(2)

SOLAR/1026-82/50
(DE82012822)

Solar Project Description

HELIO-THERMICS, INC., LOT NO. 8
SINGLE FAMILY RESIDENCE
Greenville, South Carolina
March 26, 1982

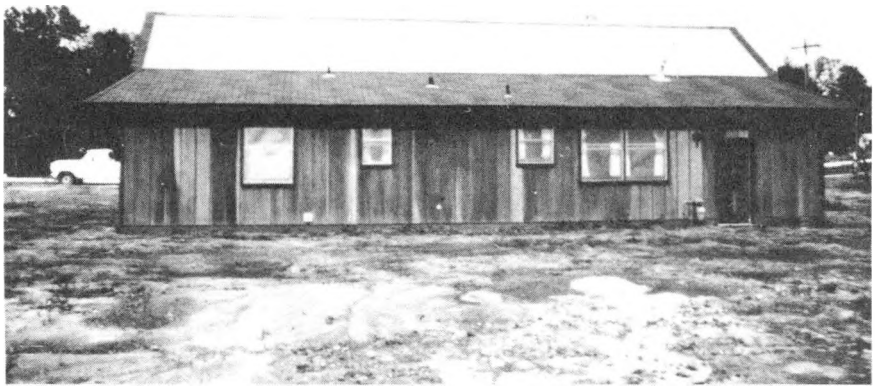
U.S. DEPARTMENT OF ENERGY

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1026-82/50
(DE82012822)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
HELIO-THERMICS, INC., LOT #8
SINGLE-FAMILY RESIDENCE, GREENVILLE, SOUTH CAROLINA



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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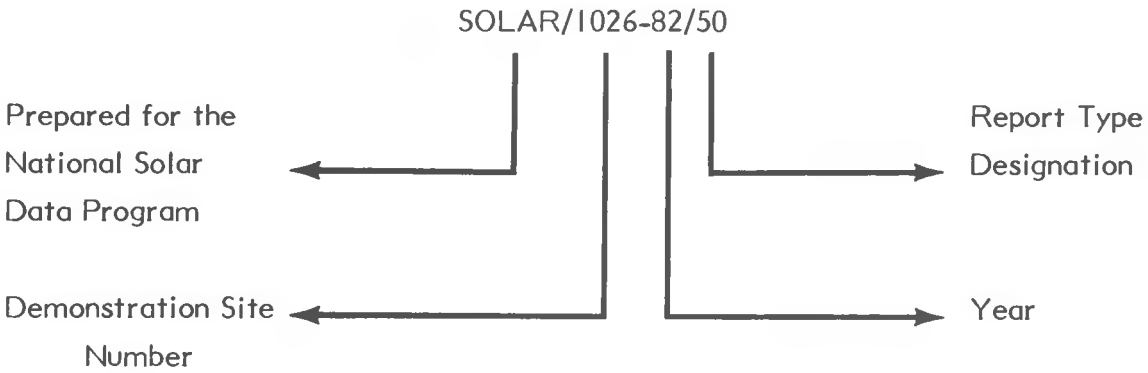
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Helio-Thermics, Inc. Lot #8 project site is designated as SOLAR/1026-82/50. 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 Types -- Air & liquid flat plate
- o Freeze Protection -- Drain down
- o Application -- Heating & DHW
- o Storage -- Rock bin storage & 82-gallon preheat DHW tank
- o New or Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- Use of two types of collectors

The Helio-Thermics Inc. House Lot #8 (Grant H-2744) is one of two instrumented single-family residences in Greenville, South Carolina. The home has approximately 1086 square feet of conditioned space. Solar energy is used for space heating the home and preheating domestic hot water (DHW).

The solar energy system utilizes the attic space as the solar energy collector. The attic roof faces 10 degrees west of south and is pitched at an angle of 51 degrees from the horizontal. Solar energy enters the attic through a 416-square-foot aperture which is double-glazed with corrugated, translucent, glass fiber reinforced, acrylic panels. The interior of the attic is painted black to maximize the absorption of solar energy. Warm air accumulates in the peak of the attic roof and circulates through the conditoned space or through storage by an air handler.

Solar energy is stored in an 870-cubic-foot storage bin containing 85,460 pounds of crushed rock. The storage volume is 36 feet long x 24 feet wide x 1 foot deep located under the house and is insulated with 2-inch polystyrene insulation.

Cold water is preheated in the attic by thermosiphoning water from the 82-gallon preheat tank through a manifold system of copper tubes. These tubes are attached to black sheet-metal plates, thus enhancing absorption of solar radiation for preheating the water as it circulates to and from the preheat tank. Preheated city

water is stored in the preheat tank and supplied, on demand, to a conventional 80-gallon DHW tank.

When solar energy is insufficient to satisfy the space heating load, an electrical heating element in the hot air supply-duct provides auxiliary energy for space heating. Similarly, an electrical heating element in the DHW tank provides auxiliary energy for water heating. The system has eight modes of operation.

The dwelling has been fully instrumented for performance evaluation since August 1978 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)

Helio-Thermics, Lot #8, is one of two instrumented residences located in Greenville, SC. Solar energy is utilized for space heat and DHW.

- Building type - Single family detached
- Latitude - 34^{o} N
- Longitude - 83^{o} W
- Altitude - 980 ft

HEATING DESIGN TEMPERATURES

- Outdoor - 32^{o} F
- Indoor - 70^{o} F

BUILDING

- Building faces - North
- Average stories above ground - 1
- Average stories below ground - 0
- Height above grade - 25 ft
- Conditioned floor area - 1086 ft^2
- Roof type - Gable

DESIGN HEAT LOSS/LOAD

- Heat Loss - 12,385 Btu/hr
- Heat gain - Unknown
- Shading (glass area)
  - Heating season - 62 ft^2
  - Cooling season - 132 ft^2

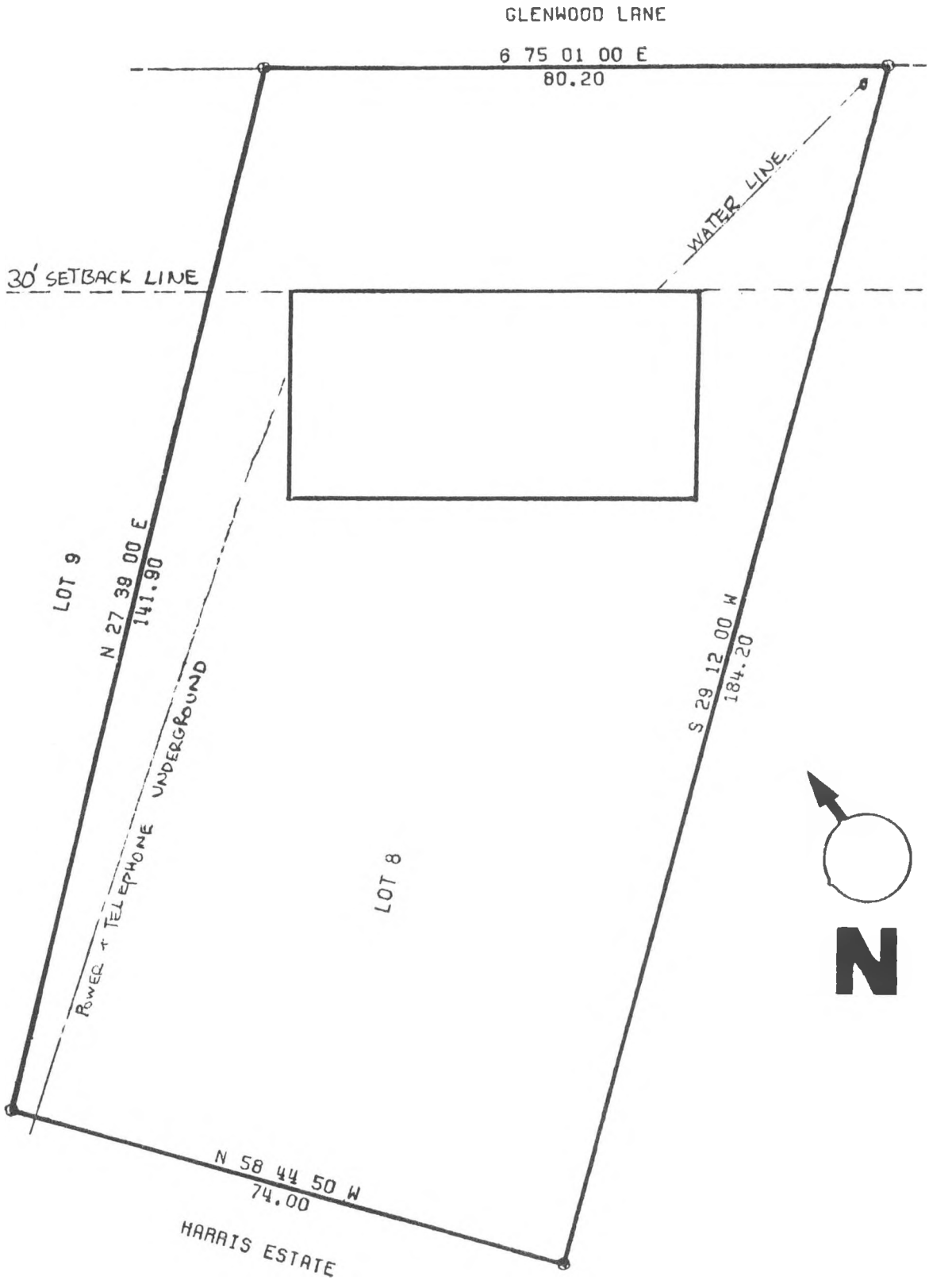


Figure III-1. Site Plan

- Appliance, lighting and equipment load - 600 Btu/hr
- Domestic hot water daily requirements - 20-gal/person
- Average horizontal insolation
  - January - 1288 Btu/ft^2
  - July - 2558 Btu/ft^2
- Annual degree days
  - Heating - 2884
  - Data location - Greenville/Spartanburg, SC
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

MECHANICAL SYSTEM

- Heating
  - Solar - Air type collector
  - Auxiliary - Electric heating element in hot air supply duct
  - Distribution - Air duct & blowers

DOMESTIC HOT WATER

- Daily water demand - 20 gal/day/person
- Solar - Liquid plate (paddle type) collector
- Auxiliary - Electric element in DWH-1

GENERAL DATA

- Manufacturer - Helio-Thermics
- Model name/number - Andromeda IV
- Type of systems - Air active (heating); liquid passive (DHW)

SYSTEM AND COMPONENT SUMMARY

- Collector types - 2
- Circulation loops - 5
- Thermal storage units - 2 (TSU-1, TSU-2)

- Operational modes - 8
- Pumps - 1
- Valves - 4
- Blowers - 1
- Dampers - 1 type (8 places)
- Sensors - 5
- Flow regulators - 0
- Pressure regulators - 0
- Fail safe controls - 2

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (Helio-Thermics Lot # 8 Grant H-2744) located at Greenville, SC utilizes active/liquid passive systems for space heat/DHW. Auxiliary units are ERH-1 for space heat and an electric element in DWH-1.

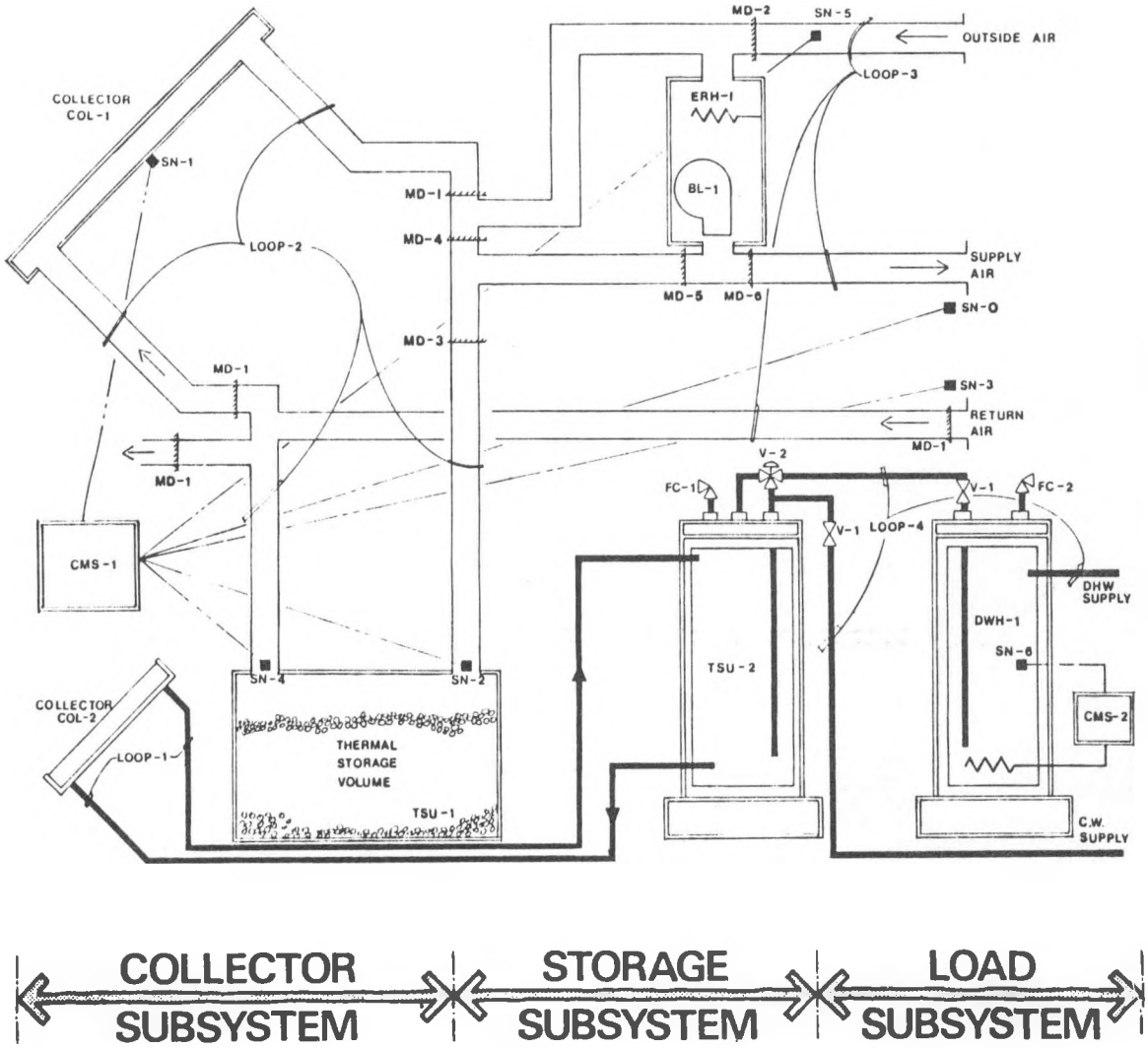


Figure IV-A-1. General Overview

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)

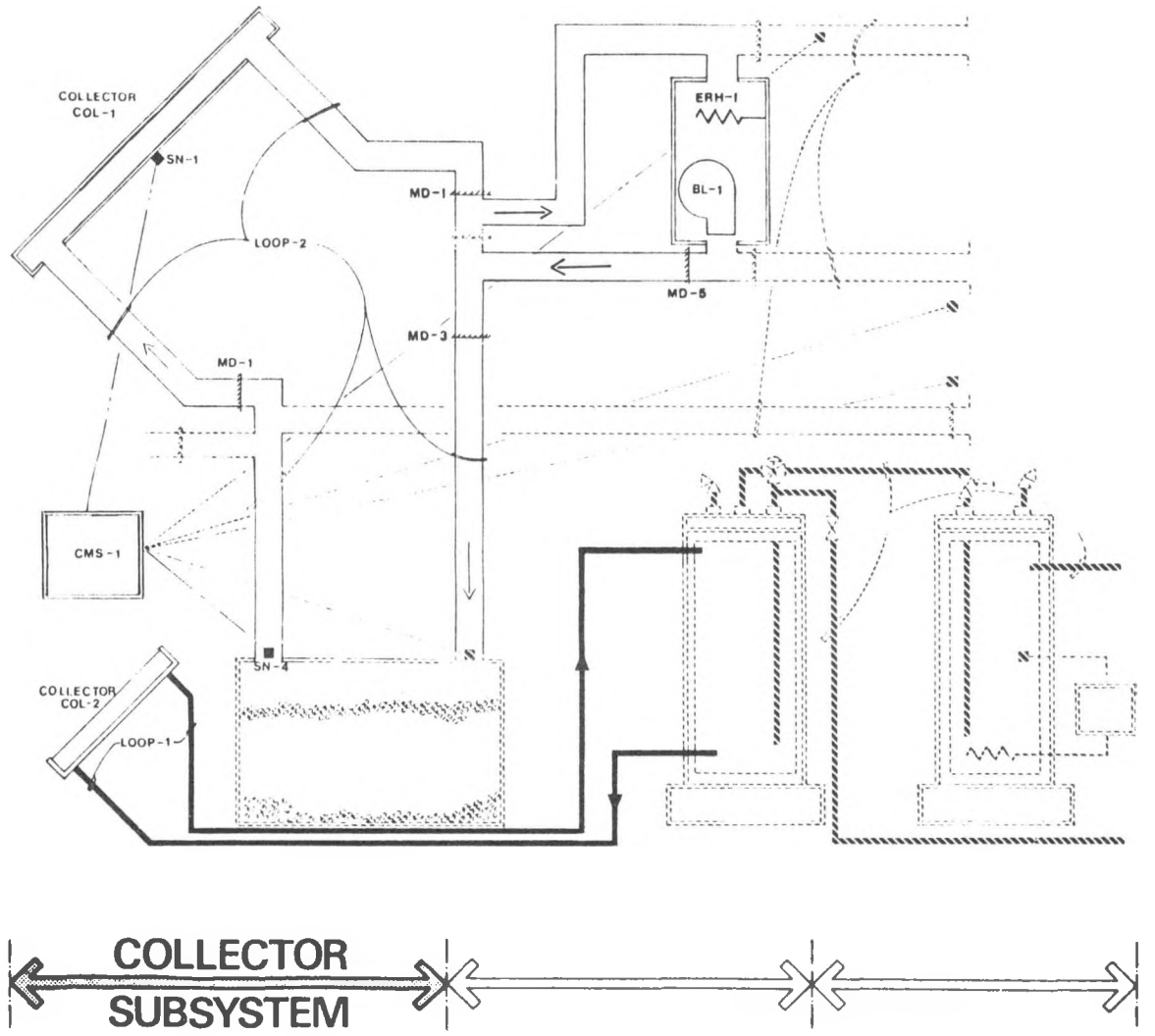


Figure IV-B-1. Collector Subsystem

Collector array system for space heating consists of one (1) air active collector (50 ft by 8 ft) panel. The collector for DHW is one (1) liquid plate (20 ft by 3.5 ft) panel. Freeze protection is provided for the liquid plate collector by drain down.

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

- Manufacturer - Helio-Thermics
- Model name/number - Andromeda IV
- Type - Attic
- Location - Residence attic is the collector
- Orientation - 10° W of S
- Tilt angle - Fixed at 51° from horizontal
- Collector characteristics
  - Number of panels - 1
  - Total gross area of array - 416 ft^2
  - Net aperture area - 400 ft^2
  - Net absorber area - 416 ft^2
  - Weight per panel, empty - Not applicable
  - Weight per panel, full - Not applicable
  - Weight of filled array and support structure - Unknown
  - Panel length - 50 ft
  - Panel width - 8 ft
  - Frame depth - Unknown
  - Standoff height - Not applicable
- Built-in collector - Yes
- Collector shading -
  - Area shaded in June - 0%
  - Area shaded in December - 0%
  - Maximum shade during functional season - 0%

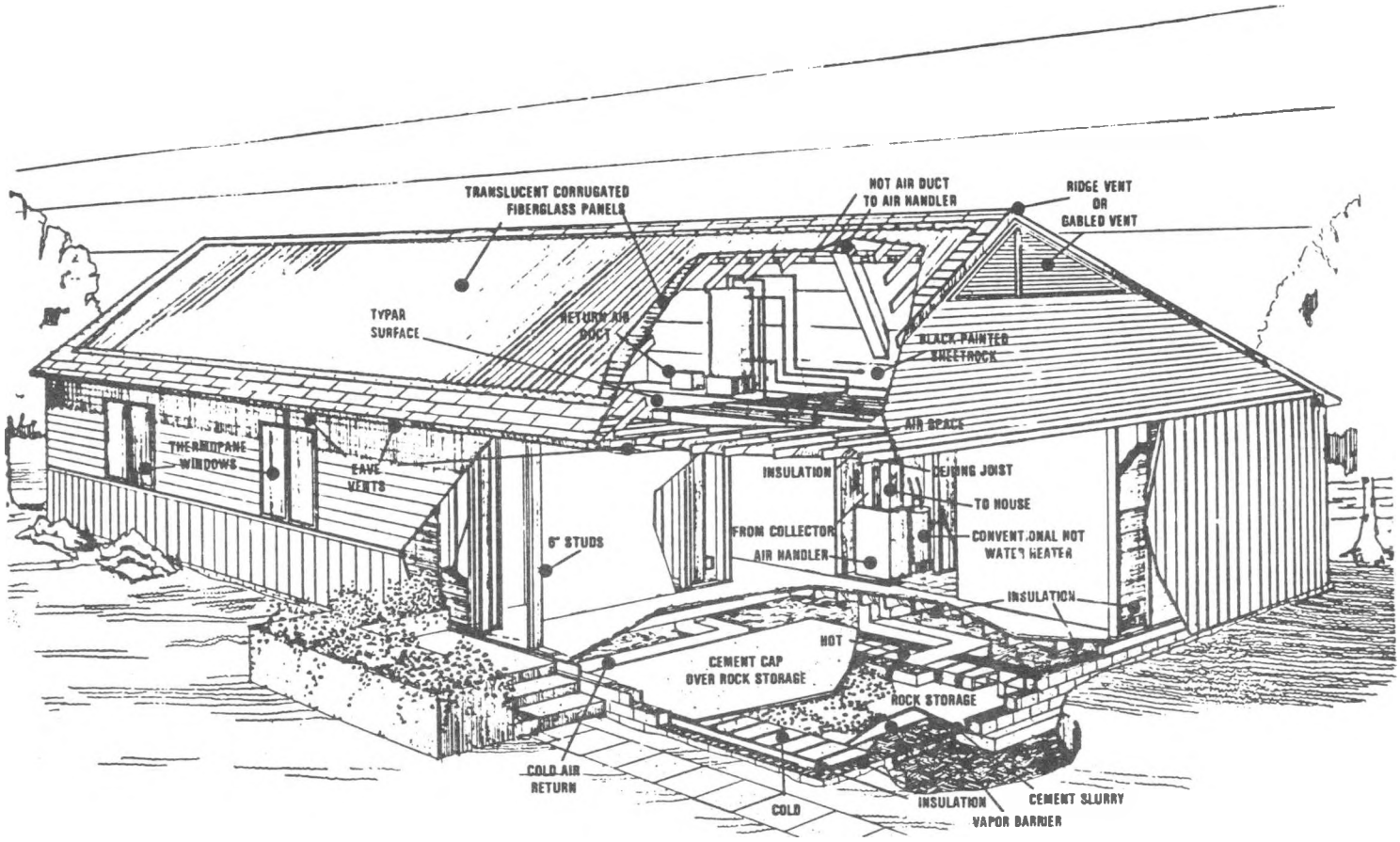


Figure IV-B-2. Solar Collector

- Collector cooling -
  - Exhaust fan, Dayton 3C145 or equal
  - Powered shutter, Dayton 3C308 or equal
  - Controller, Honeywell T675A 1458 or equal
- Cover plates
  - Number of cover plates - Two
- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer - Helio-Thermics
  - Product name/number - Site built
  - Material - Fiberglas
  - Thickness - 0.062 inch
  - Length - 96 inch
  - Width - 48 inch
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	75%	
- Reflectance -	4%	
- Emittance - Unknown		

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - Tedlar film
  - Coating function - Protective
  - Application - Cast in place during manufacturing
- Cover plate No. 2 (Inner layer)
  - Manufacturer - Helio Thermics
  - Product name/number - Andromedia IV
  - Material - Fiberglas reinforced plastic, polyester filler (plastic)
  - Thickness - 0.062 inches

- Optical properties

	(solar region)	(infrared region)
- Transmittance -	.76	
- Reflectance -	.04	
- Emittance -		

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - Tedlar
  - Coating function - Protective
  - Application - Cast in place during manufacturing
- Gaskets and sealants
  - Manufacturer - 3 M
  - Inner cover - Weatherban, 1202T
  - Outer cover - Weatherban, 1202T
- Frame
  - Manufacturer - Helio-Thermics
  - Product name/number - Site built
  - Material - Wood
  - Protective coating - None
  - Number of structure attach points per module to building - Continuous
  - Built-in collector - Yes
  - Reflectors - None
  - Desiccant - No
  - Freeze protection - Not required (air collector)
  - Overheating protection - Air cooling
- Collector performance - No data available
  - Method of evaluation - Due to the nature of construction, it cannot be tested by either standard

- Absorber
  - Manufacturer - Helio-Thermics
  - Model name/number - Site built
  - Material - 1 inch foil-faced Celotex isocyanurate insulation board
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - TYPAR
  - Surface material - UV stabalized TYPAR

	(solar region)	(infrared region)
o Absorptance -	95%	
o Reflectance -	5%	
o Emittance -	95%	

- Heat transfer fluid passages
  - Location - Above absorber
  - Pattern - Parallel
  - Materials - Fiberglas/wood
  - Wall thickness - Unknown
  - Internal diameter - Unknown
  - Maximum operating conditions
    - Temperature - 120° F
    - Pressure - Atmospheric
  - Fluid passage bond to substrate - None
  - Protective coating inside fluid passage - None
- Insulation
  - Layer one - Sides (not applicable)

- Layer one - Back
  - Manufacturer - Owens Corning
  - Product name/number - Glass fiber
  - Material - Fiberglas
  - Thickness - 6 in
  - Thermal resistance - R-19
- Layer two - Back
  - Manufacturer - Owens Corning
  - Product name/number - Glass fiber
  - Material - Fiberglas
  - Thickness - 12 in
  - Thermal resistance - Unknown

COLLECTOR (COL-2) (See Figure IV-B-3)

- Manufacturer - Helio-Thermics
- Model name/number - Andromeda IV
- Type - Liquid flat plate, tube & plate
- Location - In solar attic
- Orientation - 10^{o} East of South
- Tilt angle - 10^{o} from horizontal
- Collector characteristics
  - Number of panels - 1
  - Total gross area of array - 70 ft^2
  - Net aperture area - 70 ft^2
  - Net absorber area - 70 ft^2
  - Weight per panel, empty - 100 lb
  - Weight per panel, full - 130 lb
  - Weight of filled array and support structure - Unknown

- Panel length - 20 ft
- Panel width - 3.5 ft
- Frame depth - N/A
- Standoff height - N/A

- Built-in collector - Yes
- Collector shading -
  - Area shaded in June - 0%
  - Area shaded in December - 0%
  - Maximum shade during functional season - 0%
- Cover plates
  - Number of cover plates - Two
- Cover plate No. 1
  - Location - Outer layer of multiple layers or single cover
  - Material - Fiberglas reinforced plastic, polyester filler (plastic)
  - Thickness - 0.062 inch
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	.76	
- Reflectance -	.04	
- Emittance -		

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - Tedlar
  - Coating function - Protective
  - Application - Cast in place during manufacturing

ILLUSTRATION
NOT
AVAILABLE

Figure IV-B-3. Solar Collector (COL-2)

- Cover plate No. 2
  - Manufacturer - Helio Thermics
  - Material - Fiberglas reinforced plastic, polyester filler (plastic)
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	.76	
- Reflectance -	.04	
- Emittance -	.90	

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - Tedlar
  - Coating function - Protective
  - Application - Vacuum deposited (cast in-place during manufacturing)

- Absorber
  - Manufacturer - Helio-Thermics
  - Material - Aluminum 6063-T5
  - Substrate material dimension
    - Thickness - 0.156 in
    - Length - 240 in
    - Width - 42 in
  - Number of absorbers per collector - 1

- Coating
  - Manufacturer - Helio-Thermics
  - Model name/number - Paint
  - Coating material - Flat black paint, acrylic enamel

	(solar region)	(infrared region)
Absorptance -	95%	
Reflectance -	5%	
Emittance -	95%	

- Heat transfer fluid passages
  - Location - Above absorber
  - Pattern - Parallel
  - Materials - Copper, Type L
  - Outside diameter - 0.5 in
  - Internal diameter - Unknown
  - Maximum operating conditions
    - Temperature - 180° F
    - Pressure - 200 psi
  - Protective coating inside fluid passage - None
- Frame
  - Manufacturer - Helio-Thermics
  - Product name/number - Site built
  - Built-in collector - Yes
  - Desiccant - None
  - Freeze protection - Drain down
  - Overheating protection - Air cooling
- Collector performance - No information available

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

- Heating
  - Design operating temperature
    - Maximum - 120° F
    - Minimum - 50° F
  - Heating design air flow
    - Maximum - 1200 cfm
    - Minimum - Unknown

- Components within circulation loop
  - Collector(s) - COL-1
  - Thermal storage unit(s) - TSU-1
  - Damper(s) - MD-1 through MD-6
  - Blower - BL-1
- Blower
  - Manufacturer - Helio-Thermics
  - Model name/number - Unknown
  - Design conditions

	Low Static Mode	High Static Mode
- Circulating volume	1200 cfm	
- Motor operation	0.5 bhp	
- Pressure	0.5 psi	

- Damper (MD-1 through MD-6)
  - Manufacturer - Helio-Thermics
  - Model name/number - Unknown
  - Function - Flow switching
  - Operation - Motorized
- Ducting
  - Type - Aluminum
  - Location - Above grade
  - Maximum operating temperataure - 120° F
  - Thermal resistance - Unknown
  - Insulation - Glass fiber

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

- Maximum design operating temperature - 210° F
- Design operating pressure - Unknown
- Heating
  - Design liquid flow - Unknown
  - Design pump speed - N/A (Thermosiphon)
- Heat transfer medium
  - Volume of liquid in loop - 100 gal
  - Anticipated liquid temperature
    - Maximum 180° F
    - Minimum - 110° F
  - Provisions for expansion - Relief valve
  - 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
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - None
  - Inhibitor - None
- Components within circulation loop
  - Pump(s) - None (Thermosiphon)
  - Thermal storage unit(s) - TSU-2
  - Collector(s) - COL-2
  - Valve(s) - 0

- Piping
  - Rigid - Copper, Type L
  - Insulation - None
  - Location - Above grade

CONTROL MODE SELECTOR (CMS-1)

- Manufacturer - Helio-Thermics
- Model name/number - Unknown
- Modes controlled
  - Collector to storage
    - ON - (SN-1) > (SN-4) + 26° F
    - OFF - (SN-1) < (SN-4) + 16° F
- Sensors (SN-1) and (SN-4)
  - Thermostatic sensor

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

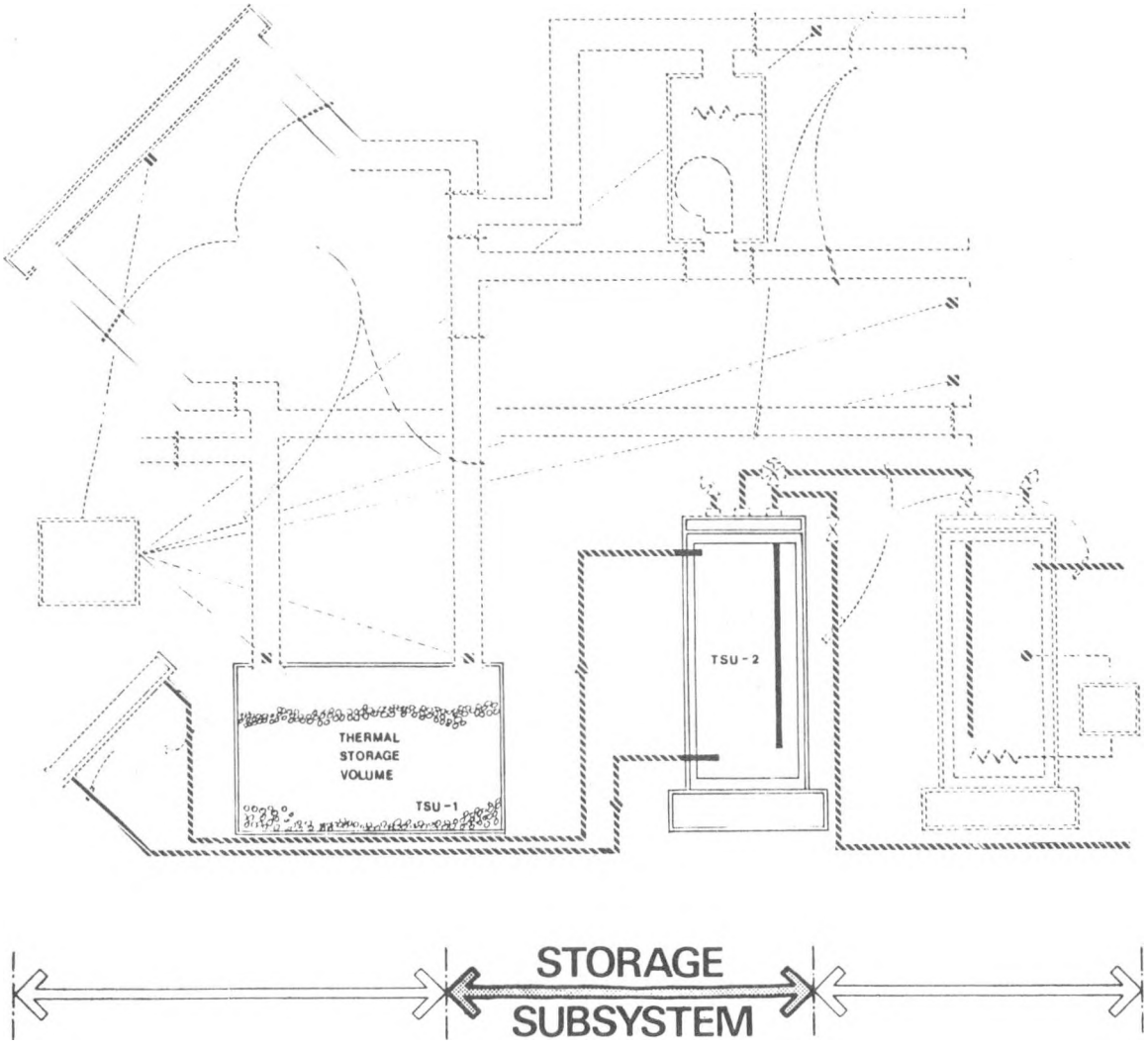


Figure IV-C-1. Storage Subsystem

Solar energy is stored in a 864-cubic-foot storage bin containing 72,575 pounds of crushed rock. The shallow 1 foot deep storage volume is located under the house and is insulated with 2-inch polystyrene insulation. Cold water is preheated in the attic by thermosiphoning water from the 82-gallon preheat tank through a manifold system of copper tubes. These tubes are attached to black sheet-metal plates, thus enhancing absorption of solar radiation for preheating the water as it circulates to and from the preheat tank. Preheated city water is stored in the preheat tank and supplied, on demand, to a conventional 82-gallon DHW tank.

THERMAL STORAGE UNIT (TSU-1)

- Manufacturer - Helio-Thermics
- Model name/number - Site built
- Total storage container volume - 864 ft^3
- Volume of storage medium - 864 ft^3
  - Length - 36 ft
  - Width - 24 ft
  - Height - 1 ft
- Maximum rated operating conditions
  - Temperature - 150° F
  - Pressure - Atmospheric
- Storage medium
  - Design operating temperatures
    - Heating - 150° F
    - Cooling - 50° F
  - Medium - Crushed stone (1.5 to 2.5 inches in size)
  - Specific heat - 0.20 Btu/lb/° F
  - Density - 84 lbs/ft^3
  - Heat capacity - 16.8 $Btu/ft^3/°$ F
- Medium manufacturers recommended use of temperature -
  - Maximum - 150° F
  - Minimum - 50° F
  - Total weight of crushed granite - 85,460 lbs

- Container construction
  - Type - Concrete block
  - Interior lining - Polyethylene
  - Location - Crawl space
  - Insulation - Styrofoam
  - Exterior finish - Black enamel on block
  - Filters - No
  - Getters - No

THERMAL STORAGE UNIT (TSU-2)

- Manufacturer - Helio-Thermics
- Model name/number - Site built
- Total storage container volume - 12.8 ft^3
- Volume of storage medium - 82-gal
  - Height - 5.0 ft
  - Diameter -1.8 ft
- Rated operating conditions
  - Maximum - 210° F
  - Minimum - 120° F
- Storage medium
  - Design operating temperatures
    - Maximum - 210° F
    - Minimum - 120° 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 - 210° F
  - Minimum - 120° F
- Toxicity - Potable
- pH Factor - 7.0
- Inhibitor - No
- Container construction
  - Type - Metal
  - Interior lining - Glass
  - Location - In attic
  - Auxiliary heaters - No
  - Insulation - Glass fiber
  - Exterior finish - None
  - Filters - No
  - Getters - No

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

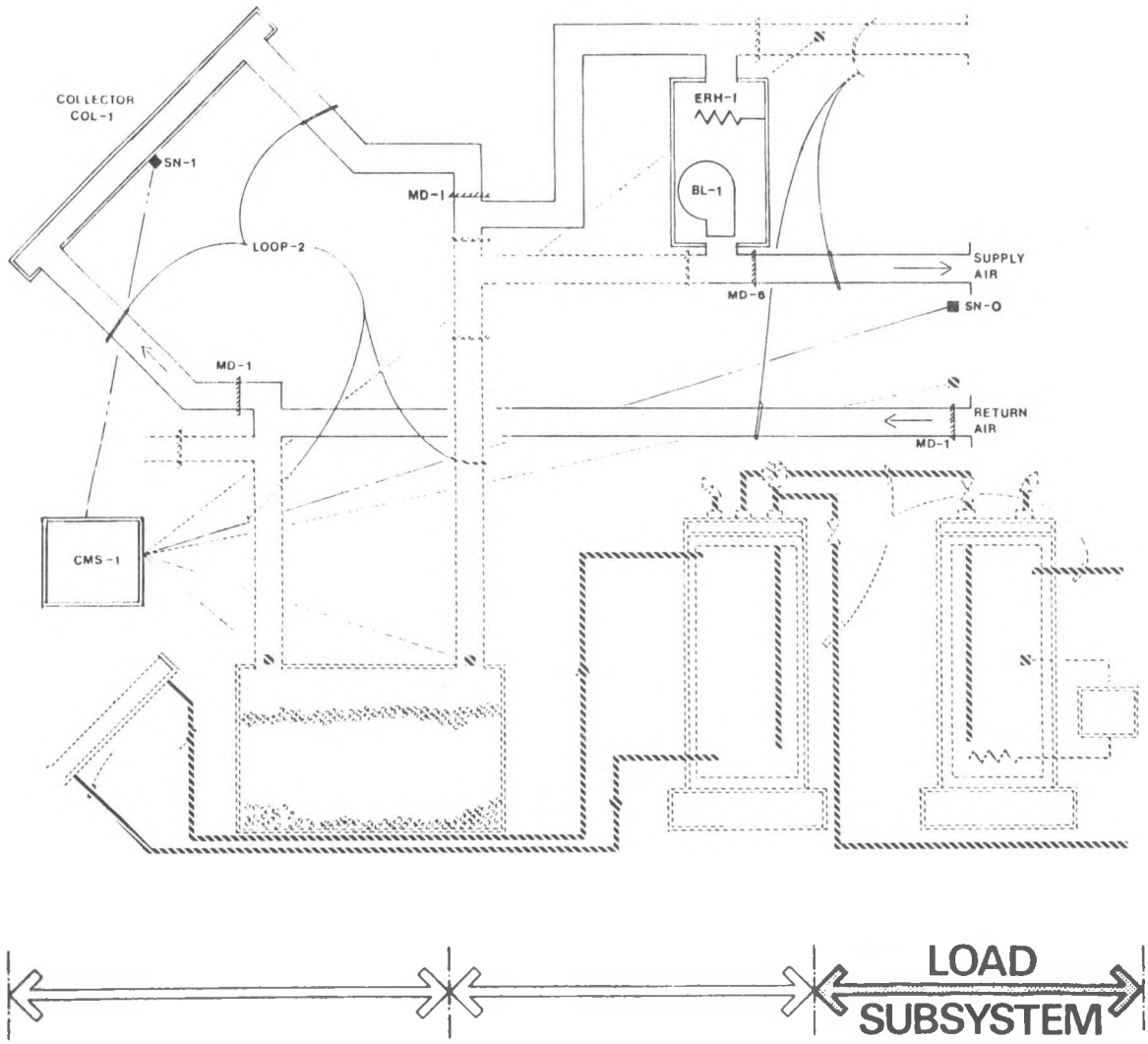


Figure IV-D-1. Energy-to-Load Subsystem, Collector-to-Space Heating

Solar heated air is circulated by the air-handler fan to the living area. Auxiliary space heating, supplementing this source, is provided by an electric heat element in the duct system.

Preheated city water is stored in the preheat tank and supplied, on demand, to a conventional 80-gallon DHW tank.

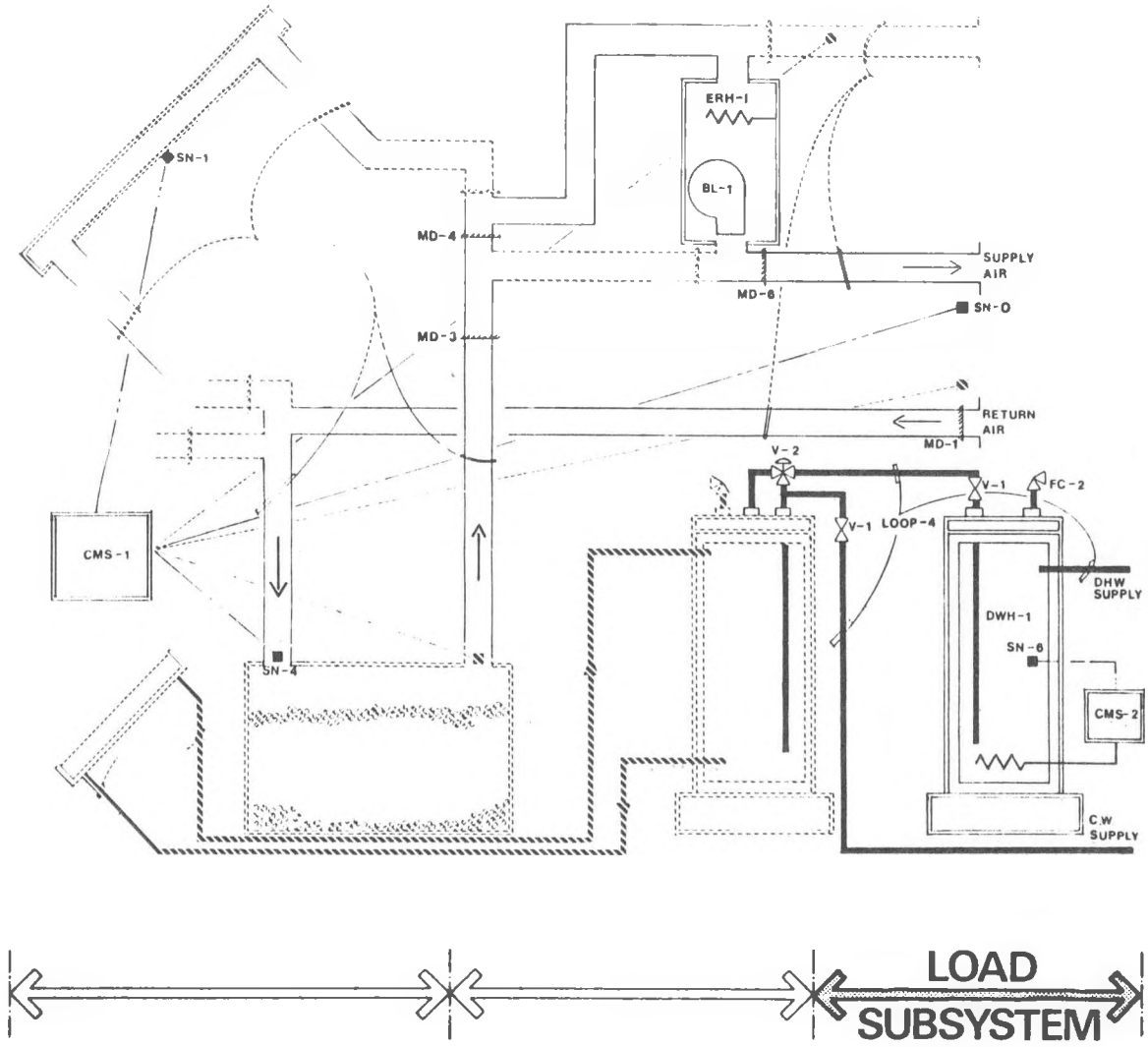


Figure IV-D-2. Energy-to-Load Subsystem, Storage-to-Space Heating

Thermal energy storage is provided to 870 cubic feet of crushed granite located beneath the floor of the house. Air flow through the storage chamber is horizontal, flowing from the center of storage to return registers adjacent to the north and south walls of the house. Solar heated air is circulated by the air-handler fan to the living area. Pre-heated water is drawn on demand from the preheat storage tank. Auxiliary energy is provided by an electric element in DHW-1.

AIR CIRCULATION LOOP NO. 3 (SPACE HEAT)

- Heating
  - Maximum design operating temperature - 120° F
  - Heating design air flow - 1200 cfm maximum
- Components within circulation loop
  - Blower(s) - BL-1
  - Damper(s) - MD-1 through MD-6
  - Auxiliary Heater - ERH-1
- Ducting
  - Type - Rigid aluminum
  - Location - Above grade, inside building
  - Maximum operating temperature - 120° F
  - Insulation - Glass fiber
- Electric Resistance Heater Strip (ERH-1)
  - Manufacturer - NO INFORMATION AVAILABLE
  - Model name/number - NO INFORMATION AVAILABLE
  - Energy source - Electric; (5kW)

LIQUID CIRCULATION LOOP NO. 4 (HW Supply/Demand)

- Design maximum operation temperature - 120° F
- Design maximum operation pressure - 150 psi
- Heating
  - Design liquid flow - 7 gpm maximum
  - Design pump speed - 1750 rpm
- Heat transfer medium
  - Volume of liquid in loop - 150 gal

- Anticipated liquid temperatures
  - Maximum - 180° F
  - Minimum - 120° F
- Provisions for expansion -
- Medium - Water
- Specific heat - 1.00 Btu/lb/° F
- Density - 62.4 lb/ft^3/° F
- Heat capacity - 62.4 Btu/ft^3/° F
- Boiling point - 212° F
- Freezing point - 32° F
- Medium manufacturer's recommended use temperature -
  - Maximum - 130° F
  - Minimum - 100° F
- Toxicity - Potable
- pH factor - 7.0
- Chemical feeder to maintain pH factor - No
- Inhibitor - No

- Components within circulation loop
  - Domestic water heater(s) - DHW-1
  - Thermal storage unit(s) - TSU-2
  - Valve(s) - V-1, V-2
  - Other(s) - FC-2

- Piping
  - Rigid - Copper, Type L
  - Interior coating - None

- Insulation - Cellular rubber (Armaflex)
- Location - Above grade
- Filters - No
- Getters - No

- Distribution Valve (V-1)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Function - ON/OFF
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Unknown
- Distribution Valve (V-2)
  - Manufacturer - Watts
  - Model name/number - 70
  - Function - Flow adjusting/tempering
  - Operation - Automatic, motorized
  - Type - Ball
- Fail Safe Control (FC-1)
  - Manufacturer - Unknown
  - Product name/number - Unknown
  - Type - Pressure relief valve
- Fail Safe Control (FC-2)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Pressure relief valve

CONTROL MODE SELECTOR (CMS-1)

- o Manufacturer - Helio-Thermics
- o Modes controlled
  - o Collector to space
    - ON-(SN-0) < 70^{o} F, and (SN-1) > (SN-0) + 10^{o} F
    - OFF - (SN-1) < (SN-0) + 6^{o} F
  - o Storage to space
    - ON - (SN-0) < 70^{o} F (SN-1) $\leq$ (SN-0) + 10^{o} F, and (SN-4) > (SN-0) + 5^{o} F
    - OFF - (SN-4) $\leq$ (SN-0)
  - o Sensors (SN-0) through SN-5)
    - o Type - Thermostatic sensor

CONTROL MODE SELECTOR (CMS-2)

- o Manufacturer - Helio-Thermics
- o Model name/number - Unknown
- o Modes Controlled
  - o Auxiliary to hot water
    - ON - (SN-06) < 160^{o} F
- o Sensors (SN-6)
  - o Type - Thermostatic, thermister

E. Auxiliary Subsystems (See Figure IV-E-1, IV-E-2, IV-E-3, and IV-E-4)

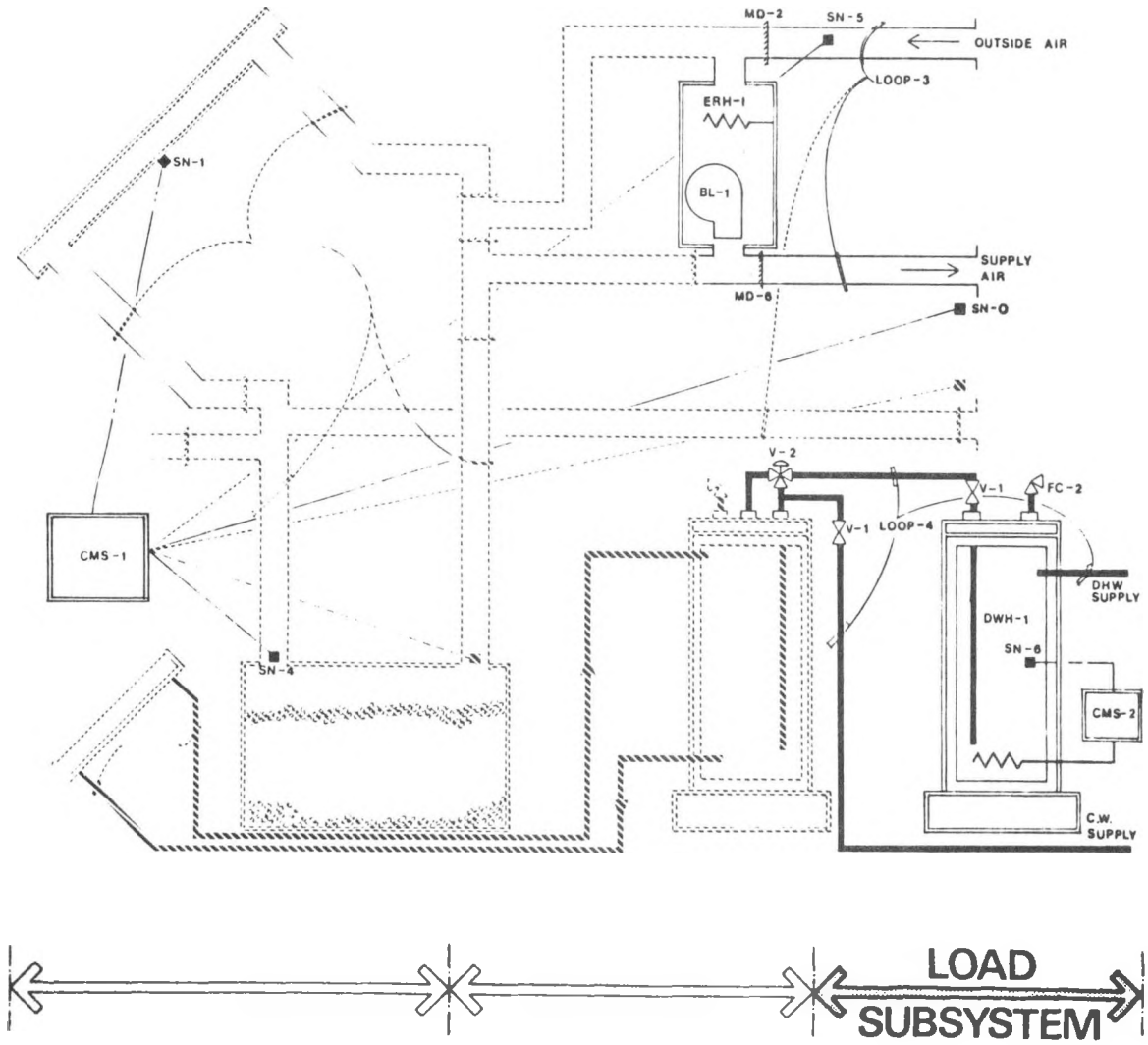


Figure IV-E-1. Auxiliary-to-Load Subsystem, Energy-to-Space Heating

The auxiliary subsystems, ERH-1 and DWH-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.

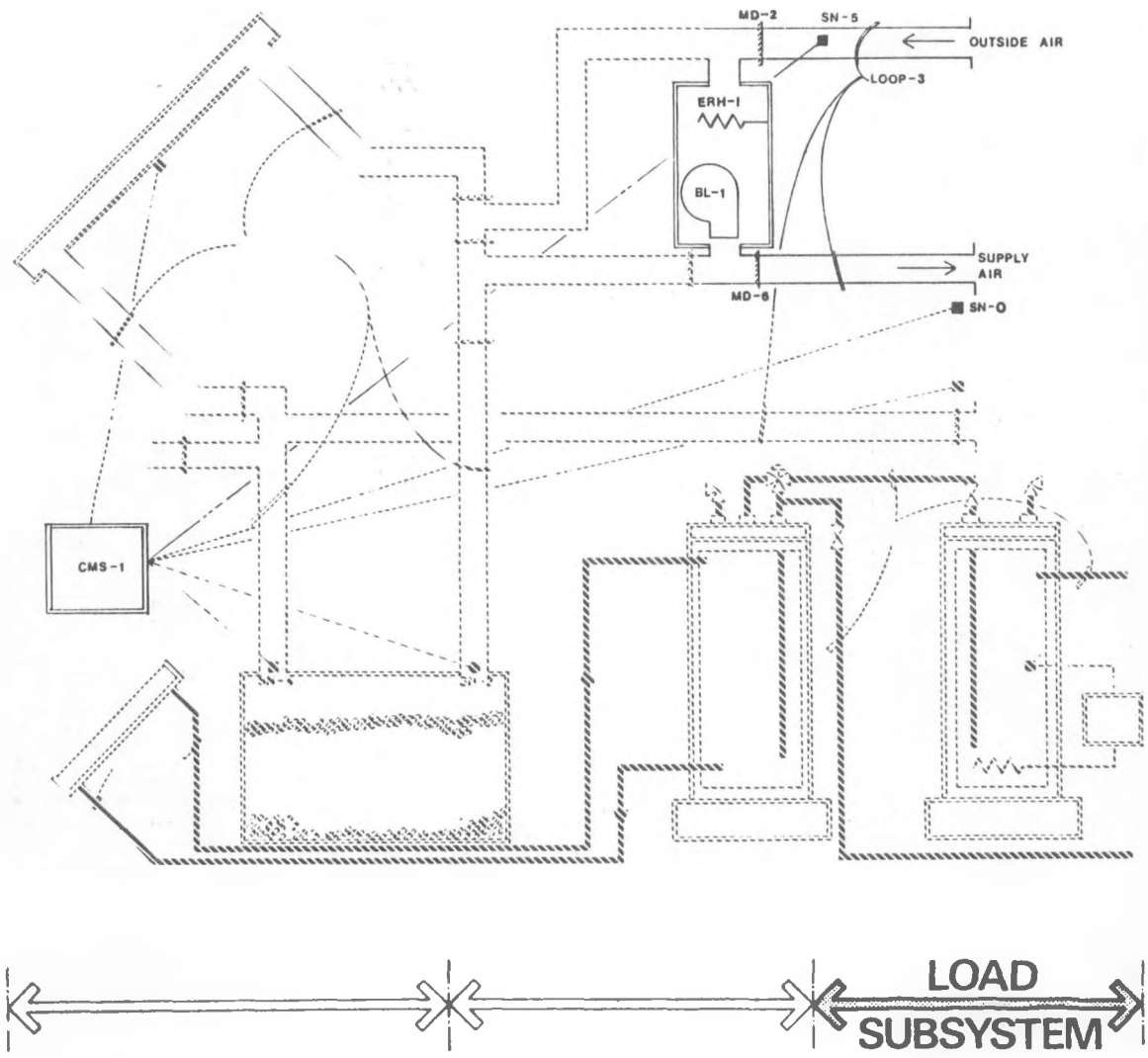


Figure IV-E-2. Auxiliary-to-Load Subsystem, Summer Mode - Space Cooling

Cool outside air is drawn through the air-handler fan to the living area.

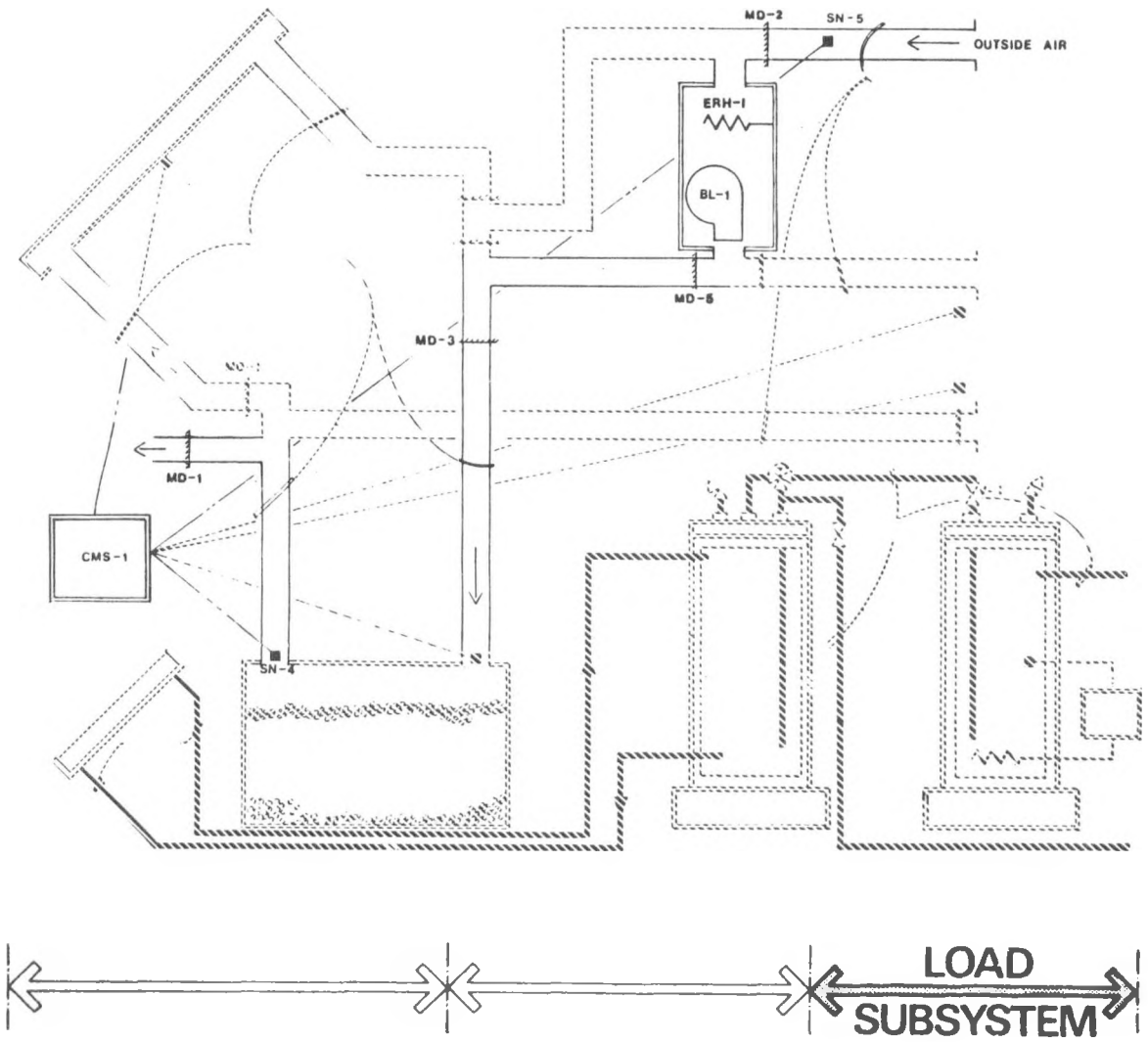


Figure IV-E-3. Auxiliary-to-Load Subsystem,
Summer Mode - Passive Cooling Storage

Cool outside air is drawn by the air-handler fan through the rock storage.

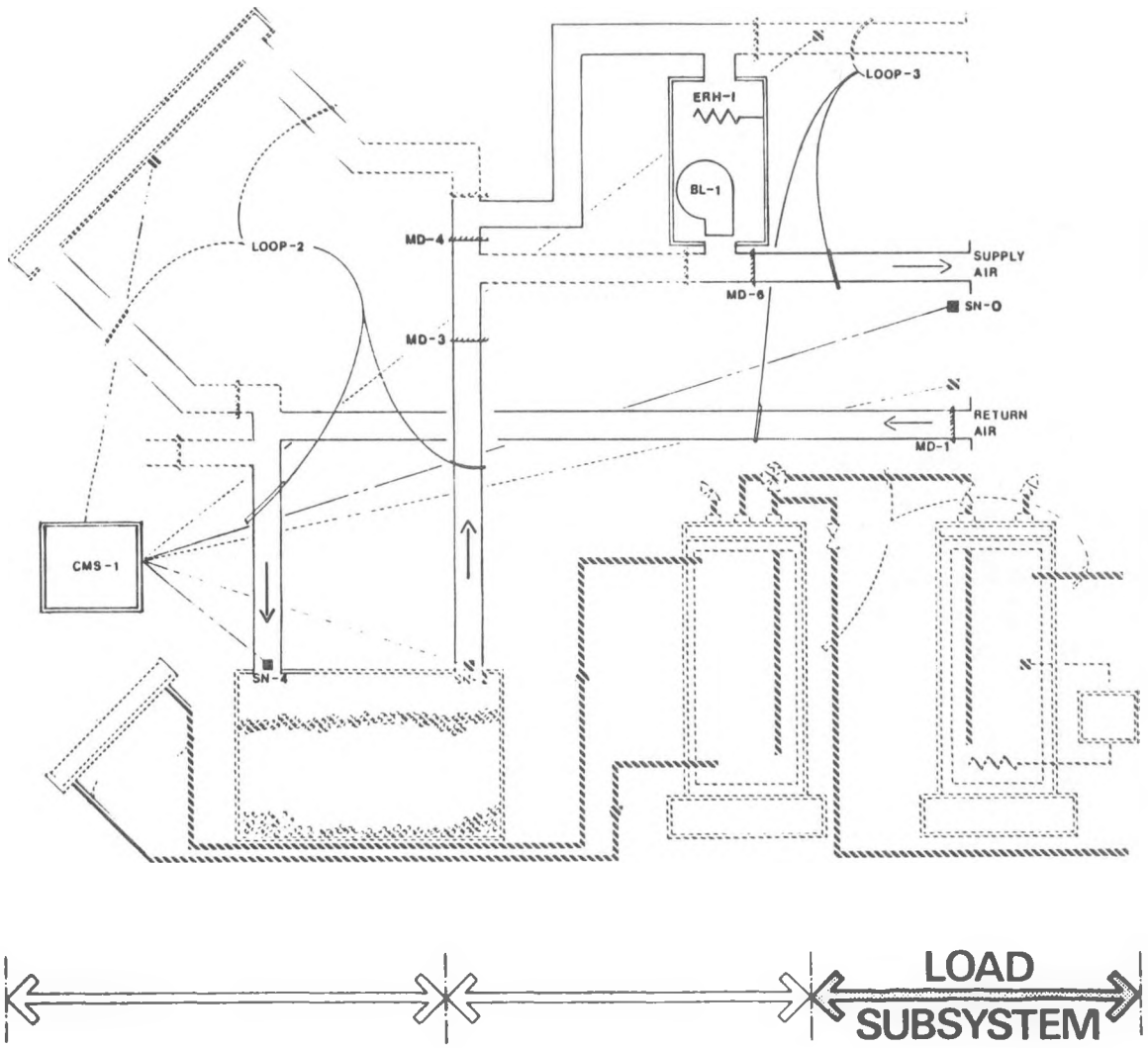


Figure IV-E-4. Auxiliary-to-Load Subsystem,
Summer Mode - Storage-to-Space Cooling

Cool air from storage is drawn through the air-handler fan to the living area.

AUXILIARY LOADS

- Domestic Water Heater (DWH-1)
  - Manufacturer - Mor-Flo
  - Model - Unknown
  - Energy source - Electric 4.5 kW; 3 phase; 60 Hz
  - Tank size - 50 gal
  - Energy input - 60,000 Btu/hr
  - Energy output - 54,000 Btu/hr
  - Maximum pressure rating - 150 psi
  - Temperature rating
    - Maximum - 210° F
    - Minimum - 100° F
  - Design operating pressure - 150 psi
  - Heating stages - Single
  - Maximum recovery rate - 50 gal/hr
  - Yearly average inlet temperature - 60° F
  - Design output temperature
    - Maximum - 180° F
    - Minimum - 100° F
  - Thermal resistance - Unknown
  - Standby heat loss - 1%/hr
  - Corrosion protection anodes - No

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

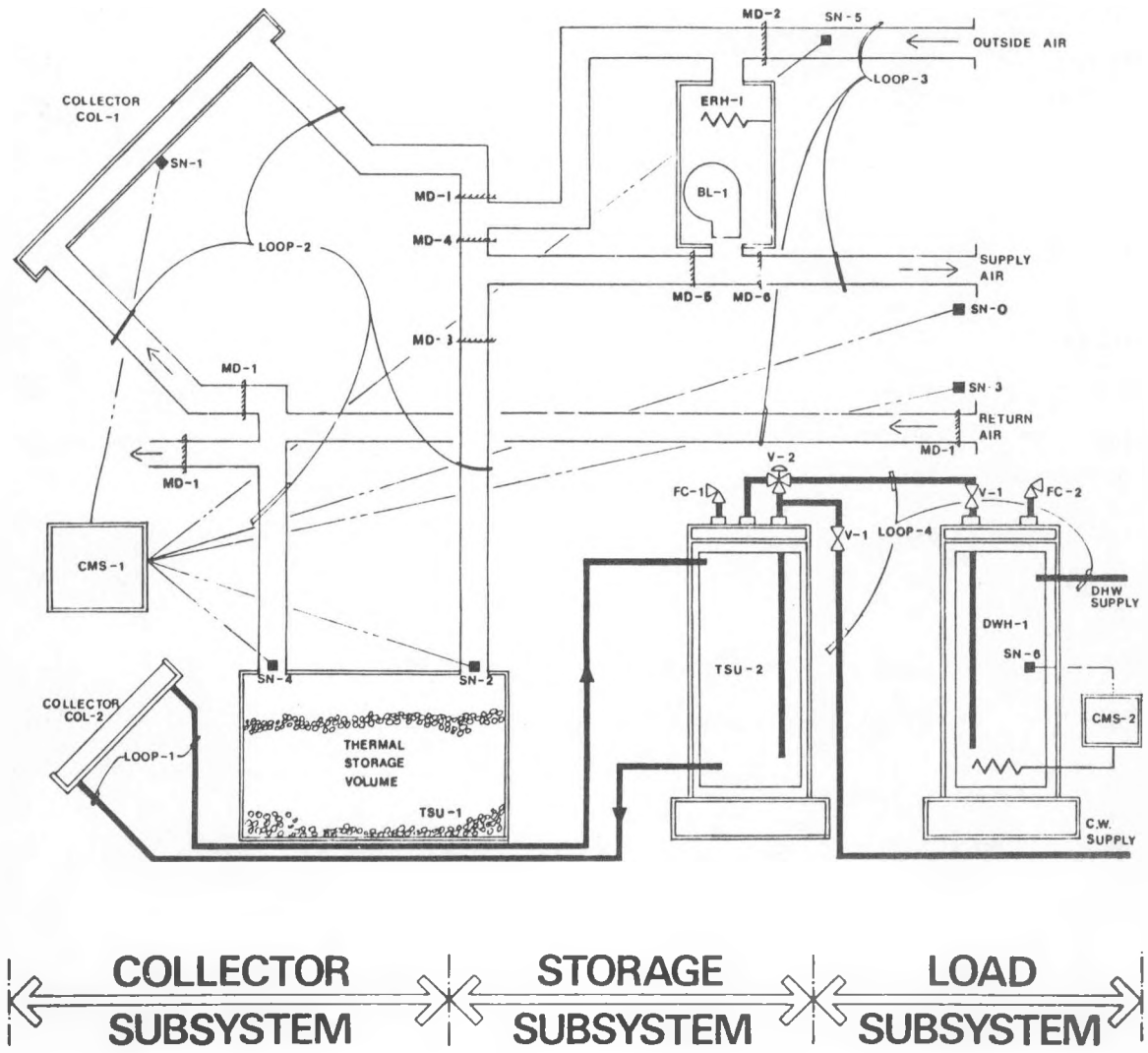


Figure IV-F-1. Controls Diagram

The Helio-Thermics (Lot # 8) solar system is shown on Figure IV-F-1. The system consists of the following four subsystems: a) Collector, b) storage, c) load DHW & ERH and d) auxiliary load subsystems.

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

Mode 1 - Collector-to-Space Heating

This mode activates when space heating is required and the collector supply-duct air temperature is 10 degrees higher than the building ambient air temperature. This mode terminates when the temperature difference drops to less than 6 degrees or the space heating requirement is satisfied.

Mode 2 - Collector-to-Storage

This mode activates when there is no demand for space heating and the collector supply-duct temperature is 26 degrees higher than the storage temperature. This mode terminates when the temperature difference between the collector and storage is less than 16 degrees.

Mode 3 - Storage-to-Space Heating

This mode activates when space heating is required (but is not available from the collector) and the storage temperature exceeds the building ambient temperature by 5 degrees. This mode terminates when the building ambient temperature equals the storage temperature or when space heating is no longer required.

Mode 4 - Auxiliary Energy-to-Space Heating

This mode activates when heat is required in the living area and thermal energy is not available from the collectors or storage. An electrical heating element in the hot air supply-duct remains on until the requirement for heat is satisfied.

Mode 5 - Summer Mode, Space Cooling

This mode can be activated when cool air from the outside is desired in the living area. The outside air-intake damper opens, the duct to the living area opens, and the air-handler fan activates.

Mode 6 - Summer Mode, Passive Cooling Storage

This mode can be activated when the residents wish to store cool air in storage for circulation the next day. The air-handler fan activates and an outside air-intake damper opens to allow the cool air to circulate through the attic and storage.

Mode 7 - Summer Mode, Storage-to-Space Cooling

This mode can be activated when cool air from storage is desired in the living area. The outside air-intake damper closes, the duct to the living area opens, and the air-handler fan activates.

Mode 8 - DHW Preheating

This mode activates when there is a demand for hot water. Water is drawn from the conventional DHW tank and replenished with heater water from the preheat tank. The DHW subsystem has this one independent mode of operation for preheating.

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.

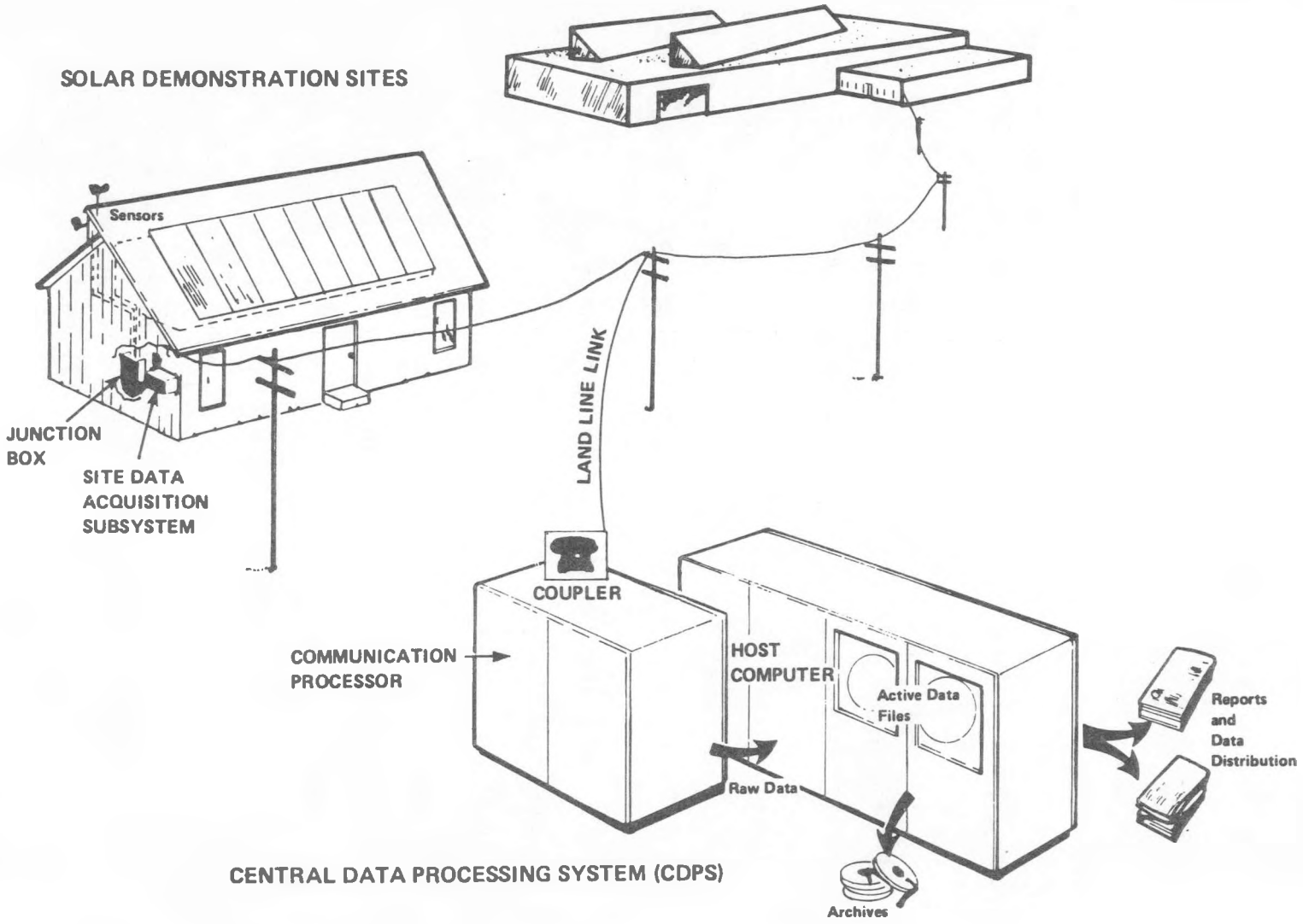


Figure V-A-1. The National Solar Data Network

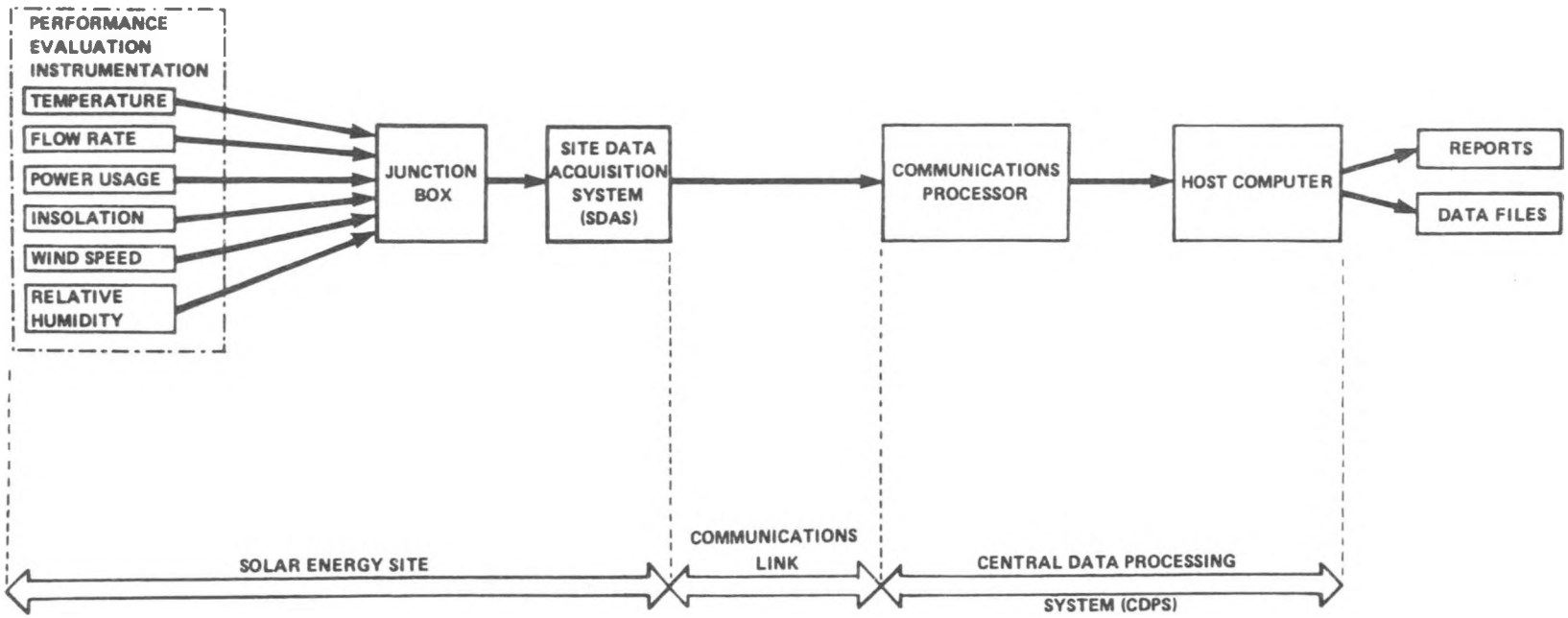


Figure V-A-2. Data Flow Path for the National Solar Data Network

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
T300	Temperature, CW makeup	S53P-60
T310	Temperature, Pre-heat tank, outlet	S53P-100
W300	Flow, Totalizer, HW system	Hersey 430
T301	Temperature, DHW tank inlet	S53P-60
T311	Temperature,DHW tank outlet	S53P-100
T100	Temperature, collector inlet	S53P-60
T110	Temperature, collector outlet	S53P-60
W100	Flow, to air handler	Kurz 430 DC
W101	Flow, from storage	Kurz 430 DC
T200	Temperature, storage supply	S53P-100
T111	Temperature, storage return	S53P-100
T600	Temperature, air to heated space	S53P-28
T601	Temperature, return air	S53P-100
EP401	Power, air circulating blower	PC5-10F
T201	Temperature, storage, SE of NW quad.	S53P-100
T202	Temperature, storage, S center of NW quad.	S53P-100
T203	Temperature, storage, SW of NW quad.	S53P-100
T204	Temperature, storage, NE of NW quad.	S53P-100
T205	Temperature, storage, N center of NW quad.	S53P-100
T206	Temperature, storage NW of NW quad.	S53P-100
EP402	Power, electric DHW 4.5 KW	PC5-29
EP403	Power, electric heater, 5 KW	PC5-29

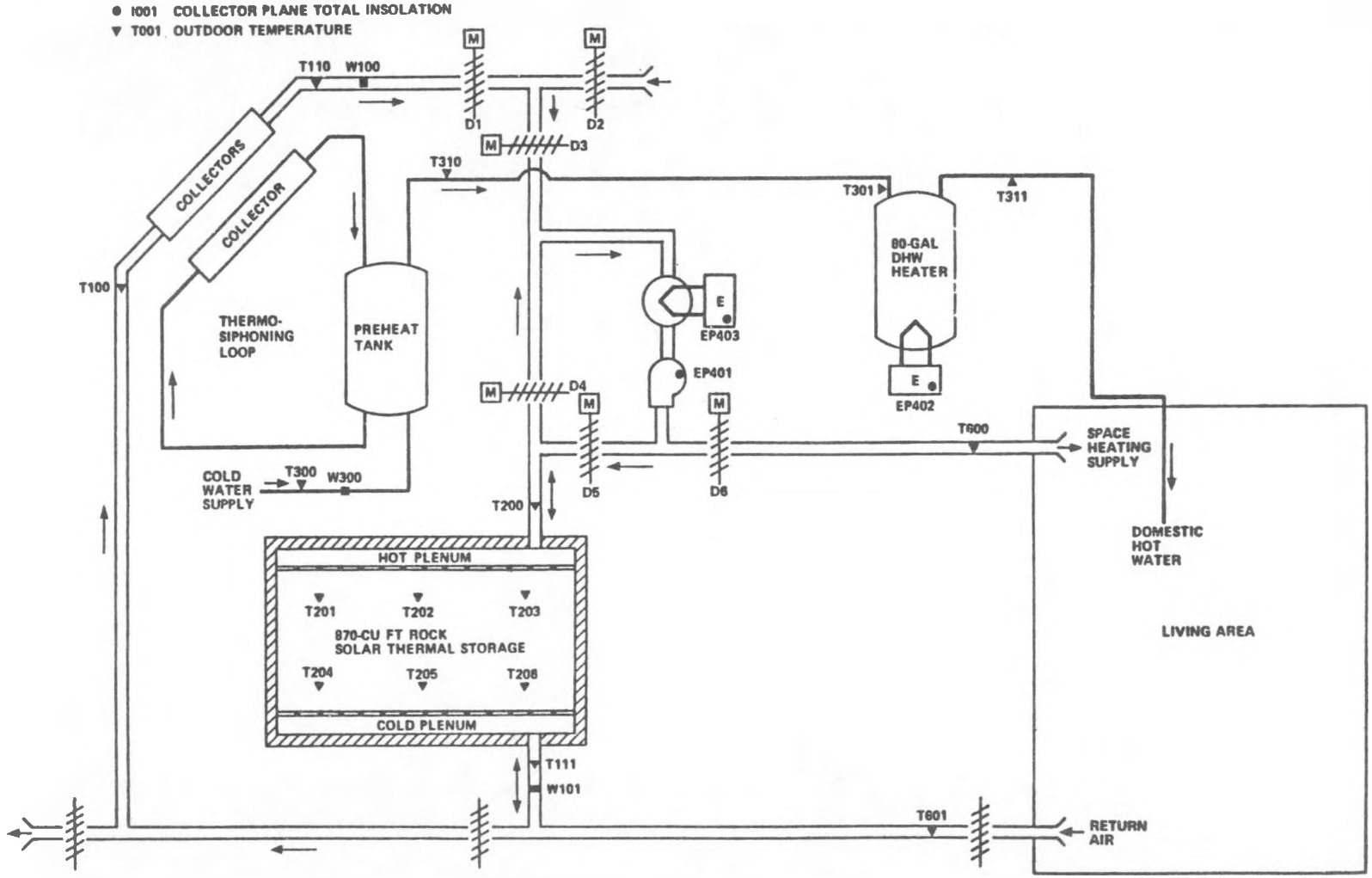


Figure V-B-1. Sensor and Control Diagram

VI. COST DATA

A. General

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

B. Construction Grant Funds

Solar Subsystem	Applicants Request	Construction Grant
Collectors		
Energy Storage		
Distribution and Controls		
Installation		
Other		
Total	$5,000	$4,000

C. Construction Period: May 1977 through November 1978

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^{o} F to 60^{o} 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.

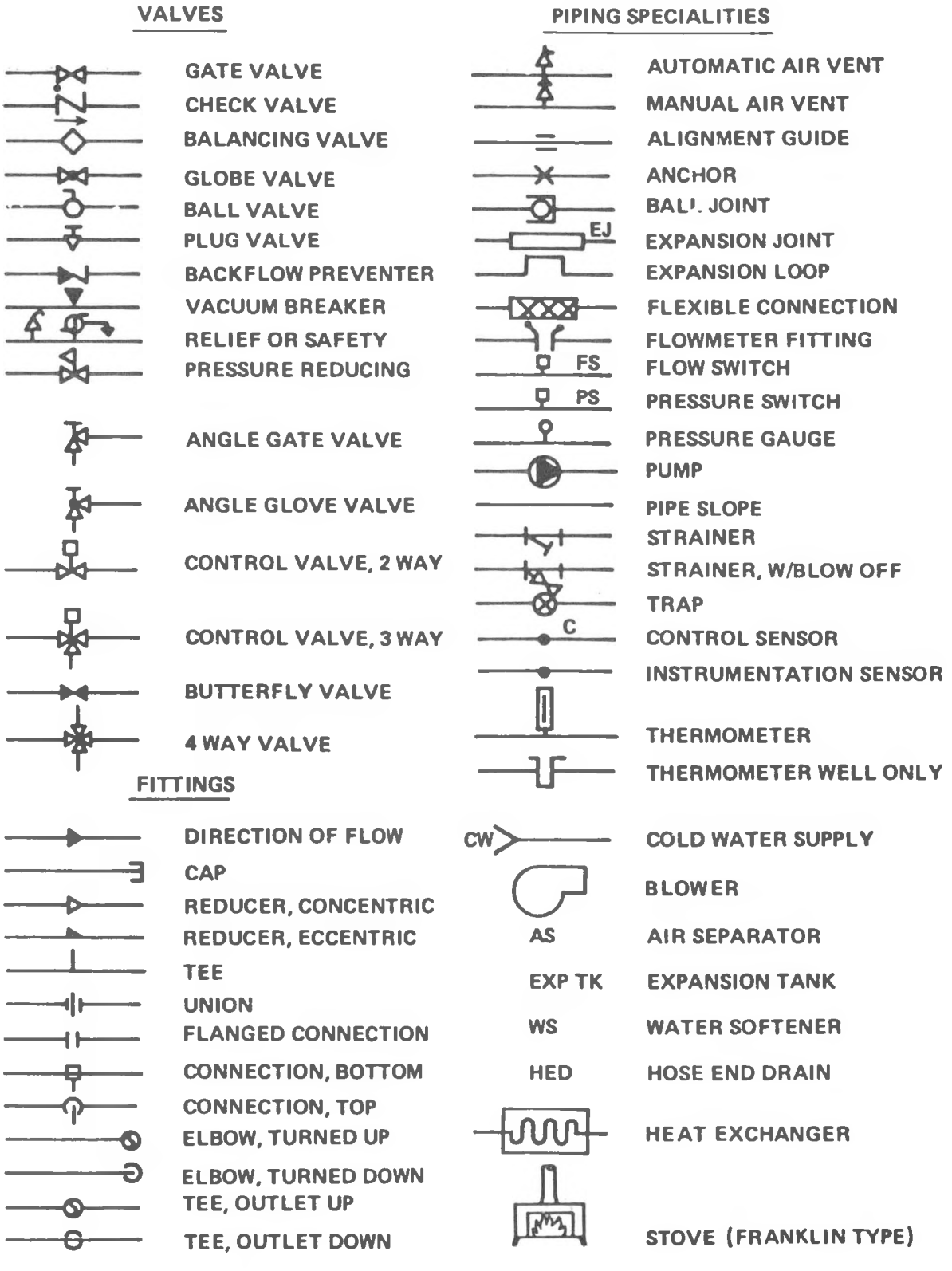
TON OF REFRIGERATION - A unit of refrigeration which is equivalent to 12,000 Btu/hr.

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



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