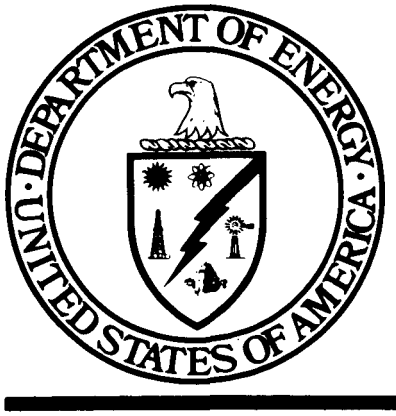
SOLAR/1009-81/50
(DE82002543)

Solar Project Description

GREENMOSS BUILDERS INCORPORATED SINGLE FAMILY RESIDENCE

Waitsfield, Vermont
October 23, 1981



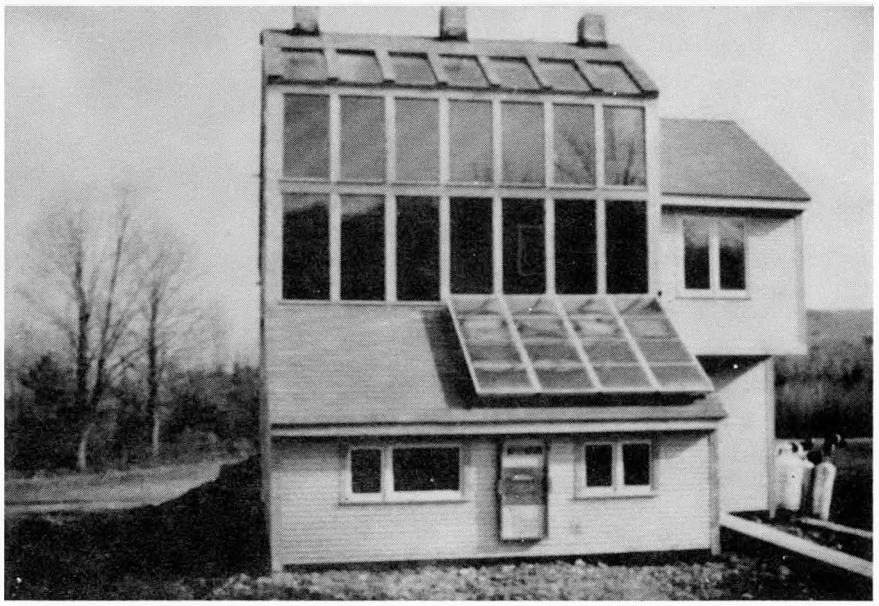
U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1009-81/50
(DE82002543)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
GREENMOSS BUILDERS INCORPORATED
SINGLE FAMILY RESIDENCE - WAITSFIELD, VERMONT



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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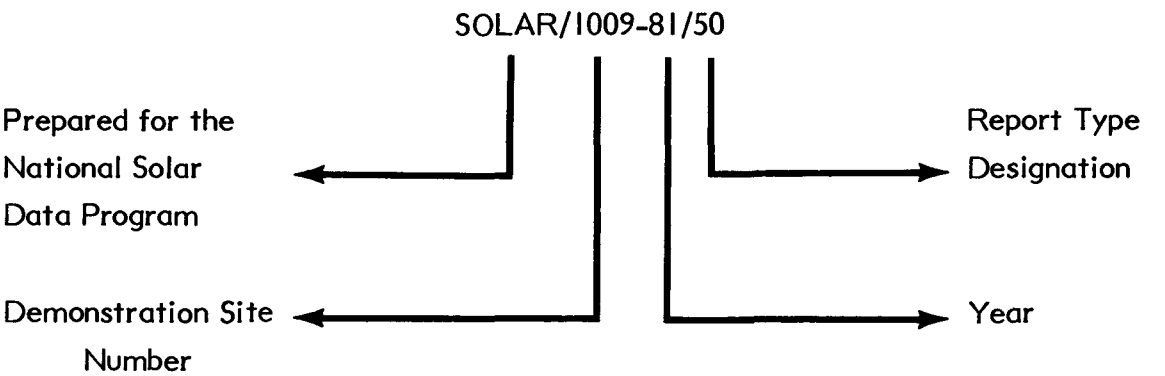
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Greenmoss Builders, Incorporated project site is designated as SOLAR/1009-81/50. 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 Greenmoss Builders, Incorporated Solar Energy System (Grant H-2708) is installed in a two-story single-family residence located in Waitsfield, Vermont. The system is designed to provide passive solar energy for space heating and active solar energy for domestic hot water preheating.

The following are the major solar energy descriptors:

- o Collector Type -- Passive-vertical wall, ducted/Active-flat plate
- o Freeze Protection -- Passive-none/Active-drain down
- o Application -- Passive-space heating/Active-DHW
- o Storage -- Passive-concrete block (Trombe) wall/Active-86 gallon pre-heat tank
- o New or Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes

II-A.SPACE HEATING

The passive space heating subsystem consists of a large window (approximately 278 square feet) on the south side of the two-story building. This allows direct solar irradiation of a concrete block storage wall. A small area on the west side of the building is also glazed. This allows more energy to be admitted during the afternoon hours.

Air returns for the furnace are placed on the south side of the storage wall. These returns take advantage of the heated air between the glazing and the storage wall. Additional collected solar energy is transferred directly through the storage wall to the rooms on the north side of the wall. A thermal barrier curtain covering the south window would provide the capability to add insulation to the south wall at night and during periods of low solar radiation. Auxiliary space heat is provided by a standard gas-fired furnace and two wood burning stoves. Summer overheating protection is provided by venting the space between the block wall and the window. The thermal barrier curtain will also aid in control of overheating.

II-B. DOMESTIC HOT WATER

A solar hot water subsystem utilizes roof-mounted flat-plate collectors that face south. The collected solar energy is used to preheat water for the domestic hot water supply.

GENERAL

The dwelling has been fully instrumented for performance evaluation since July, 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 VII 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 Greenmoss Builders Incorporated single-family residence utilizes passive solar energy for space heating and an active solar system for domestic hot water. This document will cover each system separately.

- Building type - Two-story, Single-family residence
- Latitude - 44^{o} -15' North
- Longitude - 73^{o} West
- Altitude - 490 ft (approximately)

HEATING DESIGN TEMPERATURES

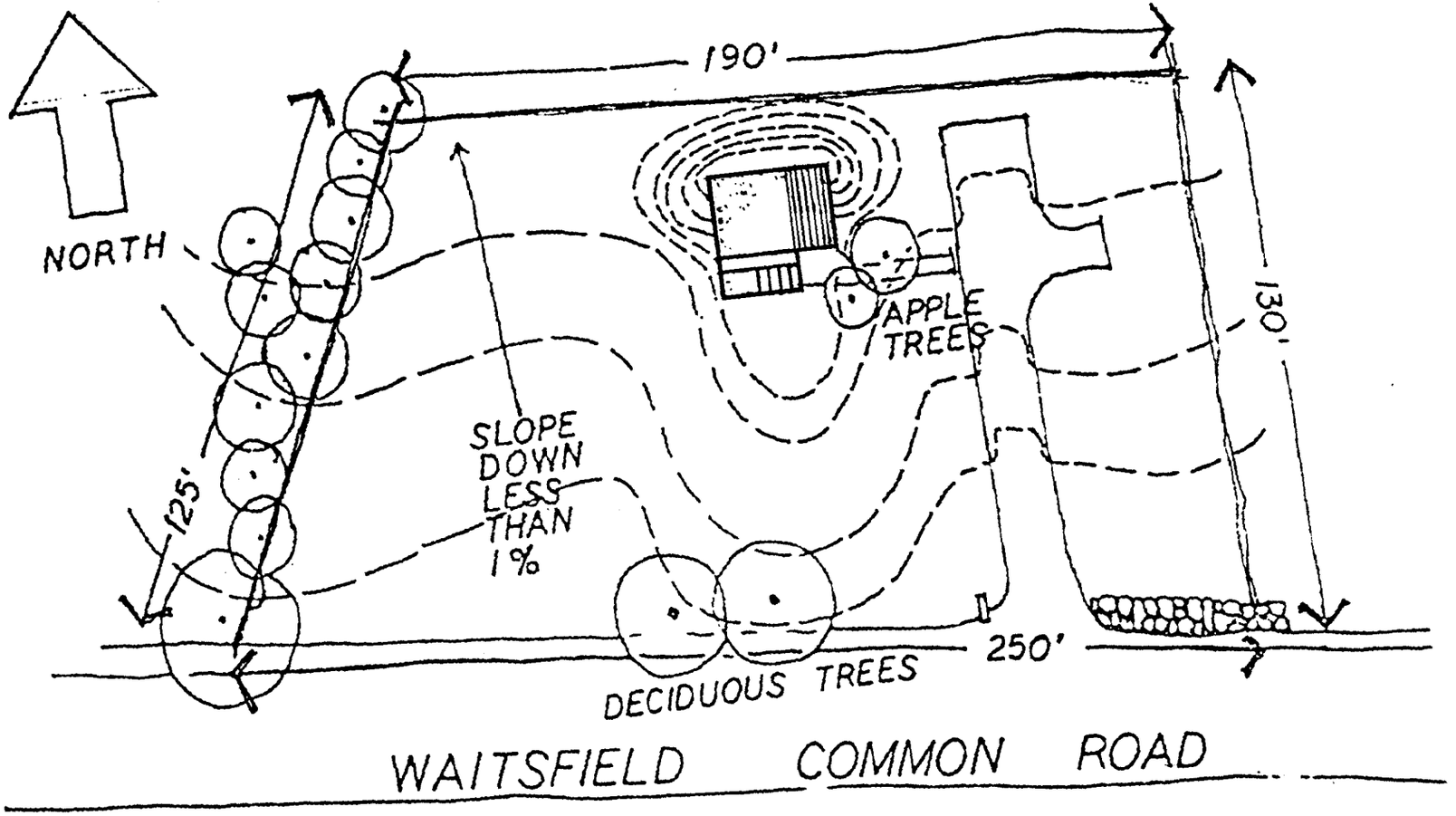
- Outdoor - 7^{o} F
- Indoor - 68^{o} F

BUILDING

- Building faces - South
- Average stories above ground - 2
- Average stories below ground - 0
- Height above grade - 28 feet
- Conditioned floor area - 1400 ft^2
- Roof type - Gable

DESIGN HEAT LOSS/LOAD

- Heat Loss - 35,700 Btu/hr
- Heat gain - Variable
- Shading
    - Heating season - None
    - Cooling season - None



1" = 40 FEET ±

Figure III-1. Site Plan

- Appliance, lighting and equipment load - Unknown
- Domestic hot water daily requirements - 80 Gal/Day
- Average horizontal insolation
  - January - 385/Btu/ft^2/day
  - July - 1,721/Btu/ft^2/day
  - Data reference - ASHRAE
- Annual degree days
  - Heating - 7875
  - Data location - Burlington, Vt.
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

SPACE HEATING SYSTEM

- Heating
  - Solar - Passive
  - Auxiliary - Wood burning stove and gas-fired air furnace
  - Distribution - Ducted air and radiated heat

SYSTEM AND COMPONENT SUMMARY **(SPACE-HEATING SYSTEM)**

- o Collector types - 1
- o Circulation loops - 2
- o Thermal storage units - 1
- o Operational modes - 4
- o Blowers - 2
- o Dampers - 1
- o Sensors - 3

DOMESTIC HOT WATER

- o Daily water demand - 80 gallons per day
- o Solar - Active, flat plate collectors
- o Auxiliary - Gas-Fired DHW heater

SYSTEM AND COMPONENT SUMMARY (DHW)

- o Collector types - 1
- o Circulation loops - 2
- o Thermal storage units - 1
- o Operational modes - 3
- o Pumps - 1
- o Valves - 6
- o Sensors - 3
- o Fail safe controls - 3

IV. SOLAR SYSTEM DESCRIPTION - SPACE HEATING

A. General Overview

This residential solar demonstration project (Greenmoss Builders, Incorporated, Grant H-2708) located at Waitsfield, Vermont is a hybird passive/active system utilized for space heating. Gas-fired auxiliary units are provided to supplement the solar energy system.

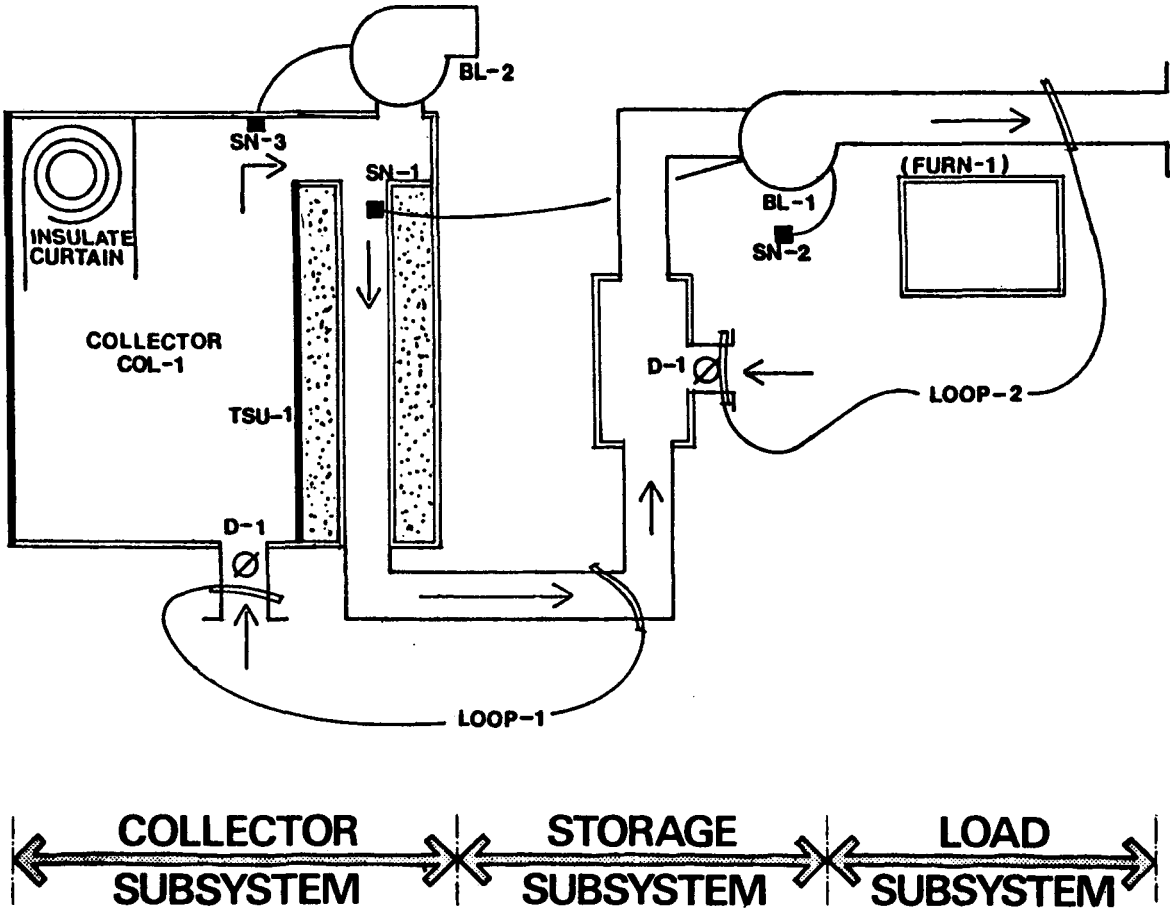


Figure IV-A-1. General Overview (Space Heating System)

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)

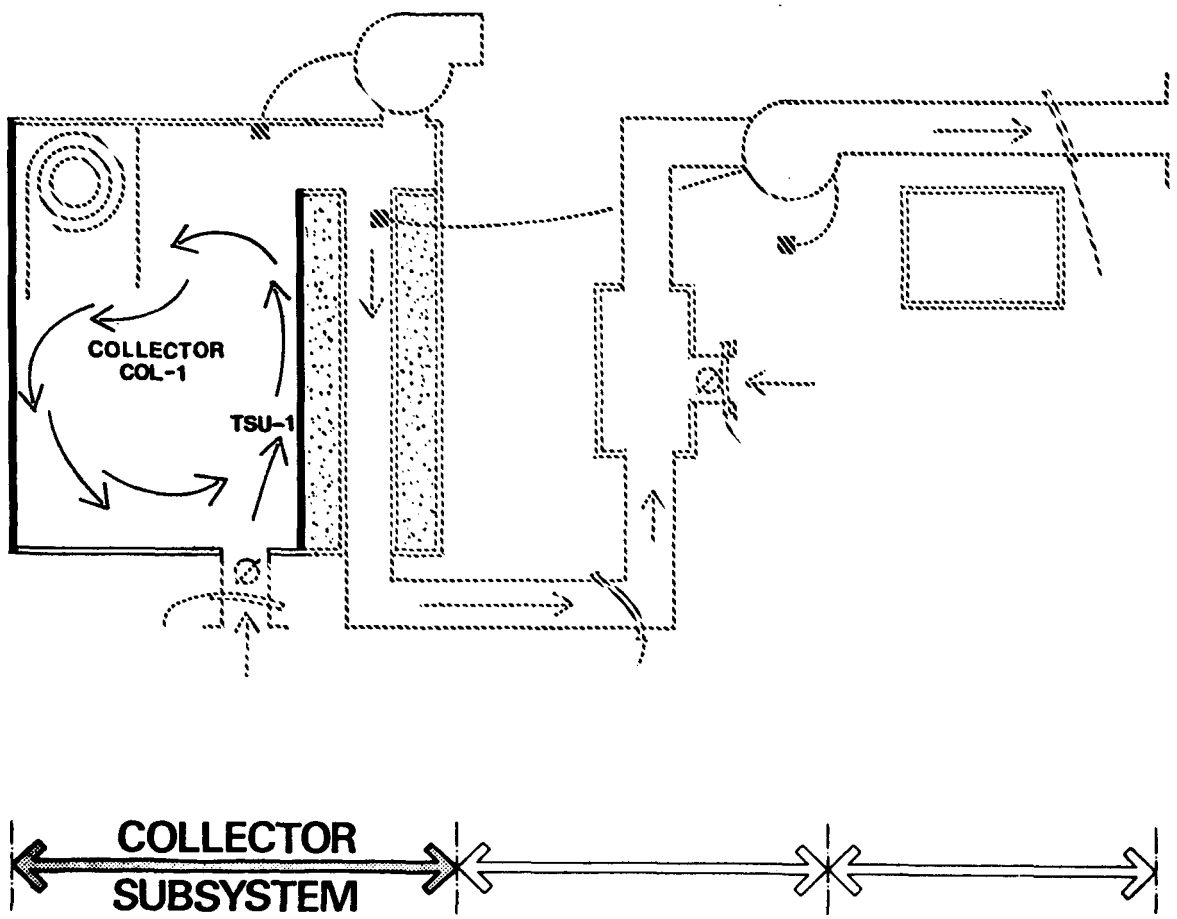


Figure IV-B-1. Collector Subsystem

Collector array system consists of 278 square feet of window area passing solar energy to a 500 square foot concrete block wall.

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

- Manufacturer - Greenmoss Builders, Incorporated
- Type - Ducted vertical wall
- Location - Interior concrete block storage wall
- Orientation - 7^{o} west of south
- Tilt angle - 90^{o} from horizontal
- Collector characteristics
  - Number of panels - 1
  - Total gross area of array - 278 ft^2
  - Panel length - 180 inches
  - Panel width - 224 inches
- Built-in collector - Windows built into and forms weatherproof surface of wall and portion of roof
- Collector shading
  - Area shaded in June - None
  - Area shaded in December - None
  - Maximum shade during functional season - None
- Cover plates
  - Number of cover plates - Two
- Cover plate No. 1
  - Location - Outer layer of two
  - Manufacturer -
  - Product name/number -
  - Material - Glass plate
  - Thickness - .125 inch

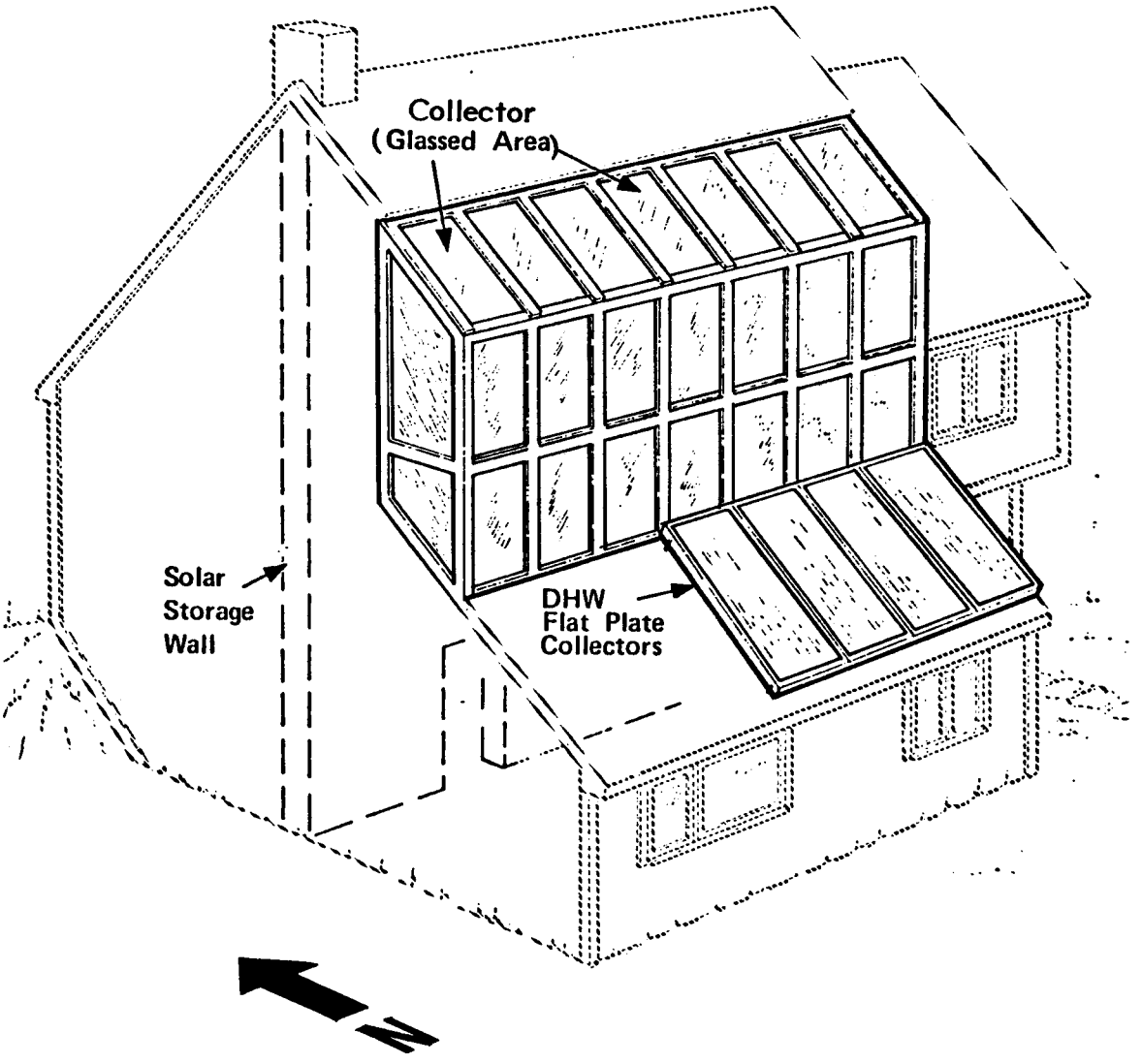


Figure IV-B-2. Solar Collector

- Optical properties

	(solar region)	(infrared region)
- Transmittance -	.84	
- Reflectance -	.08	
- Emittance -	.93	

  - Edge or surface treatment, other than coating - Mechanically ground
  - Coating on cover plate material - None
- Cover plate No. 2
  - Manufacturer -
  - Product name/number -
  - Material - Glass plate
  - Thickness - .125 inch
  - Optical properties

	(solar region)	(infrared region)
- Transmittance	.84	
- Reflectance	.08	

  - Edge treatment - Mechanical, ground
  - Coating - None
- Absorber
  - Manufacturer - Greenmoss Builders, Incorporated
  - Model name/number -
  - Material - Concrete block
  - Substrate material dimension
    - Thickness - Average 12 inches (including ducts)
    - Length - 18.7 feet
    - Height - 28 feet
  - Number of absorbers per collector - One

- Coating
  - Manufacturer - Greenmoss Builders, Incorporated
  - Coating material - Flat purple and maron alkyd enamel

	(solar region)
o Absorptance -	.85
o Reflectance -	.15
o Emittance -	.90

- Heat transfer fluid passages
  - Location - In absorber (block wall)
  - Pattern - Parallel
  - Materials - Openings case in blocks
  - Wall thickness - one inch
  - Fluid passage bond to substrate - Integral
  - Protective coating inside fluid passage - None
- Insulation - None
- Frame
  - Manufacturer - Greenmoss Builders, Incorporated
  - Product name/number - Site-built
  - Material - Building
  - Protective coating -
  - Standoffs used -
  - Number of structure attach points per module to building - Continuous
  - Built-in collector - Frame is part of lead-supporting structure
- Reflectors -
- Number of reflectors per collector - One
  - Substrate material - Earth

- o Reflective coating - Snow or lawn
- o Protective coating - None
- o Physical dimensions
  - Length - 75 feet (approximate)
  - Width - 50 feet (approximate)
  - Shape - Parabolic (graded earth)
- o Freeze protection - None
- o Overheating protection - None

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

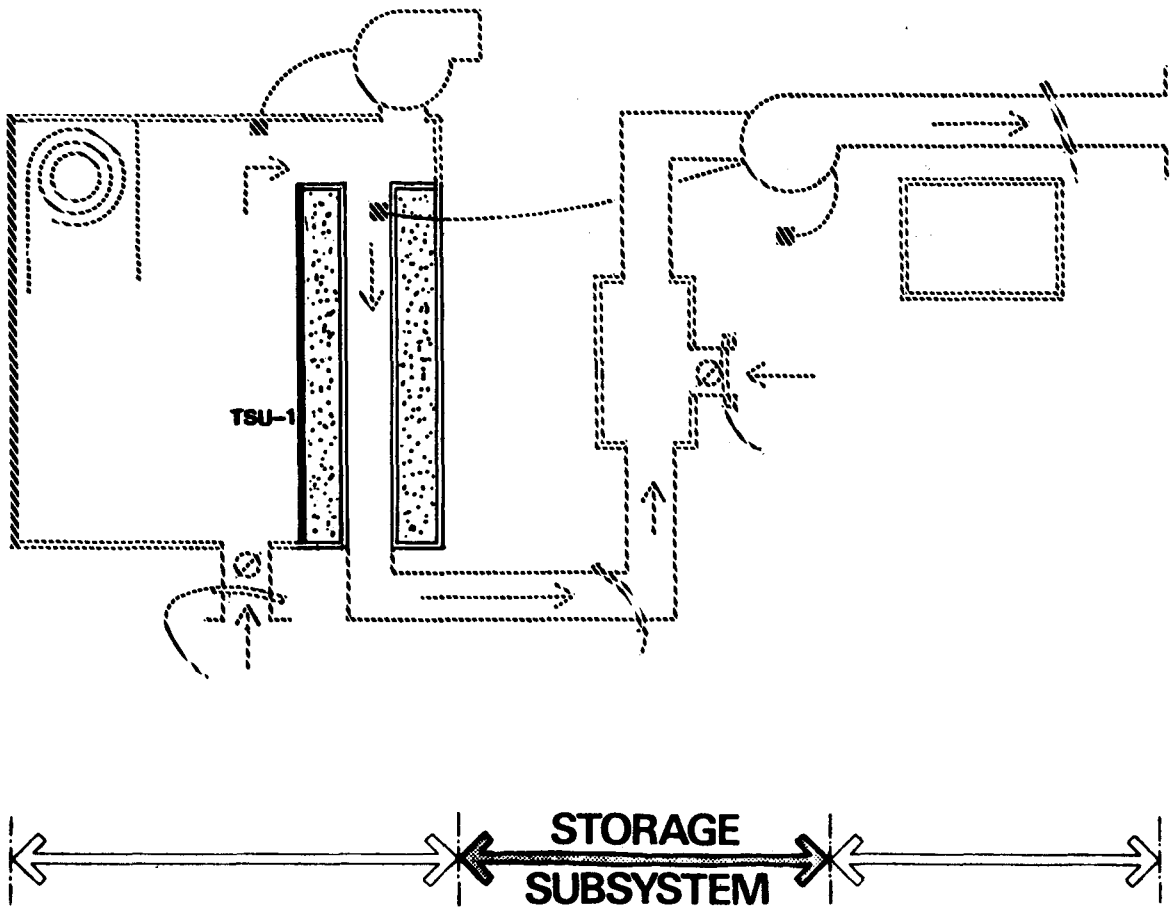


Figure IV-C-1. Storage Subsystem

Solar energy is stored in a concrete block wall (trombe wall) 19 feet long, 28 feet high and one foot thick. Flues from two stoves and the furnace are vertical passages in the wall. Return air to the furnace is through passages in the wall and ducts located in the plenum formed between the collector windows and the trombe wall.

THERMAL STORAGE UNIT (TSU-1)

- Manufacturer - Greenmoss Builders, Incorporated
- Model name/number - N/A
- Total storage container volume - 532 ft^3
- Volume of storage medium - 506 ft^3
  - Length - 19 ft
  - Width - 1 ft
  - Height - 28 ft
- Storage medium
  - Design operating temperatures
    - Heating - 120° F
  - Medium - Concrete (block)
  - Specific heat - 0.156 Btu/lb/° F
  - Density - 130 lb/ft^3
  - Heat capacity - 20 $Btu/ft^3/°$ F
- Medium manufacturers recommended use of temperature - N/A

D. Energy-To-Load Subsystem (See figure IV-D-1)

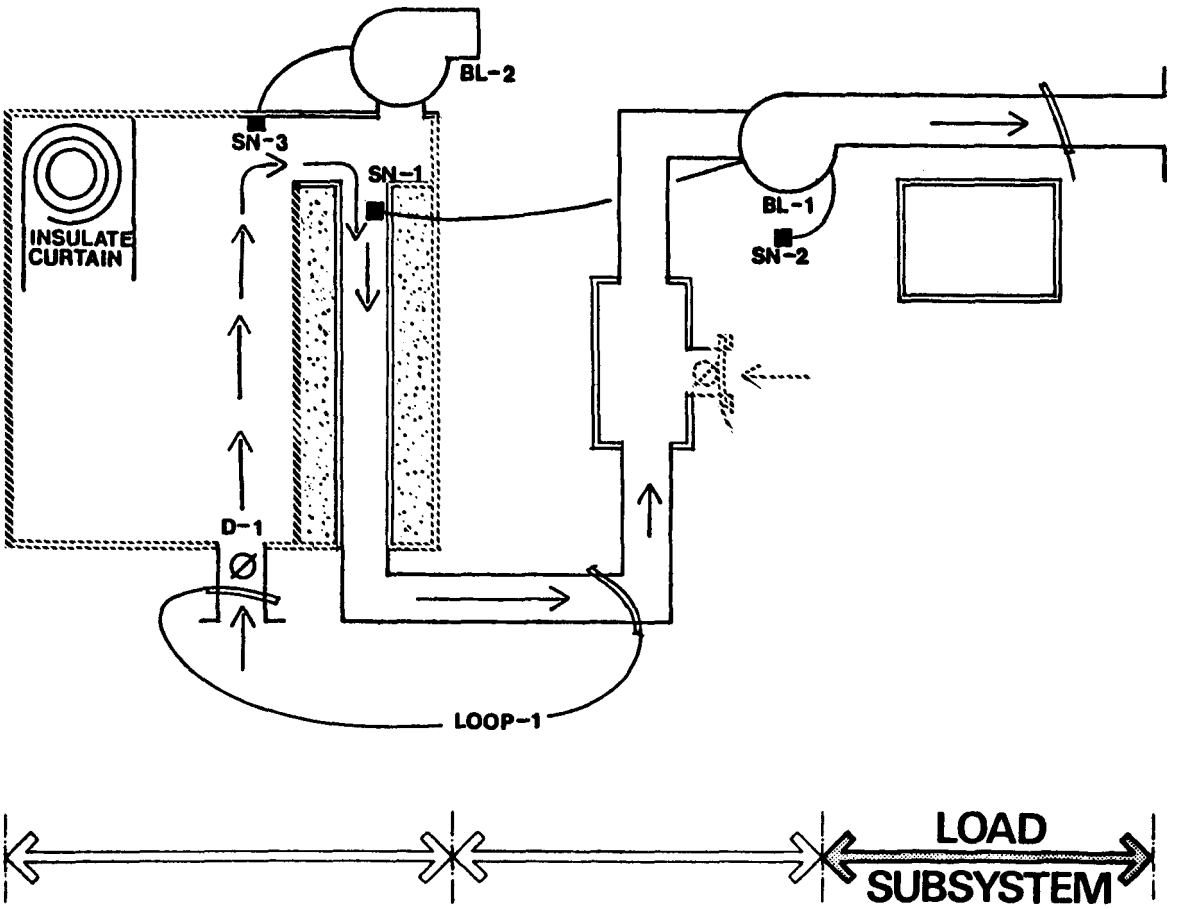


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy stored in the concrete block (trombe) storage wall is used to meet the space heating demands by circulating heated air through heating ducts in the air distribution system. Auxiliary space heating, supplementing this source, is provided by two stoves and a (propane) gas-fired furnace.

Summer overheating protection is provided by venting the space between the block wall and the window. The thermal barrier curtain aids in control of overheating.

AIR CIRCULATION LOOP NO. 1 (Collector to Space, or Vent to Outside)

- Heating
  - Maximum design operating temperature - 75° F
  - Heating design air flow - 1080 CFM
- Components within circulation loop
  - Blower(s) - 2
  - Furnace - 1
  - Thermal storage unit(s) -
  - Damper(s) - 1
  - Supplemental Heaters - Two stoves (Franklin type)
  - Other(s) - Filter
- Blower No. BL-1 (To Space)
  - Manufacturer - Lennox
  - Model name/number - Integral part of furnace
  - Type - Squirrel cage - (Integrated to furnace)
  - Design conditions

	Low Static Mode	High Static Mode
- Circulating volume	1080 cfm	

- Damper
  - Manufacturer - Steele's Incorporated Waterbury, Vermont
  - Model name/number - Unknown
  - Function - Flow-adjusting
  - Operation - Automatic-motorized
- Ducting
  - Type - Rigid galvanized steel, clamped joint
  - Location - Above grade, inside building

- Thermal resistance - R- N/A
- Insulation - None

- Blower No. (BL-2) - Vent to outside
  - Manufacturer - Dayton
  - Model number - 3C 245
  - Type -

AIR CIRCULATION LOOP NO. 2 (Direct Return to Space, Bypasses the Collector)

- Heating
  - Maximum design operating temperature - 75° F
  - Heating design air flow - 1080 CFM
- Components within circulation loop
  - Blower(s) - One (BL-1)
  - Furnace(s) - One
  - Thermal storage unit(s) - None
  - Damper(s) - One
  - Heat exchanger(s) - None
  - Other(s) - Filter
- Ducting - Direct return to space loop (bypassing)
  - Type - Rigid-steel, galvanized
  - Location - Above grade, inside building
  - Thermal resistance - R - N/A
  - Insulation - None (exterior or interior)

CONTROL MODE SELECTOR (Control by Thermostat/Sensors)

- Manufacturer - Unknown
- Model name/number - Unknown

- Modes controlled
  - Collector to storage to space
    - ON - (SN-1) > (SN-2) + 10° F
    - OFF - (SN-1) < 80° F
  - Energy dumping
    - ON - (SN-3) > 85° F
    - OFF - (SN-3) < 85° F
  - Auxiliary to space
    - ON - (SN-1) < (SN-2) + 10
    - OFF - (SN-2) > 70
- Sensors (SN-1) and (SN-2)
  - Type - Thermostat
- Sensor (SN-3)
  - Type - Thermostat
  - Function - Attic fan control

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

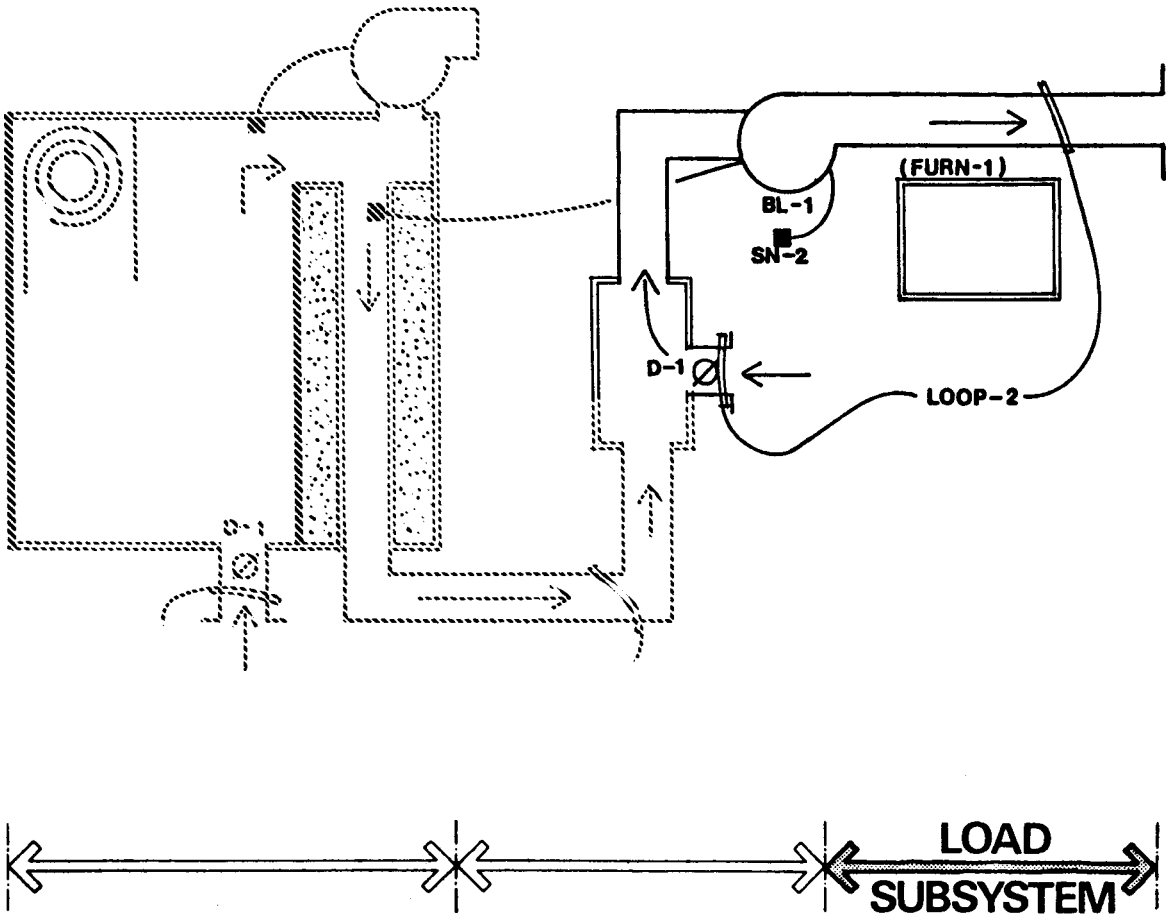


Figure IV-E-1. Auxiliary Subsystem

The auxiliary subsystems, one propane-gas-fired forced air furnace and two space-heating stoves (Franklin type) 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

- Furnace (FURN-1)
  - Manufacturer - Lennox
  - Model name/number - GS10Q3-75 horizontal stowaway
  - Energy source - Bottled liquid petrolium gas (Propane)
  - Energy input - 75,000 Btu/hr
  - Energy output - 60,000 Btu/hr
  - Burner ignition method - Pilot light
  - Flue vent - Yes (through TSU-1 storage wall)
- Space Heating Units
  - Manufacturer - Unknown
  - Model name/number - Free-standing (Franklin type) stoves
  - Energy source - Wood
  - Flue vent - Yes (through TSU-1 storage wall)

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

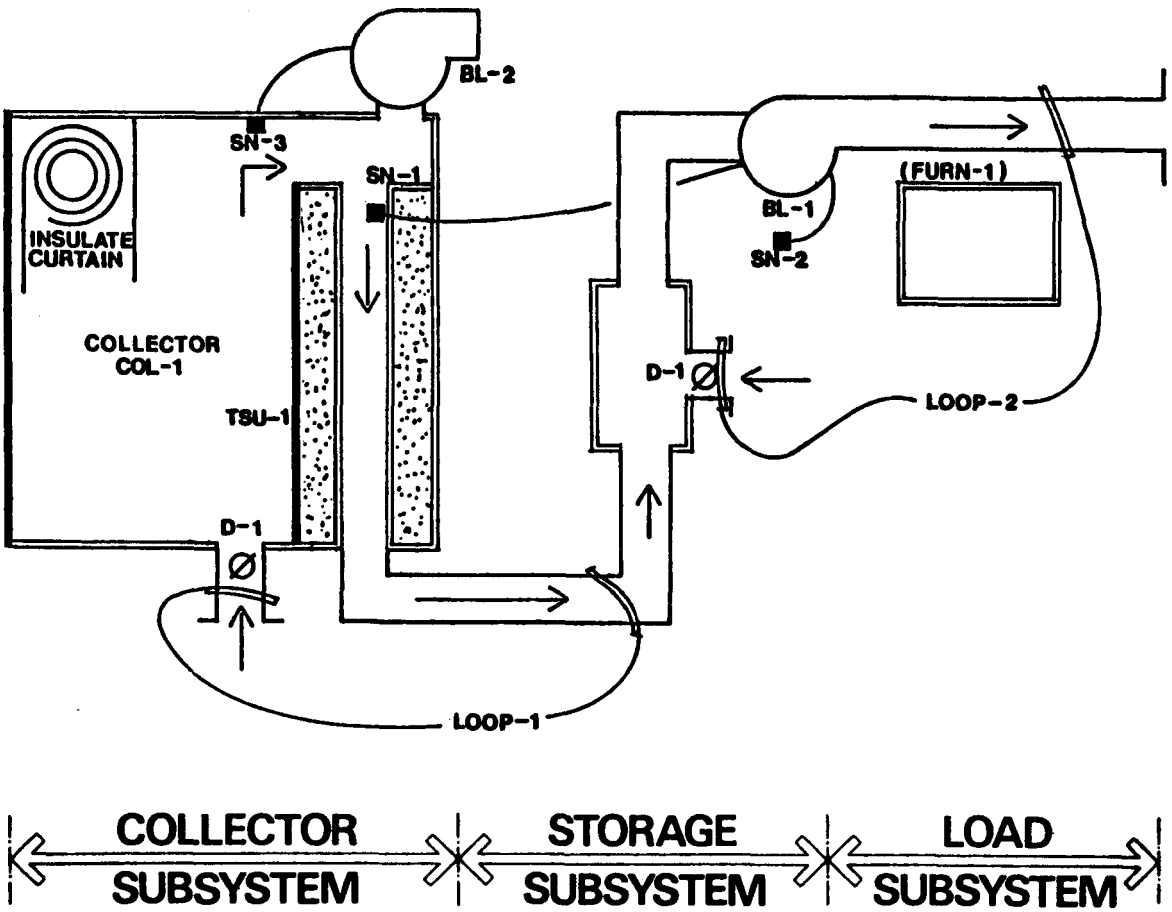


Figure IV-F-1. Controls Diagram

The Greenmoss Builders, Incorporated space-heating solar system at Waitsfield, Vermont, is shown on Figure IV-F-1. The system consists of the following four subsystems: a) collector; b) storage; c) load; and d) auxiliary load 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 - Heating - Solar Energy Only

Air circulation from plenum formed between collector windows and trombe wall through the air circulation ducts to heat living area. Thermal curtain is open (up).

Mode 2 - Heating - Solar Energy Plus Supplemental Heat Sources

Air from the plenum is circulated as above with supplemental heating from propane fueled gas-fired furnace, and/or wood burning stoves. Thermal curtain open (up).

Mode 3 - Heating - Residual Solar Plus Supplemental Heat Sources

Air from trombe wall circulated with furnace and/or stove heat supplementing - Thermal curtain closed (down).

Mode 4 - Heating by furnace and/or stove only

V. SOLAR SYSTEM DESCRIPTION - DHW

A. General Overview

The active solar hot water subsystem utilizes 88 sq. ft. of flat plate collectors with water as the heat exchange medium to a preheat tank. Potable supply water is then preheated before going to the conventional domestic hot water tank. Auxiliary water heating is provided by a gas-fired hot water heater.

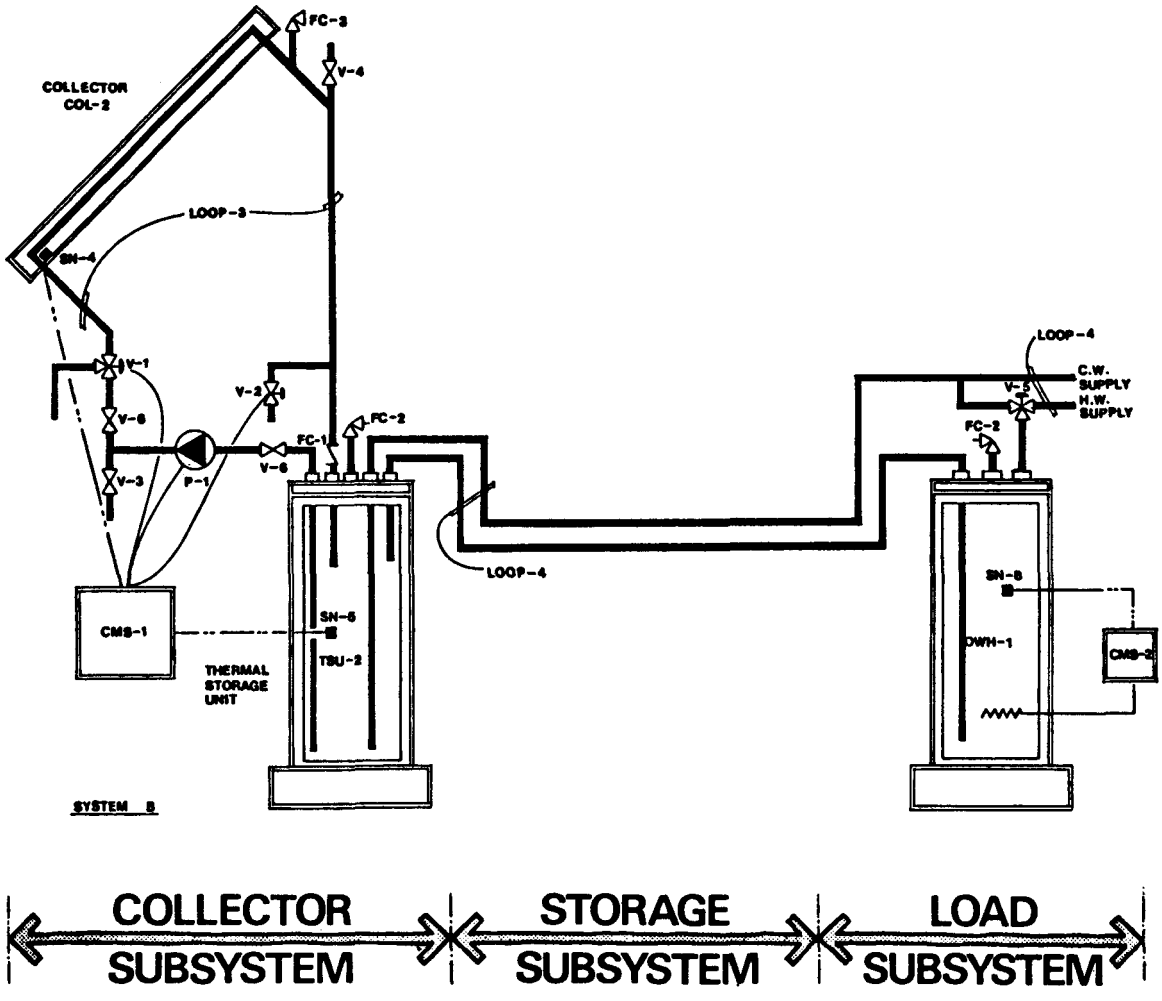


Figure V-A-1. General Overview

B. Collector Subysystem (See figure V-B-1)

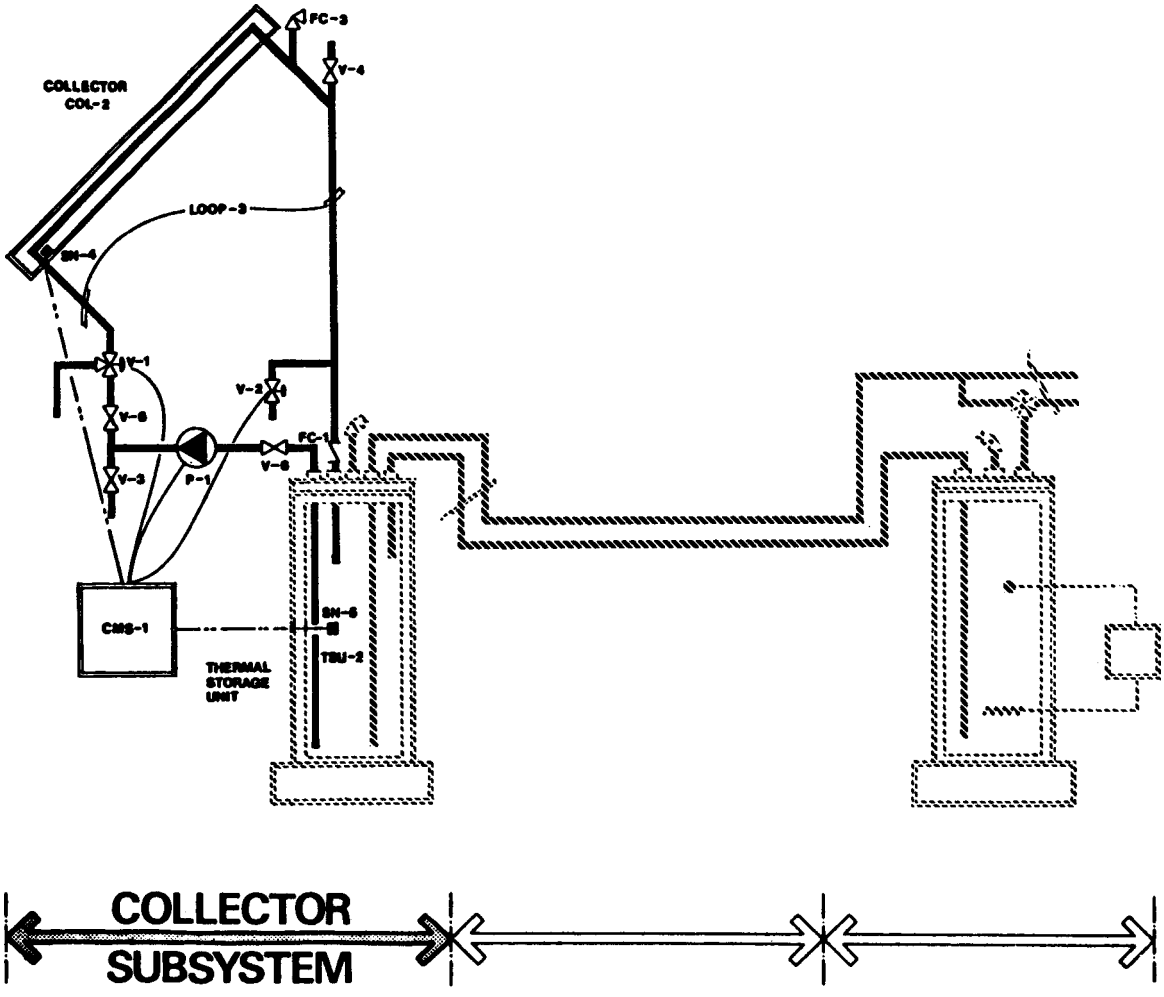


Figure V-B-1. Collector Subsystem

The collector array system consists of four flat plate collectors with a total area of 88 square feet. Freeze protection is by drain down system.

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

- Manufacturer - Sunearth Solar Products, Inc.
- Model name/number - 3597A
- Type - Flat plate, tube and plate
- Location - Roof
- Orientation - 7^{o} West of South
- Tilt angle - 37^{o} from horizontal
- Collector characteristics
  - Number of panels - Four
  - Total gross area of array - 88 ft^2
  - Net aperture area - 79 ft^2 (per array)
  - Net absorber area - 82.4 ft^2 (per array)
  - Weight per panel, empty - 74 lb
  - Weight per panel, full - 76 lb
  - Weight of filled array and support structure - 335 lb
  - Panel length - 97.3 in.
  - Panel width - 32.8 in.
  - Frame depth - 4.0 in.
  - Standoff height -
- Collector shading - None
  - Area shaded in June - 0%
  - Area shaded in December - 0%
  - Maximum shade during functional season - 0%
- Cover plates
  - Number of cover plates - 2

- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer -
  - Product name/number -
  - Material - Acrylic, high temperature
  - Thickness - 0.080 in.
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	91%	
- Reflectance -	8%	
- Emittance -		

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - None
  - Coating function -
  - Application -
- Cover plate No. 2, Inner Layer
  - Manufacturer - Dupont
  - Product name/number - Teflon Film
  - Material - Teflon Film
  - Thickness - 0.001 in.
  - Optical properties

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

  - Edge treatment - None
  - Coating - None
  - Coating function -
  - Application -

- Absorber
  - Manufacturer - Sunearth, Model 6 CP
  - Model name/number -
  - Material - Aluminum, 6063 T-6 (finned)
  - Substrate material dimension per absorber
    - Thickness - 0.08 in. average
    - Length - 92.75 in.
    - Width - 32.0 in
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - Caldwall Chemical Coating Corp.
  - Model name/number - Solarsorb
  - Coating material - Flat black paint, selective

	(solar region)	(infrared region)
o Absorptance -	94%	
o Reflectance -	6%	
o Emittance at 70° F)		57%
o Method of coating		

    - Application - Elect-Chem + 400° F bake
- Heat transfer fluid passages
  - Location - In abosrber
  - Pattern -
  - Materials - Copper, hard
  - Wall thickness - 0.025 in.
  - Internal diameter - 0.325 in. actual
  - Spacing - 5.75 in. on center

- Maximum operating conditions
  - Temperature -
  - Pressure - 125 PSI
- Fluid passage bond to substrate - Brazing
- Protective coating inside fluid passage - None

- Insulation
  - Layer one - sides
    - Manufacturer - Unknown
    - Product name/number - Unknown
    - Material - None
    - Thermal resistance - Unknown
  - Layer one - back
    - Manufacturer - Simirigid board/TW
    - Product name/number - Owens Fiberglas
    - Material - Glass fiber
    - Thermal resistance - R value - 8

- Gaskets and sealants
  - Manufacturer - G.E.
  - Product name/number - SIL Grip-SR 573

- Frame
  - Manufacturer - Sunearth
  - Product name/number -
  - Material - Aluminum, 6063T-5
  - Protective coating - None
  - Standoffs used - Yes
  - Number of structure attach points per module to building - 4
  - Built-in collector - Yes

- Reflectors - None
  - Desiccant - No
  - Freeze protection - Drain down (air bleed)
  - Overheating protection - PRV set 210° F
- Collector performance
  - Method of evaluation - $\frac{t_f - t_a}{I_t}$ (NBS)
  - y intercept $F_R(\tau\alpha)_\eta = 0.70 \frac{(^\circ F.hr.ft^2)}{BTU}$
  - Slope - $F_R U_L = 0.87$

Point Number	1	2	3	4
η = collector thermal efficiency (%) -	60.0	50.0	40.0	20.0
t_i or t_f = collector inlet temperature (° F) -				
t_a = ambient air temperature (° F) -				
I_t = insolation intensity Btu/hr ft^2 -				
$(t_i - t_a)/I_t$ -	0.13	0.26	0.37	0.56

WHERE

- η = collector thermal efficiency
- U_L = collector heat loss factor
- F_R = collector heat removal factor
- t_a = ambient air temperature, ° F
- $(\tau\alpha)_\eta$ = Transmissivity-absorptivity product at normal incidence
- t_i = collector inlet temperature, ° F
- t_f = average fluid temperature, ° F
- I_t = radiation (insolation) intensity on collector, Btu/hr.ft^2
  - Test flow rate - 3.7 lb/hr
  - Heat loss coefficient
  - Test wind speed - 10 mph

- Test collector area
  - Gross - 21.7 ft^2
  - Net - 19.3 ft^2
- Back side thermal loss - 12 Btu/hr/ft^2/^{o} F
- Edge thermal loss - 13 Btu/hr.ft^2.^{o} F
- Thermal response time constant - 4 min.
- Incidence angle modifier
  - 45^o - 0.89
  - 60^o - 0.73
  - 75^o - 0.45
- Fluid specific heat - 1.0 BTU/lb.^{o} F
- Test fluid medium - Water

LIQUID CIRCULATION LOOP NO. 3 (Collector to Storage)

- Maximum design operating temperature - 200^o F
- Maximum design operating pressure - 125 psi
- Heating design liquid flow - 2.0 GPM
- Heat transfer medium -
  - Volume of liquid in loop - 88 gal
  - Anticipated liquid temperatures - Unknown
  - Provisions for expansion - Expansion tank
  - Medium - Water
  - Specific heat - 1.00 Btu/lb/^{o} F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3/^{o} F
  - Boiling point - 212^o F
  - Freezing point - 32^o F
  - Maximum recommended use temperature - 140^o F

- Minimum recommended use temperature - 120° F or as-set
- 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
  - Collector(s) - Col 1
  - Valve(s) - V-1, V-2, V-3, V-4, V-6
  - Other(s) - FC-1, FC-2, FC-3
- Piping
  - Rigid - 1/2" copper
  - Insulation Type - Tape and mastic
  - Location - Above grade
  - Filter(s) - None
- Circulator pump (P-1)
  - Manufacturer - Taco
  - Model name/number - Circulator No. 117B
  - Type - Variable flow
  - Maximum operating conditions
    - Dynamic pressure - Unknown
    - Temperature - 200° F
  - Material exposed to heat transfer fluid - Bronze
  - Motor size - 115V, 1/20 hp

- Distribution Valve (V-1)
  - Manufacturer - ASCO
  - Model name/number - 117-001
  - Function - Flow switching, drain, 3-way, diverting
  - Operation - Automatic, motorized
  - Type - Gate, ball
- Distribution Valve (V-2)
  - Manufacturer - ASCO
  - Model name/number - 8210 B 35
  - Function - ON-OFF, drain, 2-way, diverting
  - Operation - Automatic, motorized
  - Type - Gate, ball
- Distribution Valve (V-3)
  - Manufacturer -
  - Model name/number -
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Ball
- Distribution Valve (V-4)
  - Manufacturer -
  - Model name/number -
  - Function - Air vent
  - Operation - Automatic, non-motorized
  - Type - Float

- Distribution Valve (V-6)
  - Manufacturer -
  - Model name/number -
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid -
- Flow Control (FC-1)
  - Manufacturer - Unknown
  - Type - Check valve
- Fail Safe Control (FC-2)
  - Manufacturer - Watts
  - Model name/number - 100 XL-4
  - Type - Temparature and pressure relief valve
  - Set points - Pressure: 150 psi Temperature: 210° F
- Fail Safe Control (FC-3)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Vacuum relief valve

CONTROL MODE SELECTOR (CMS-1)

- Manufacturer - Unknown
- Model name/number - Unknown
- Modes controlled
  - Collector to storage -
    - ON - (SN-04) > (SN-05) + 40° F
    - OFF - (SN-04) < (SN-05) + 40° F
  - Drain down - (SN-04)< (SN-05) - 15° F

- Sensors (SN-04) and (SN-05)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Temperature, thermistor

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

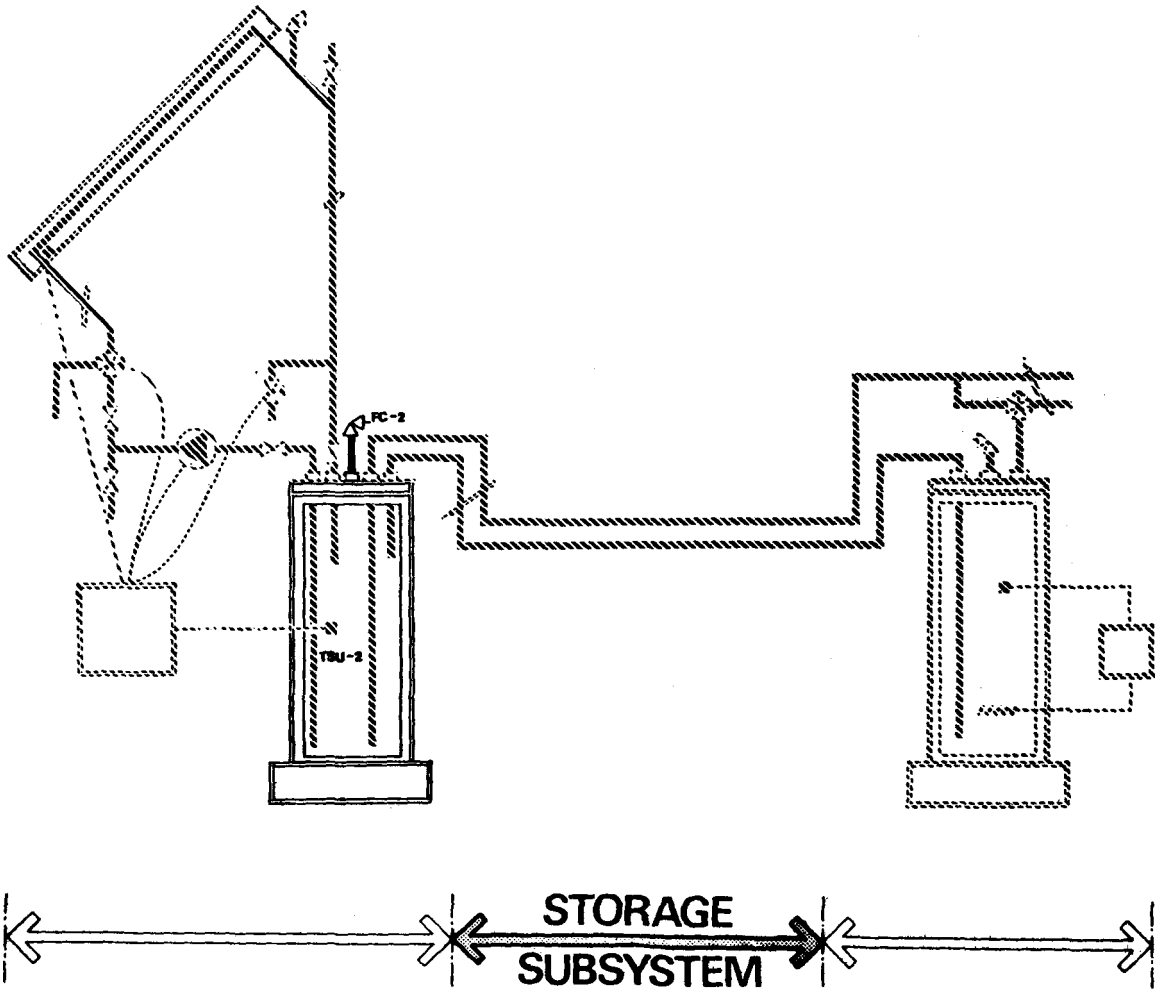


Figure V-C-1. Storage Subsystem

Solar energy storage is provided by an 82 gallon storage tank. This tank is made of steel and is covered with glass fiber insulation (R=7).

THERMAL STORAGE UNIT (TSU-1)

- Manufacturer - Unknown
- Model name/number - Unknown
- Total storage container volume - 11 ft^3
- Storage medium
  - Design operating temperatures
    - Heating - 200° F maximum
  - Medium - Water
  - Specific heat - 1.000 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 - 200° F
  - Minimum - Unknown
- Toxicity - Potable
- pH Factor - 7.0
- Inhibitor - No

- Container construction
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Steel
  - Interior lining - Glass
  - Location - In crawl space
  - Auxiliary heaters - No
  - Insulation, exterior - Glass fiber, R=7
  - Exterior finish - None
  - Filters - None
  - Getters - Yes, magnesium

D. Energy To Load Subsystem (See figure V-D-1)

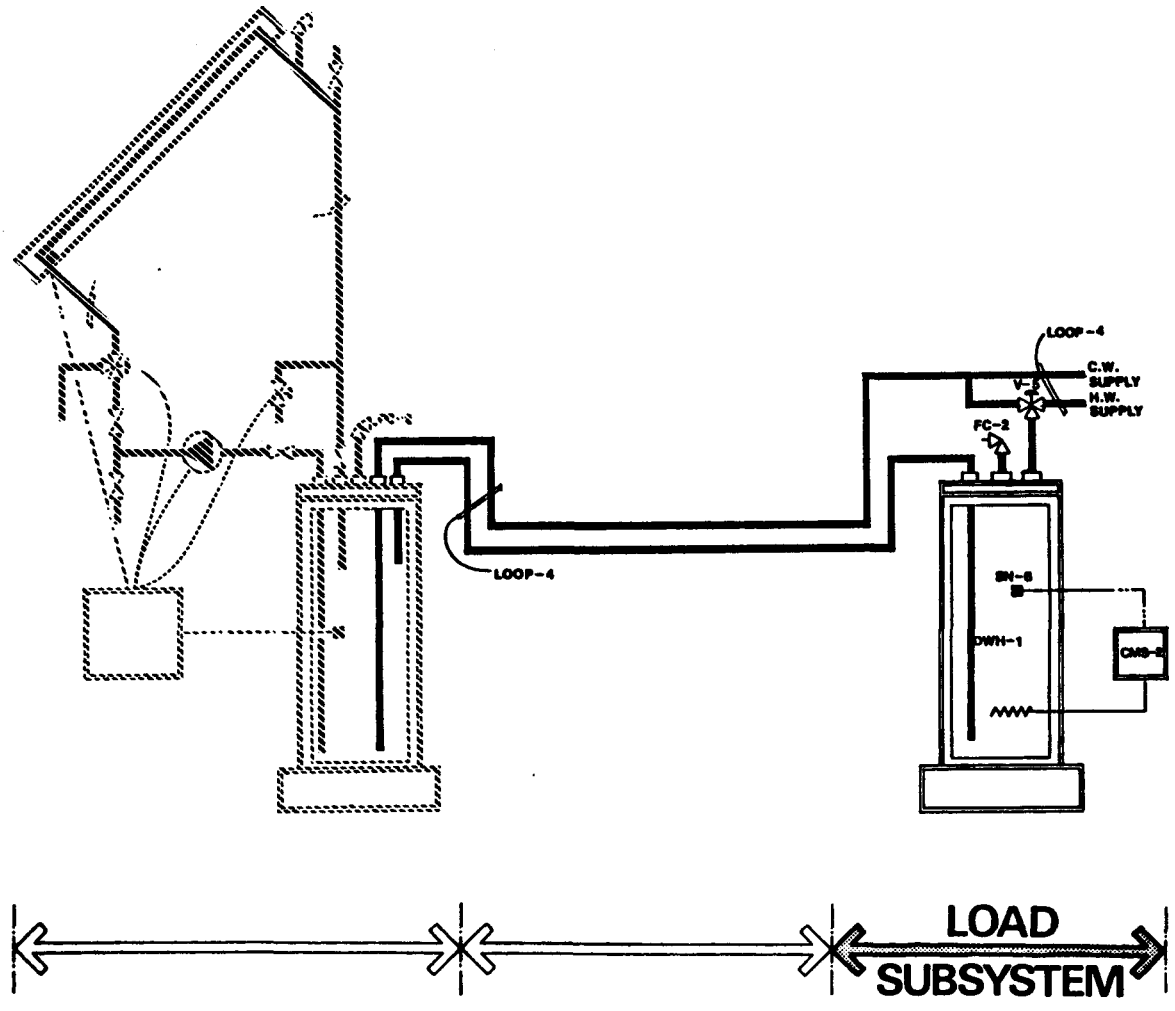


Figure V-D-1. Energy-to-Load Subsystem

Water for domestic use is stored in an 82 gallon preheat tank (TSU-2). Preheated water is supplied on demand to a 30 gallon gas-fired Domestic Hot Water tank.

LIQUID CIRCULATION LOOP NO. 4 (CW Supply to HW Supply)

- Design maximum operation temperature - 200° F
- Design maximum operation pressure - 125 psi
- Heat transfer medium
  - Volume of liquid in loop - Unknown
  - Anticipated liquid temperatures
    - Maximum - 140° F
    - Minimum - 120° F or as set
  - Provisions for expansion - Relief valve
  - Medium - Water
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Medium manufacturer's recommended use temperature
    - Maximum - 200° F
    - Minimum - N/A
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Components within circulation loop
  - Domestic water heater(s) - 1
  - Thermal storage unit(s) - 1
  - Valve(s) - 1
  - Other(s) - FC-2

- Piping
  - Rigid - Copper
  - Insulation - Tape and mastic
  - Location - Above grade
- Distribution Valve V-5
  - Manufacturer - Unknnown
  - Model name/number - Unknown
  - Function - Flow switching, 3 way-mixing
  - Operation - Automatic, non-motorized
  - Type - Tempering
  - Material exposed to heat transfer fluid - Unknown

CONTROL MODE SELECTOR

- Manufacturer - Bradford White
- Model name/number - M-30 LP 5 CX
- Modes controlled
  - Auxiliary to HW
    - ON - (SN-06) < 140° F
- Sensors (SN-3)
  - Type - Aquastat

AUXILIARY LOADS

- Domestic Water Heater (DWH-1)
  - Manufacturer - Bradford White
  - Model - M-30 LP 5 CX
  - Energy source - Propane
  - Tank size - 30 gal
  - Energy input - 22,400 Btu/hr
  - Energy output - 18,000 Btu/hr
  - Maximum pressure rating - Unknown
  - Maximum temperature rating - Unknown
  - Design operating pressure - Unknown
  - Heating stages - Unknown
  - Maximum recovery rate - 21 gal/hr
  - Yearly average inlet temperature - 50° F
  - Design output temperature - 160° F

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

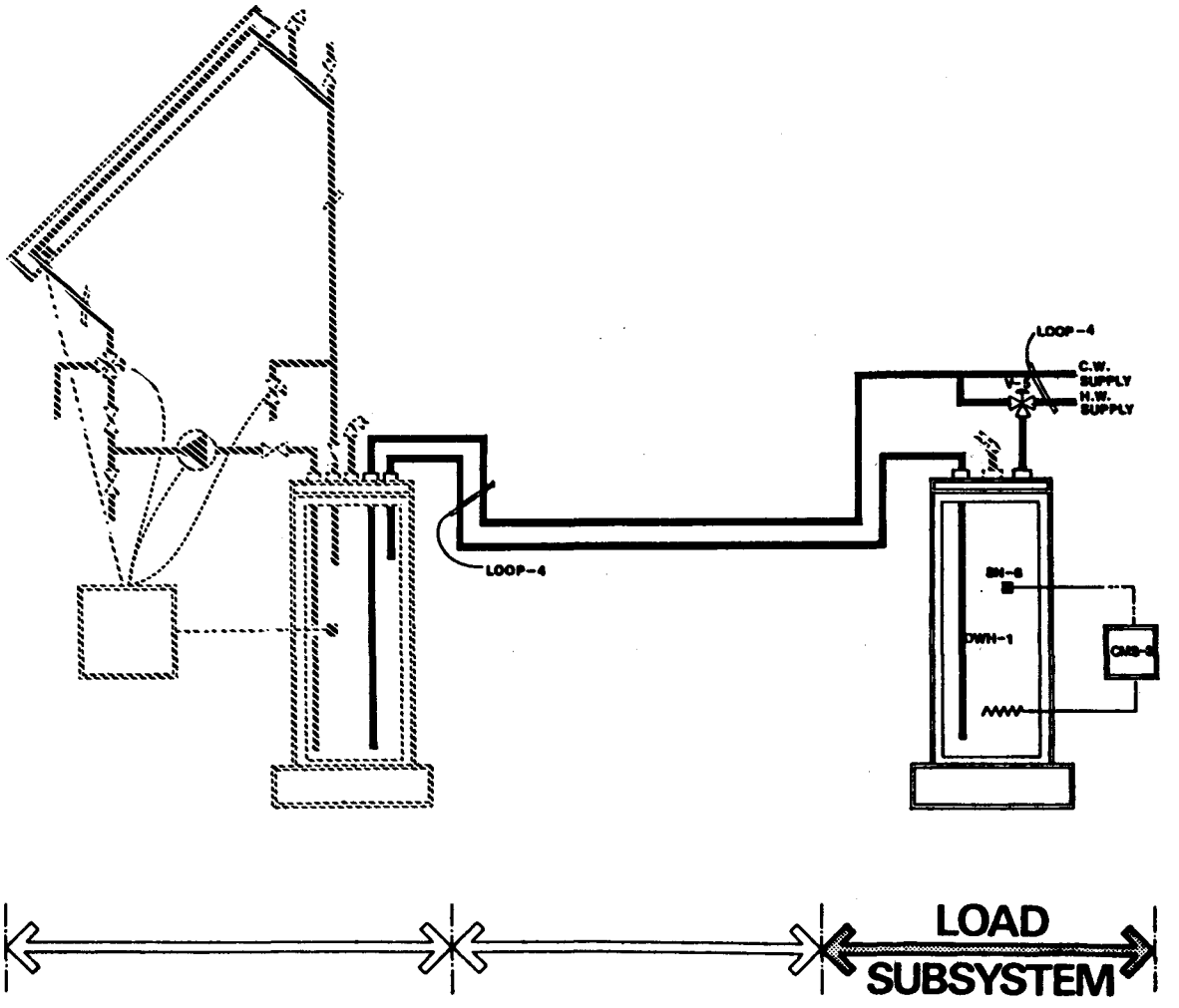


Figure V-E-1. Auxiliary-to-Load Subsystem

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

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

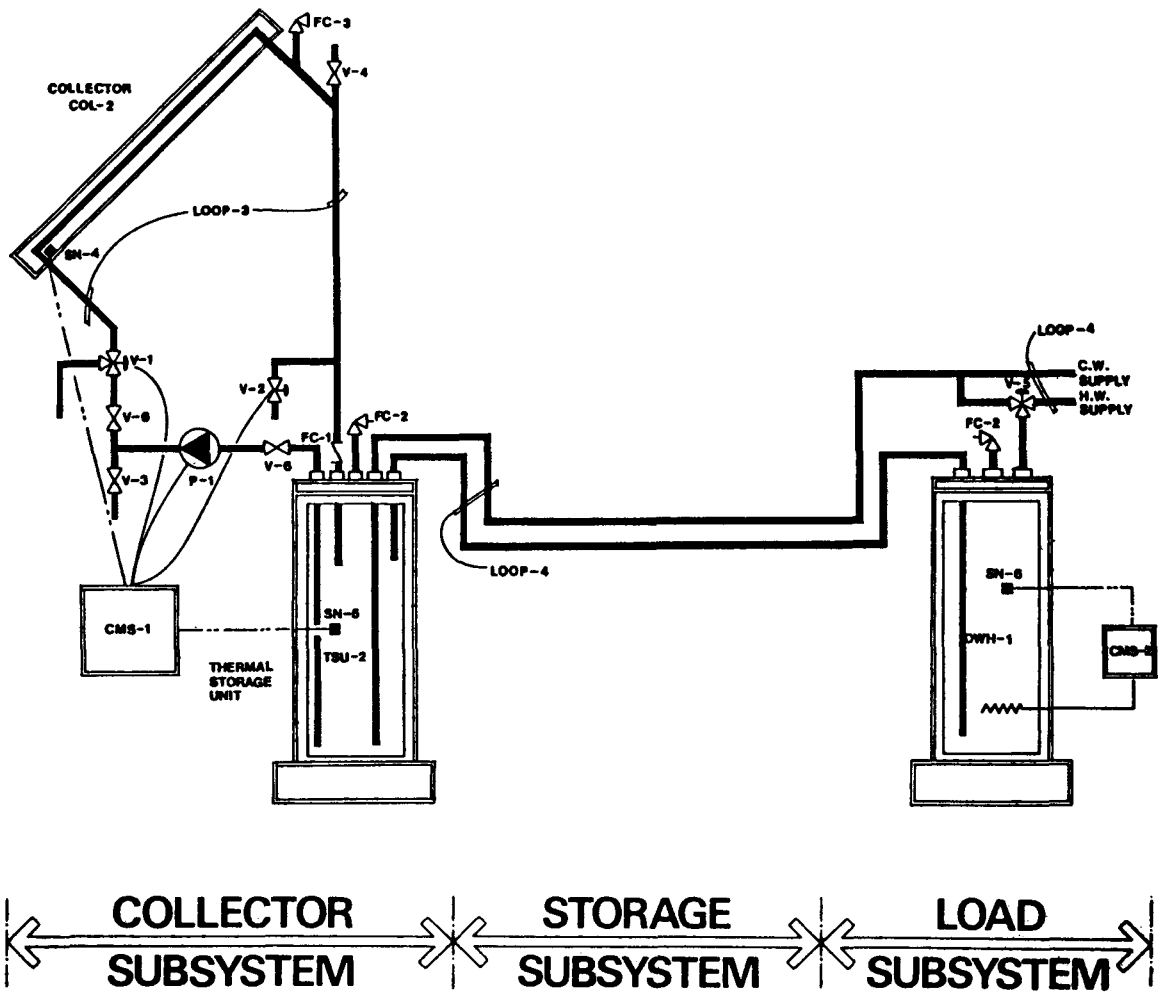


Figure V-F-1. Controls Diagram

The Greenmoss Builders, Inc. solar system is shown on Figure IV-F-1. The system consists of the following four subsystems: a) collector; b) storage; c) load (DHW) and d) auxiliary load subsystems.

Operation of the solar system and the auxiliary subsystem involves one or more of the modes of operation described below.

Mode 1 - Collector-to-Preheat

This mode activates the pump when the difference between the temperature of the collector water and the temperature of the water in the preheat tank exceeds 40 degrees Fahrenheit and the temperature of the water in the tank is below 140° F. This mode continues until the temperature difference drops below 40 degrees Fahrenheit.

Mode 2 - Preheat-to-Domestic Hot Water (DHW)

This mode activates when there is a demand for hot water. Hot water from the top of the preheat tank is transferred to the DHW tank to replace water removed. Simultaneously, city water is automatically supplied to the preheat tank.

Mode 3 - Draindown

When the water temperature in the collector drops to 15° F below the water temperature in the preheat tank, valves V-1 and V-2 are activated to drain water from the collector.

VI. 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.

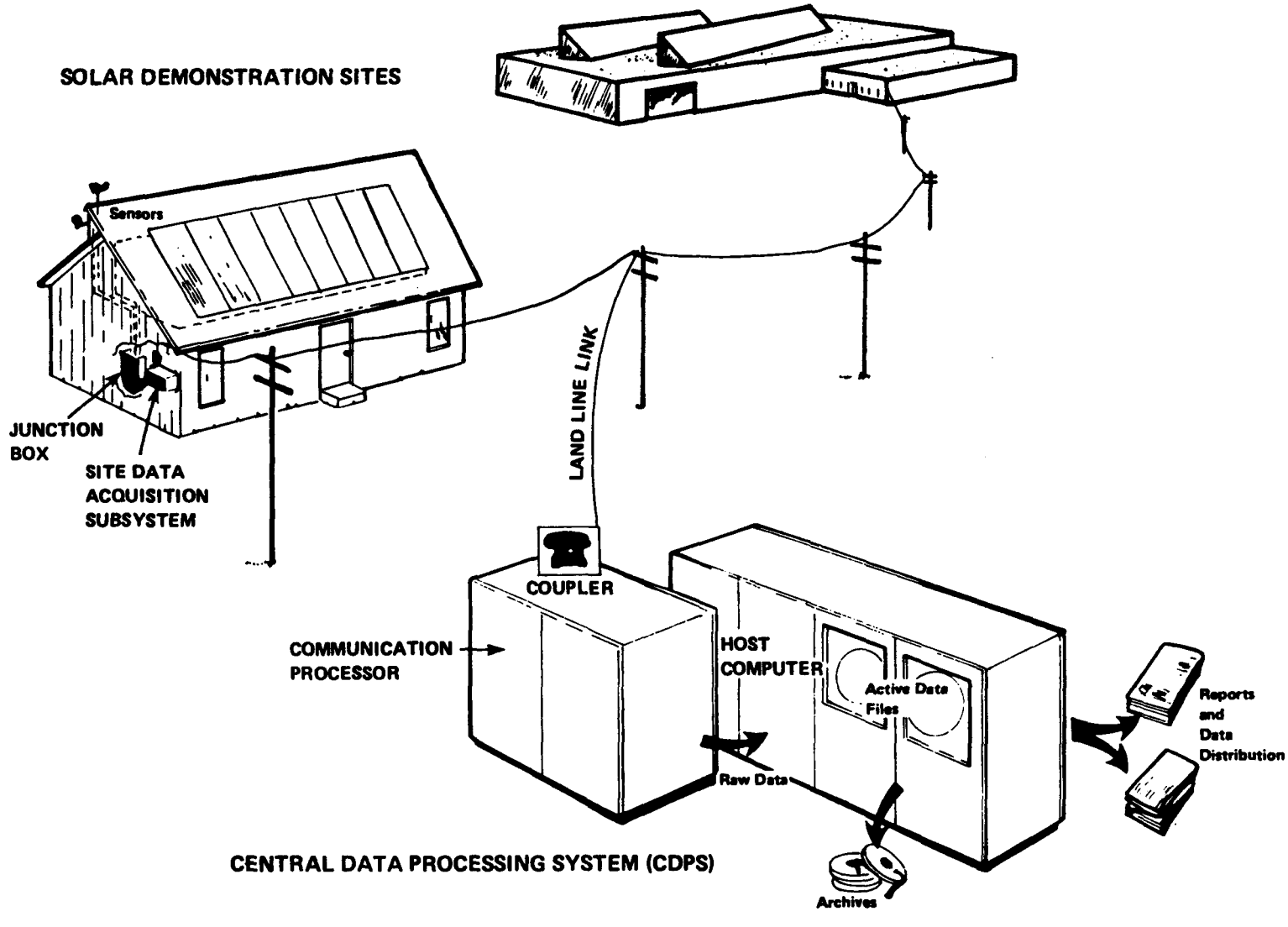


Figure VI-A-1. The National Solar Data Network

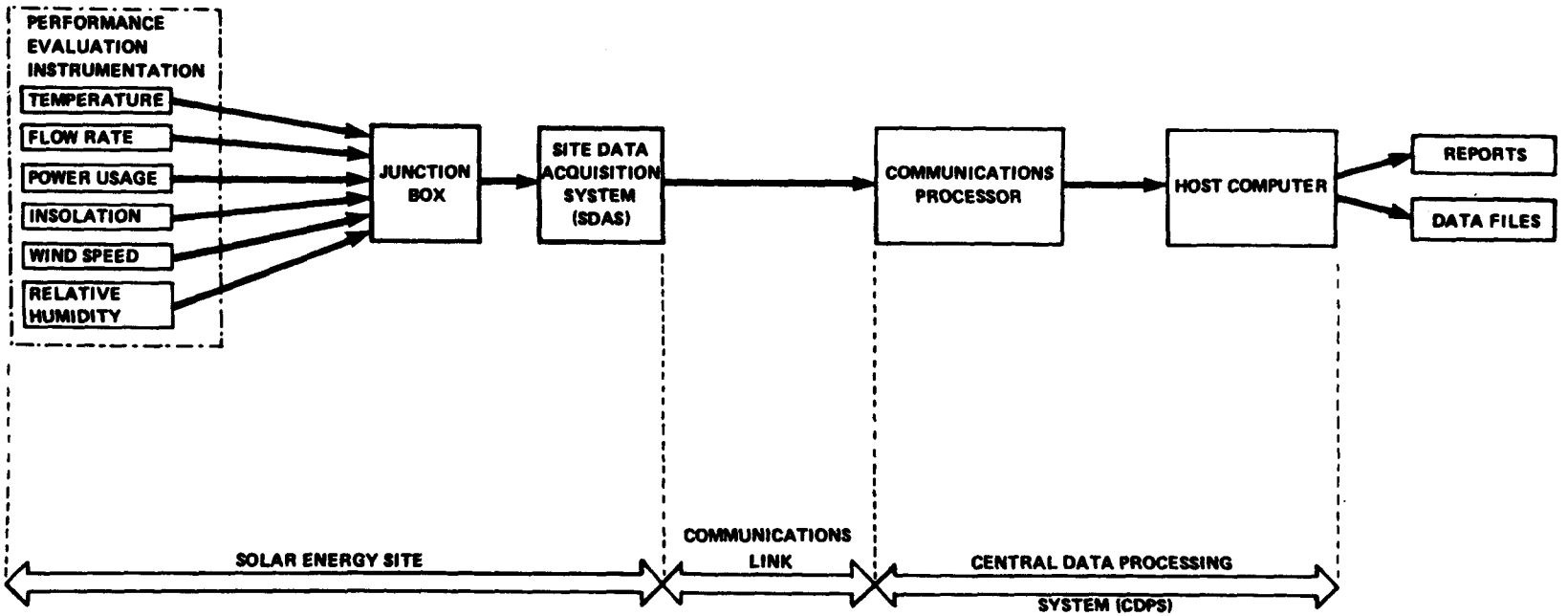


Figure VI-A-2. Data Flow Path for the National Solar Data Network

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 architectrual 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
I002	Insolation, total	Eppley PSP
T001	Temperature, outside ambient	S53P-100
T101	Temperature, solar chimney air	S53P-60
T102	Temperature, solar chimney air	S53P-60
T103	Temperature, solar chimney air	S53P-60
T104	Temperature, solar chimney air	S53P-60
T105	Temperature, solar chimney air	S53P-60
T106	Temperature, solar chimney air	S53P-60
T200	Temperature, solar wall, south side	S53P-28
T210	Temperature, solar wall, south side	S53P-28
T212	Temperature, solar wall, south side	S53P-28
T214	Temperature, solar wall, south side	S53P-28
T202	Temperature, solar wall, south side	S53P-28
T215	Temperature, solar wall, north side	S53P-28
T205	Temperature, solar wall, south side	S53P-28
T201	Temperature, solar wall, south side	S53P-28
T211	Temperature, solar wall, south side	S53P-28
T213	Temperature, solar wall, south side	S53P-28
T216	Temperature, solar wall, south side	S53P-28
T206	Temperature, solar wall, south side	S53P-28
T217	Temperature, solar wall, north side	S53P-28
T209	Temperature, solar wall, south side	S53P-28
T203	Temperature, solar wall, internal	S53P-28
T207	Temperature, solar wall, internal	S53P-28
T204	Temperature, solar wall, internal	S53P-28
T208	Temperature, solar wall, internal	S53P-28
T218	Temperature, return air duct, centerline	S53P-100
T219	Temperature, return air duct, centerline	S53P-100
T220	Temperature, return air duct, centerline	S53P-100
T221	Temperature, return air duct, centerline	S53P-100
D100	Displacement, insulating curtain position, center	RI, 4040-12"
EP400	Electrical power consumption, total, domestic furnace	O-S, PC5-10

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
W400	Air flow, air return duct to domestic furnace	TSI 1610-12"
F400	Fuel consumption, gas furance	Magnicraft W88ACPX-3
TD400L T400	Temperature, domestic furnace return-air duct	S57P-100
TD400H	Temperature, domestic furnace supply-air duct	S57P-100
T107	Temperature, vertical center inside glass panel	S32B
T108	Temperature, vertical center, inside glass panel	S32B
T109	Temperature, vertical center, inside glass panel	S32B
T110	Temperature, vertical center, inside glass panel	S32B
	DOMESTIC WATER SYSTEM	
T300 TD300L	Temperature, incoming cold water supply to solar heated storage tank	S57P-60
TD300H TD301L	Temperature, hot water transfer line to D.H.W. tank	S57P-60
TD301H	Temperature, in DHW supply line	S53P-60
W301	Flow, cold water supply, to solar heated storage tank	Ramapo MK V 3/4", 0.7 to 7 GPM
T600	Temperature, four (4) to six (6) inches below building thermostat	S53P-60

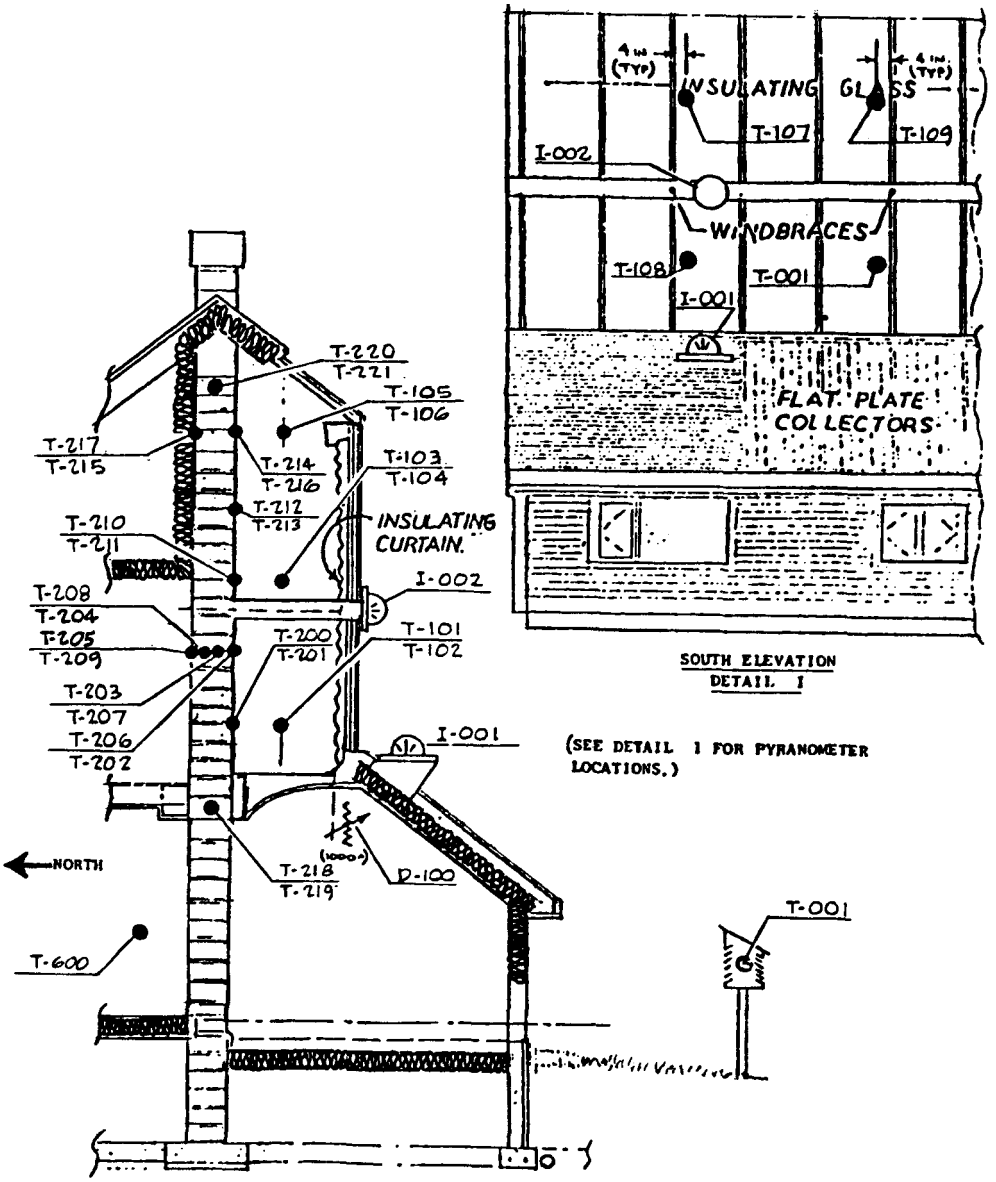


Figure VI-B-1. Space Heating Sensor and Control Diagram

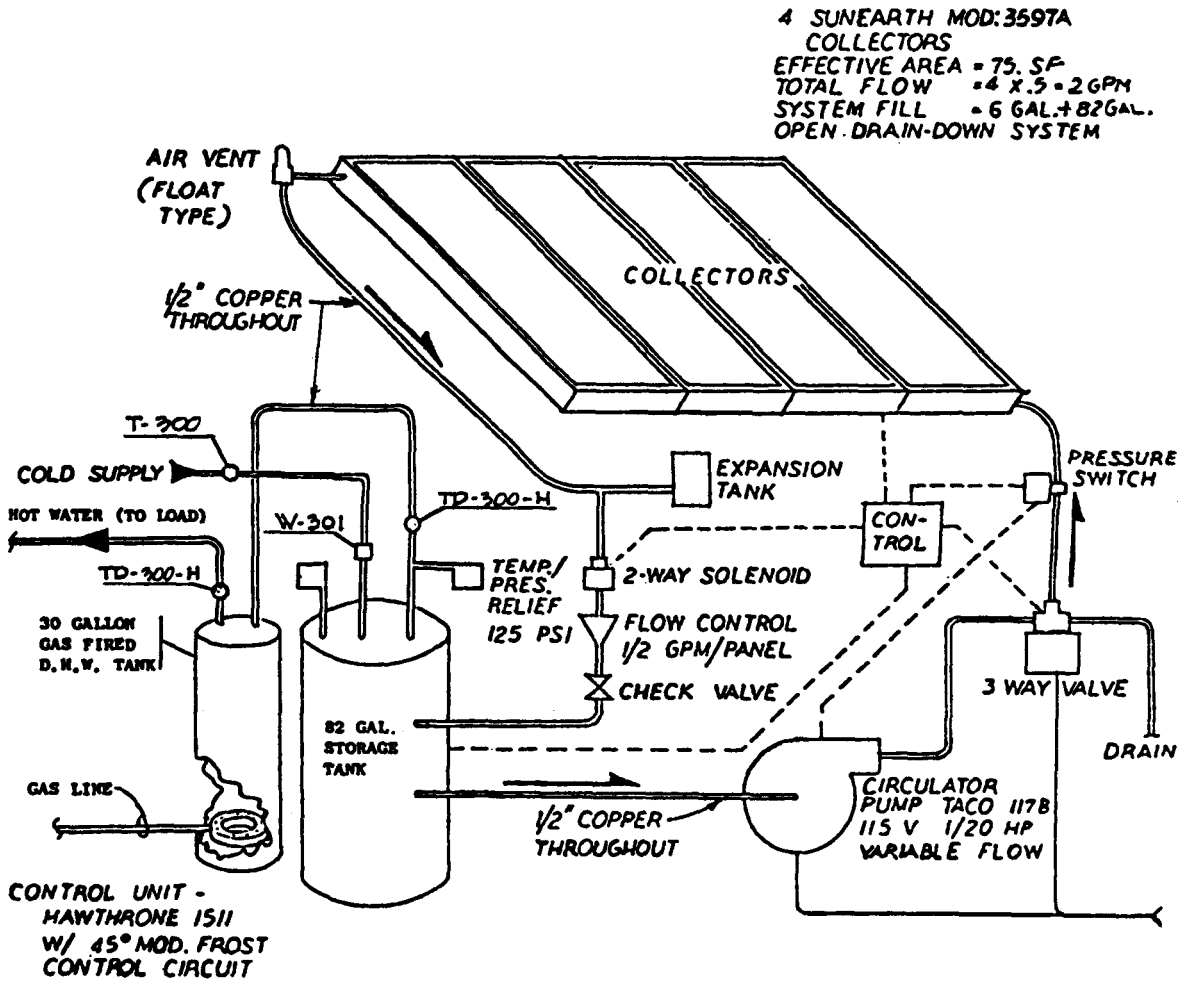


Figure VI-B-2. DHW Sensor and Control Diagram

VII. 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		
	$22,725	$17,238
Total	$	

C. Construction Period: September 1976 through April 1977

VIII. 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.

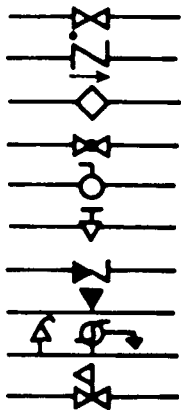
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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.

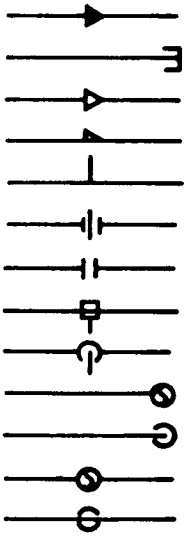
B. Legend For Solar System Schematics

VALVES



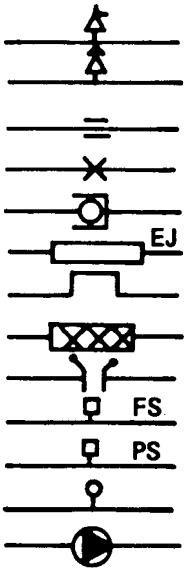
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS

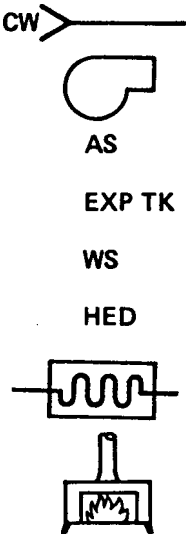


DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

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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