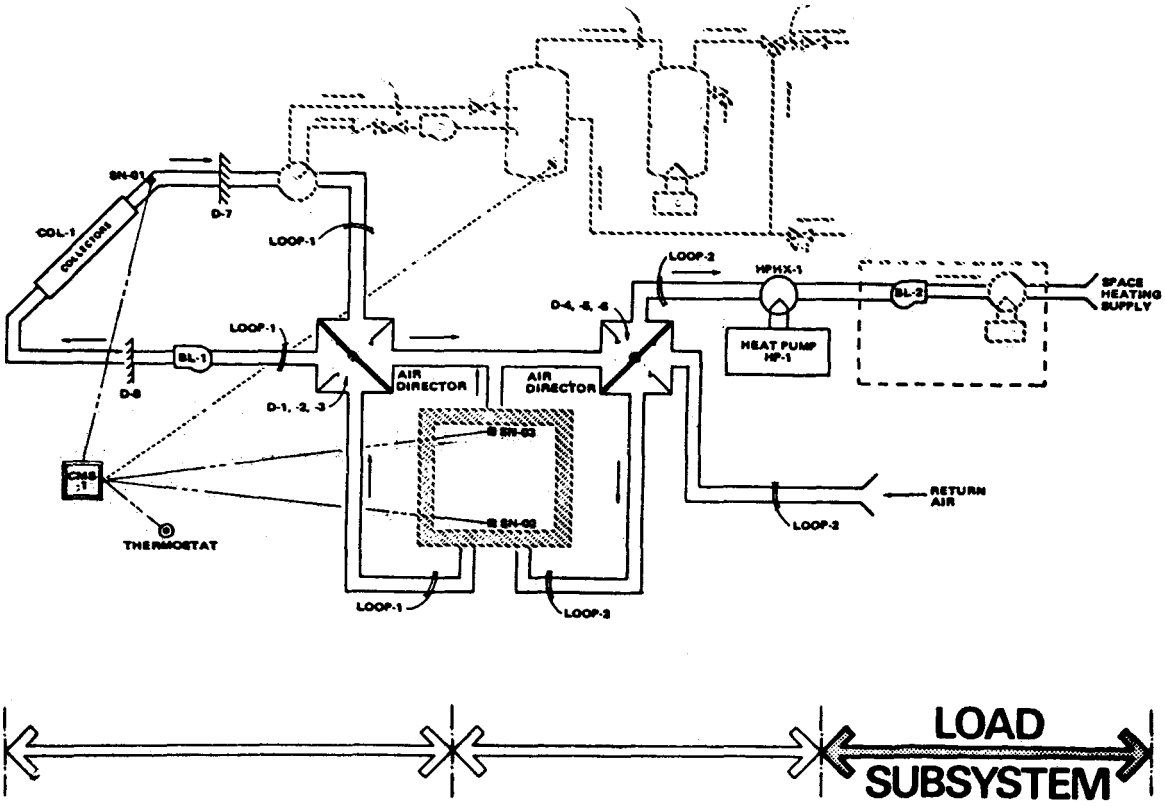


Figure IV-D-2. Energy-to-Load Subsystem, Collector to Storage to Space

When the collector temperature is 25°F higher than the storage bin, and other prerequisites are satisfied, both the heater and solar blowers are activated to provide space heating.

AIR CIRCULATION LOOP NO. 2 (TSU-2 TO SPACE)

- Design maximum operation temperature - 180° F
- Design maximum operation pressure - 0.8 in wg
- Heating design air flow - 900 cfm
- Components within circulation loop - 2
  - Blower - BL-2
  - Heat pump - HP-1
  - Thermal storage unit - TSU-2
  - Air flow director and dampers
  - Electric resistance heater - Part of HP-1
- Blower - BL-2
  - Manufacturer - B.D. Payne Co.
  - Circulating volume - 890 cfm
- Flow director dampers
  - Manufacturer - B.D. Payne Co.
  - Model name/number - Unknown
- Ducting
  - Manufacturer - Johns Manville
  - Type - Fiberglas ductboard (1")
  - Location - Above grade
  - Exterior insulation - Fiberglas blanket
  - Exterior finish - Vinyl

CIRCULATION LOOP NO. 5 (TSU-1 TO DWH)

- Maximum design operating temperature - 140° F
- Maximum design operating pressure - 150 psi
- Heat transfer medium
  - Volume of liquid in loop - 130 gallons

- Anticipated liquid temperature -
  - Maximum - 140° F
  - Minimum - 55° F
- Medium - Potable water (100%)
- Getters - None

- Components within circulation loop
  - Domestic water heater(s) - 1 (DWH)
  - Thermal storage unit(s) - 1 (TSU-1)
  - Valve(s) - 1, V-1 shutoff
  - Other(s) - 1, FC-1 (relief)

- Fail Safe Control (FC-1)
  - Manufacturer - BEACON
  - Product name/number - 1A5
  - Type - Pressure/temperature cut-off
    - Pressure cut-off - 150 psi
    - Temperature cut-off - 200° F

- Piping
  - Rigid - Copper tubing
  - Interior coating - None
  - Insulation - Cellular rubber, vinyl covered
  - Location - Above grade

- Distribution Valve (V-1)
  - Manufacturer - Nibco
  - Model name/number - 725
  - Function - On-Off
  - Operation - Manual
  - Type - Globe, 125 psi, 200° F

- Material exposed to heat transfer fluid - Bronze

- Control Mode Selector (CMS-1)
  - Manufacturer - B.D. Payne Co.
  - Model name/number - 851BSSC
  - Modes controlled
  - Storage to space
    - ON - (SN-03) > 95°F and thermostat demand
    - OFF - (SN-03)< 95°F or no thermostat demand
  - Collector to storage to space
    - ON - (SN-01) and (SN-03) > 95°F and thermostat demand
    - OFF (SN-03)< 95°F or no thermostat demand
- Sensors (SN-1) through (SN-4)
  - Manufacturer - B.D. Payne Co.
  - Model name/number - 303009-101
  - Type - Temperature, thermistor

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

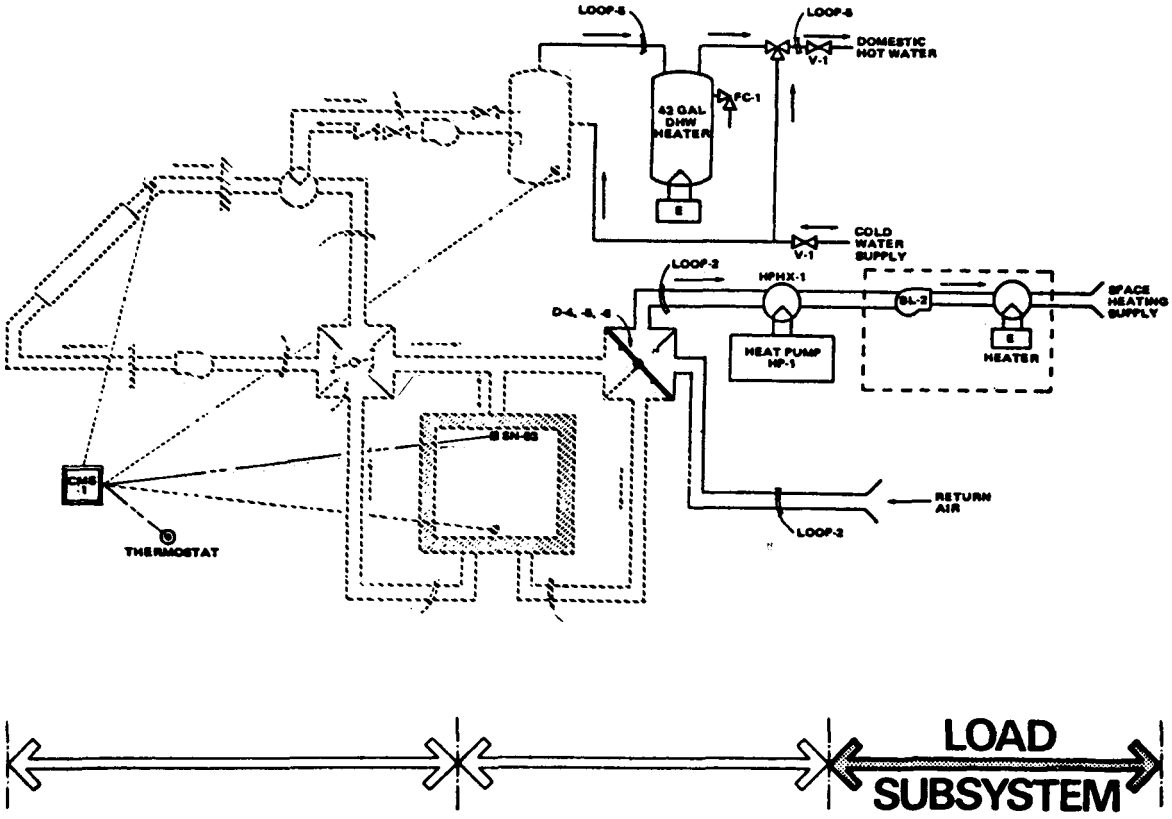


Figure IV-E-1. Auxiliary Subsystem

The auxiliary subsystems, space electric heating coils and domestic hot water tank 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

- Heat Pump, HP-1
  - Manufacturer - B.D. Payne Co.
  - Model name/number - Unknown
- Domestic Water Heater (DWH-1)
  - Manufacturer - RUUD Mfg.
  - Model - Ruudglass Pacemaker RP 40TC82
  - Energy source - Electric, 240V, 1 phase, 60 Hz
  - Tank size - 40 gallon
  - Energy input - 2,365 watts
  - Energy output - 2,325 watts
  - Maximum pressure rating - 300 psi
  - Maximum temperature rating - 200° F
  - Design operating pressure - 105 psi
  - Heating stages - 2
  - Maximum recovery rate - 20 gal/hr
  - Yearly average inlet temperature - 55° F
  - Design output temperature - 140° F
  - Thermal resistance - 8
  - Corrosion protection anodes - None

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

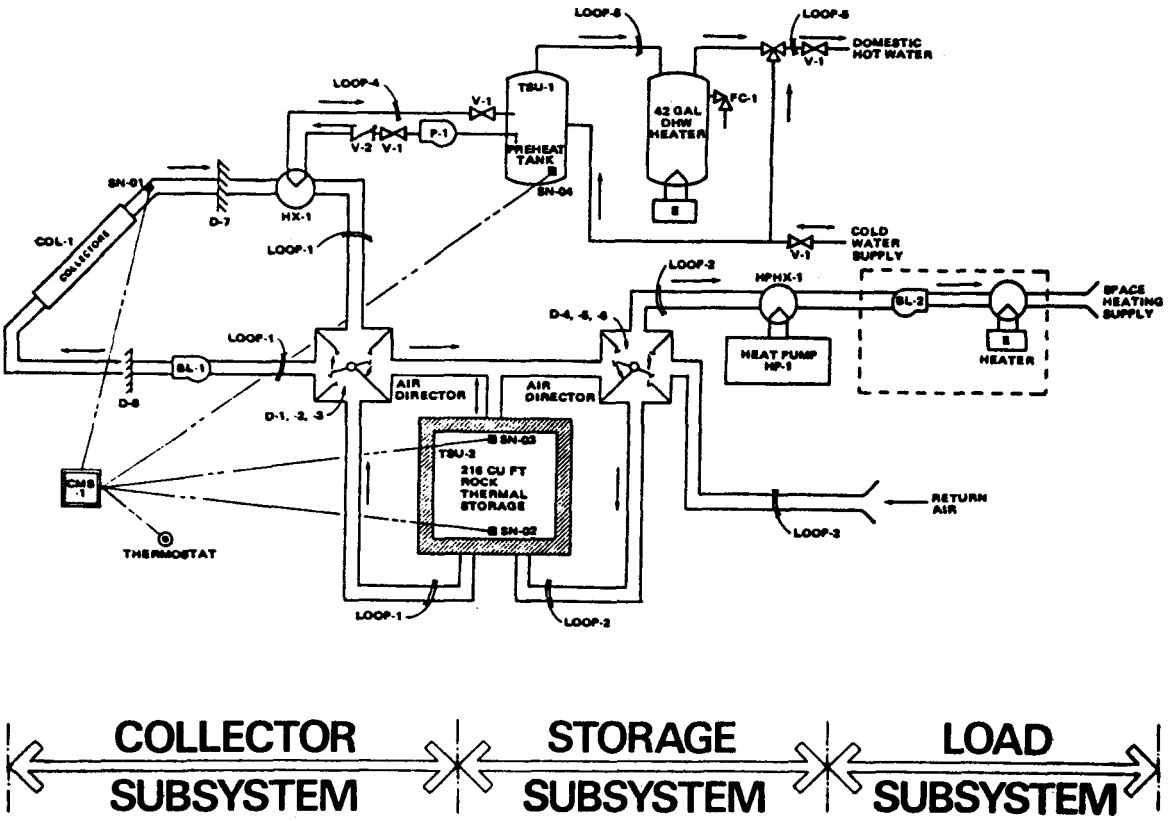


Figure IV-F-1. Controls Diagram

The First Manufactured Homes solar system is shown on Figure IV-F-1. The system consists of the following four subsystems: a) collector; b) storage; c) load (space heating and domestic hot water); and d) auxiliary load subsystems.

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

Mode 1 - Collector-to-Storage

When the temperature of the collector is at least 25° F greater than the bottom of the storage bin and the building is not demanding heat the controller will energize the solar blower and the collector air director motor. Solar energy will then be supplied to the storage bin until the temperature differential drops below 10° F.

Mode 2 - Direct Solar-to-Space Heating

For this operating mode, three conditions must be met. The first is that a 25° F temperature differential must be maintained between the collector sensor and the sensor in the bottom of the storage bin. The second is that the sensor located near the top of the rock storage bin must measure a temperature of 95° F or higher. The third is that the first stage of the building thermostat must demand heat.

When these three conditions have been met, the controller will energize the space heating blower, the solar blower, the solar air director in the collector ducts, and the solar air director in the space heating ducts.

NOTE: The water heating mode will take place concurrently with Mode 1 and Mode 2 when the control sensors indicate that solar energy is available to preheat the domestic hot water.

Mode 3 - Storage-to-Space Heating

To heat the indoor conditioned space using stored solar energy, three conditions must be met. The first is that the building thermostat must demand heat. The second is that the sensor in the top of the rock storage bin must have a temperature greater than 95° F, indicating sufficient energy in the storage bin. The third is that the temperature differential between the collector sensor and the sensor in the bottom of the bin must be less than 25° F, indicating that direct solar energy from the collectors is not available.

When these three conditions are met, the controller will energize the indoor space heating air director and blower.

If heat from the storage bin is unable to meet the building demand, the second stage of the building thermostat will energize the electric resistance auxiliary heaters. These will supply auxiliary energy concurrently with the addition of energy from the rock storage bin. To prevent excessive heat pump pressures, the heat pump compressor is locked off whenever some or all of the heating requirements can be supplied with solar energy.

Mode 4 - Preheating Domestic Hot Water

When the temperature of the collectors is at least 25^{o} F greater than the preheat tank, system controls energize the solar blower and domestic hot water pump. This mode will continue until the water temperature in the preheat tank reaches 140^{o} F, or the temperature differential drops below 10^{o} F. The water preheating mode receives the highest priority; therefore, it can activate during the summer when no solar energy is added to the rock storage bin.

Mode 5 - Auxiliary Space Heating

When solar energy is not available from either the collectors or storage, heating will be provided by the heat pump. If the outside ambient temperature is below 0^{o} F or if the heat pump cannot supply the heating demand, the electric resistance heaters energize to supply auxiliary heating.

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:

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

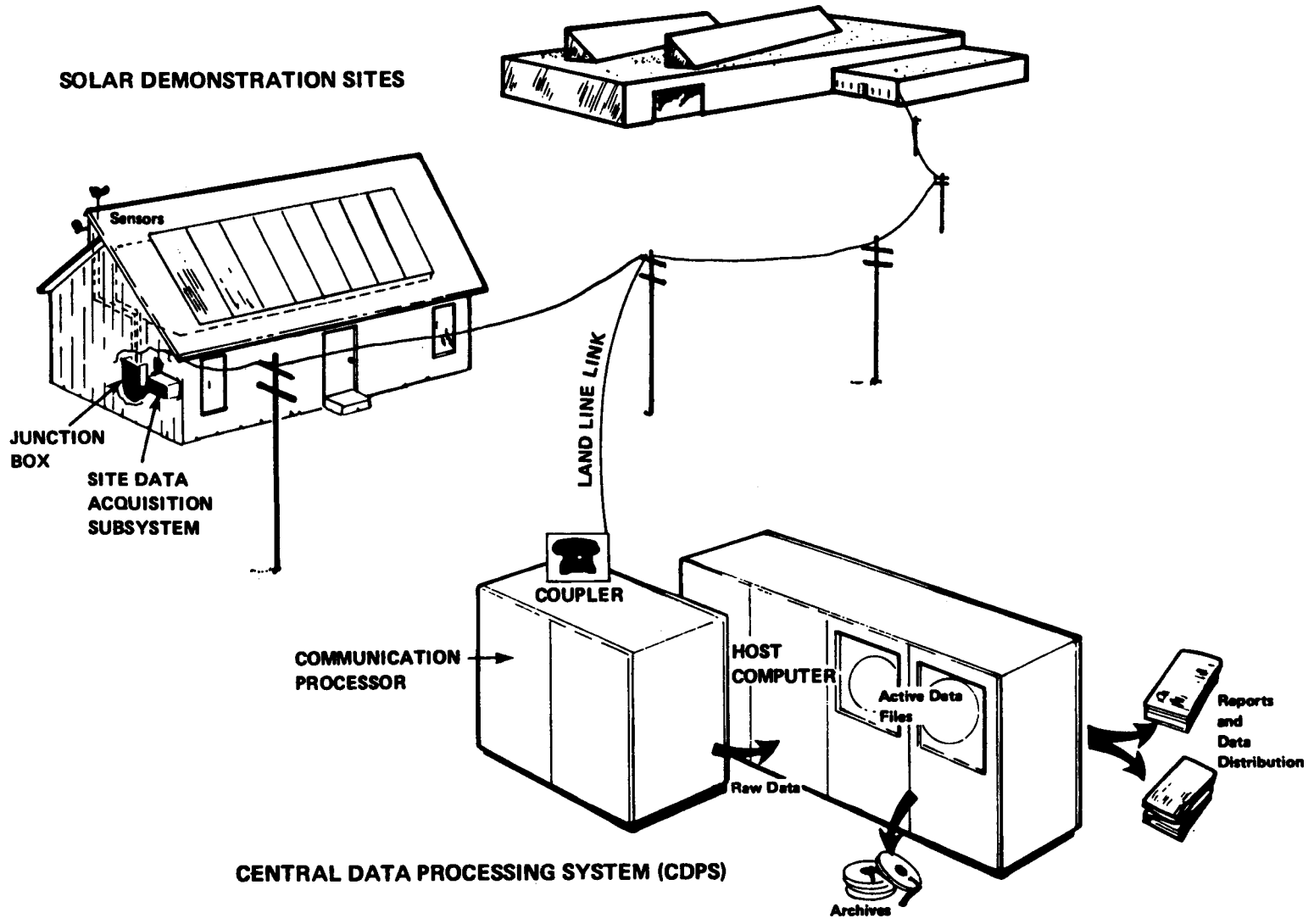


Figure V-A-1. The National Solar Data Network

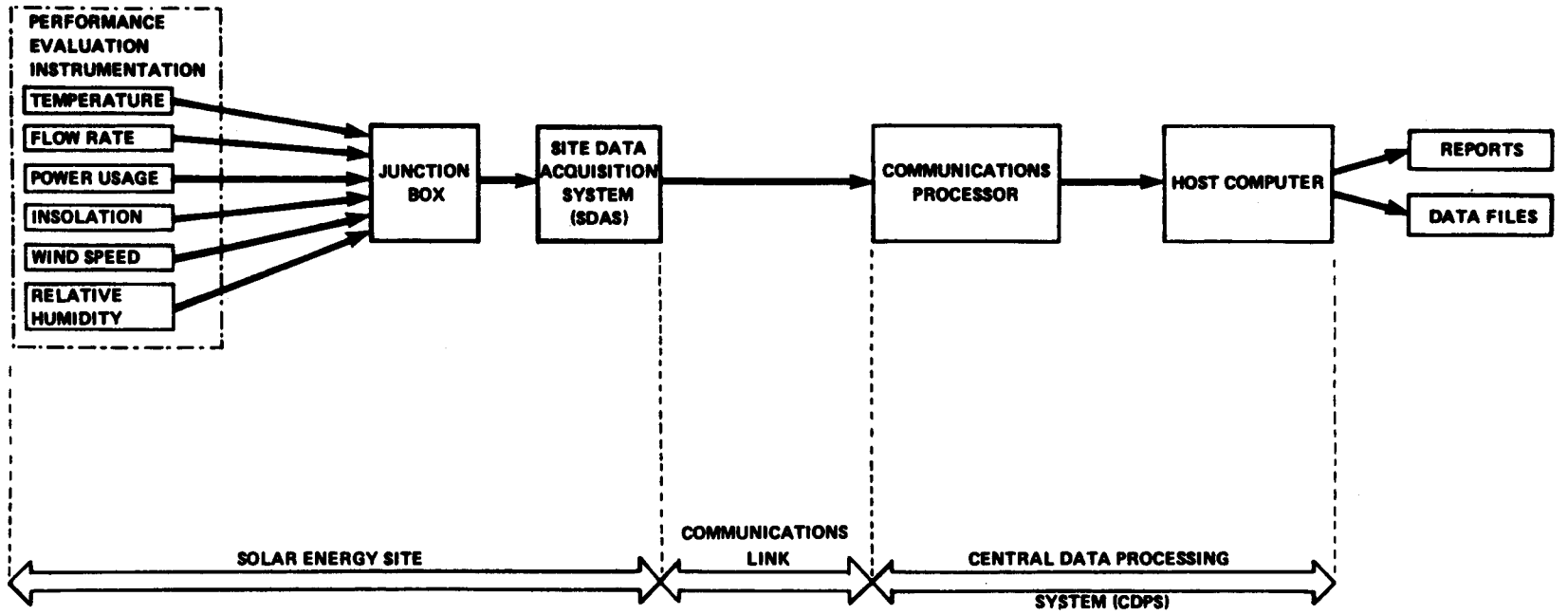


Figure V-A-2. Data Flow Path for the National Solar Data Network

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 performance 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 architectural 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.
T150	Temperature, collector inlet	S53P-100
T151	Temperature, collector outlet	S53P-100
W150	Flow, Collector air	Kurz 430DC
EP150	Power, collector solar blower	O-S PC5-2
T152	Temperature, inlet air, DHW HX	S53P-100
T153	Temperature, outlet air, DHW HX	S53P-100
T250	Temperature, upper port, rock storage	S53P-100
T251	Temperature, lower port, rock storage	S53P-100
T252	Temperature, upper rock storage	S53P-60
T253	Temperature, mid rock storage	S53P-60
T254	Temperature, lower rock storage	S53P-60
T255	Temperature, outer rock storage surface	S32B
W350	Flow, cold water to DHW preheat tank	Hersey 430
T350	Temperature, cold water inlet	S53P-60
T351	Temperature, preheat tank outlet	S53P-100
T352	Temperature, DHW tank outlet	S53P-100
W351	Flow, DHW circulation loop	Floscan 300-3
T353	Temperature, DHW heat exchanger inlet	S53P-60
T354	Temperature, DHW heat exchanger outlet	S53P-60
EP350	Power, DHW circulating pump	O-S PC5-103
EP351	Power, DHW heater	O-S PC5-29 2 passes 10KW
T355	Temperature, DHW tank outer surface	S32B
W450	Flow, space air return	Kurz 430DC
T450	Temperature, Air Cond. HX air inlet	S53P-100
T451	Temperature, Air Cond. HX air outlet	S53P-100
T452	Temperature, space return air	S53P-100
T454	Temperature, lower port, rock storage	S53P-100
T650	Temperaturae, ambient space	S53P-28
EP450	Power, space blower	O-S PC5-2
EP550	Power, outside air cond.	O-S PC5-29 2 passes 10KW
EP452	Power, Aux. electric heater	O-S PC5-29 2 passes 10KW

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
D150	Contact closure, Solar damper motor	Mag. W88ACPX-3
D450	Contact closure, House damper motor	Mag. W88ACPX-3
T356	Temperature, preheat tank outer surface	S32B
W250	Flow, storage top duct	Kurz 430DC

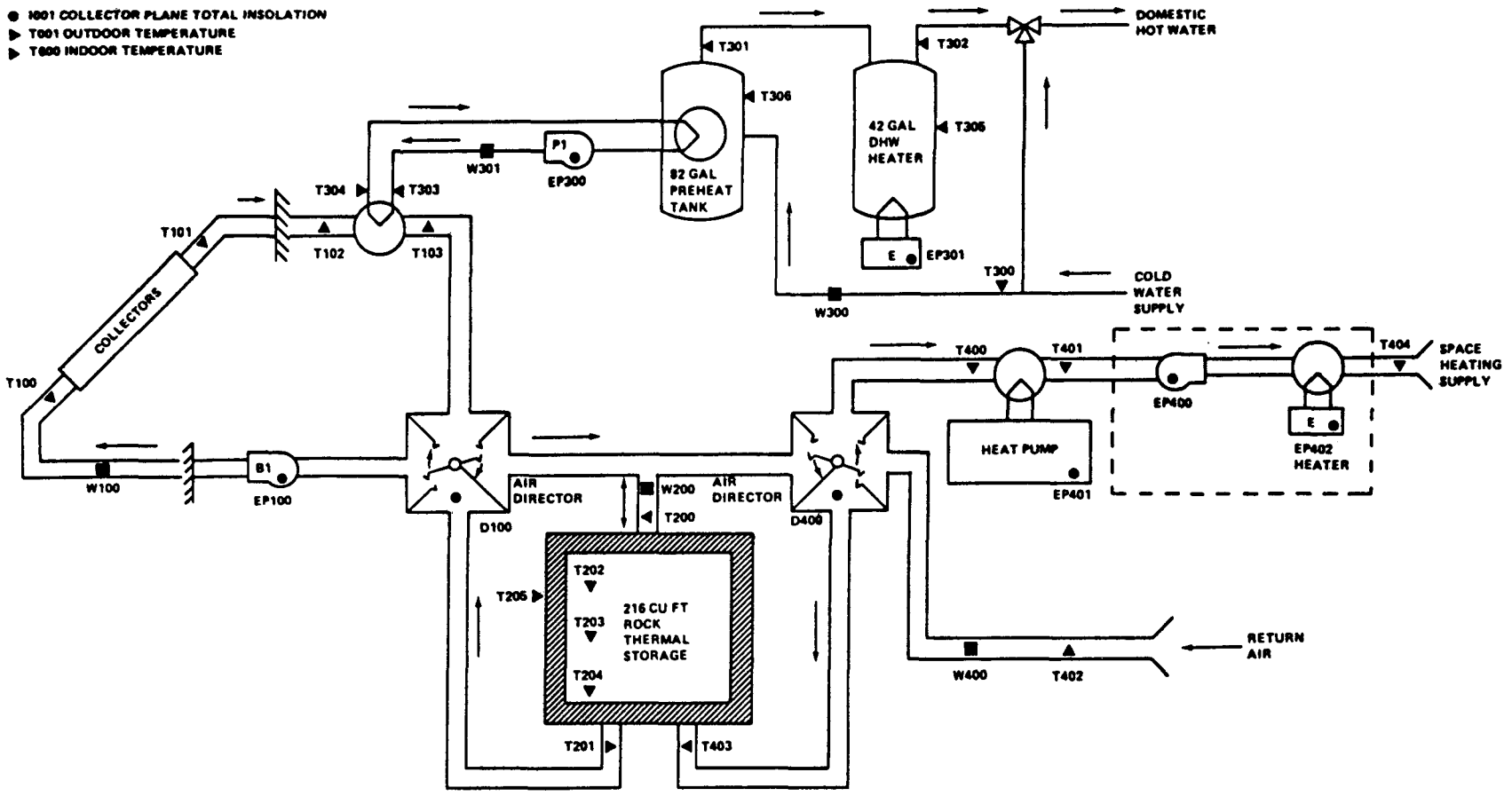


Figure V-B-1. Sensor and Control Diagram

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 they were not part of the construction effort.

B. Construction Grant Funds (5 systems, cost breakdown not available)

Solar Subsystem	Applicants Request	Construction Grant
Collectors	$3,495	
Energy Storage	1,434	
Distribution and Controls	2,411	
Installation	2,900	
	$10,240 (Lot 219)	$32,491 Total for 5 systems

C. Construction Period: 5/5/79 through 9/17/79

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.

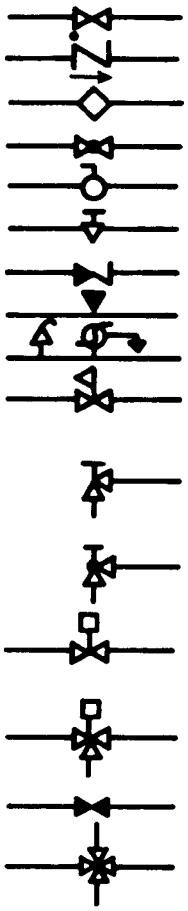
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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.

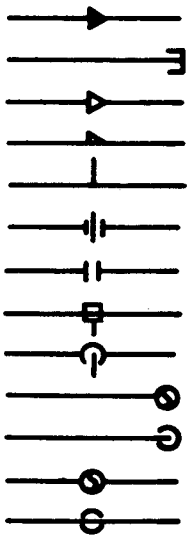
B. Legend For Solar System Schematics

VALVES



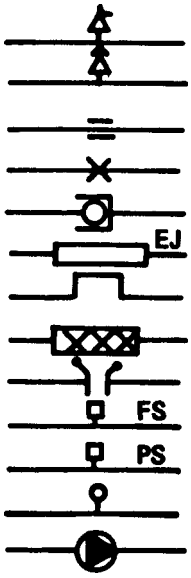
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS

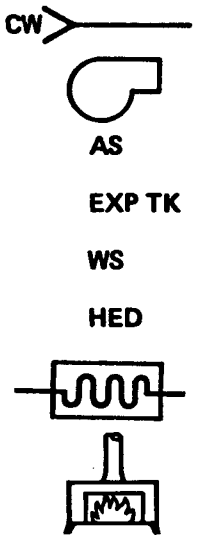


DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

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)

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