SOLAR/1046-81/50
(DE81029743)

Solar Project Description

LIVING SYSTEMS & JONATHAN HAMMOND SINGLE FAMILY RESIDENCE

Davis, California
August 31, 1981

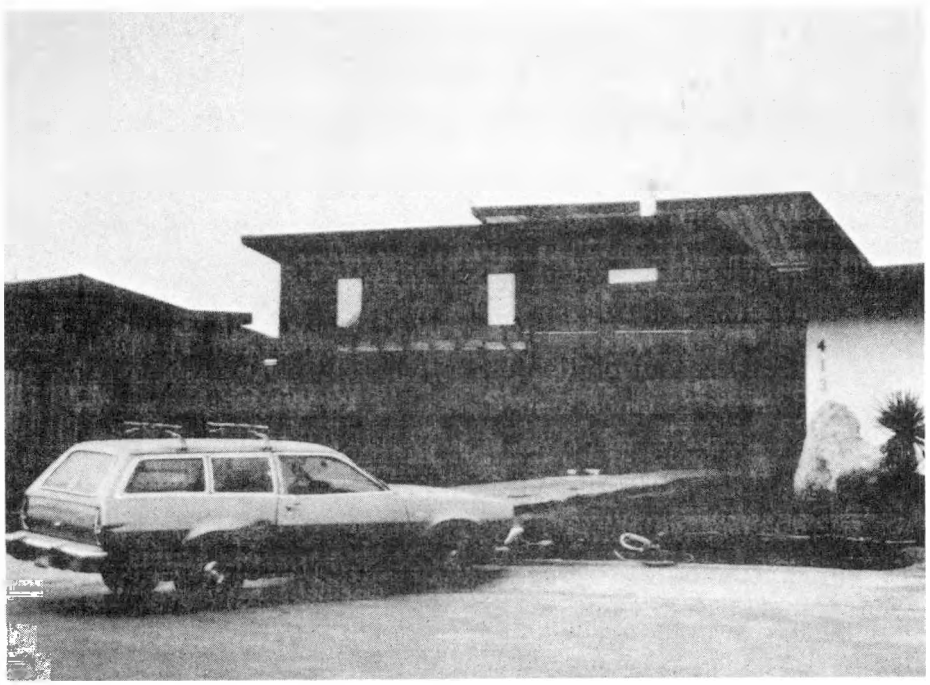
U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1046-81/50
(DE81029743)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
LIVING SYSTEMS
SINGLE FAMILY RESIDENCE - DAVIS, CALIFORNIA



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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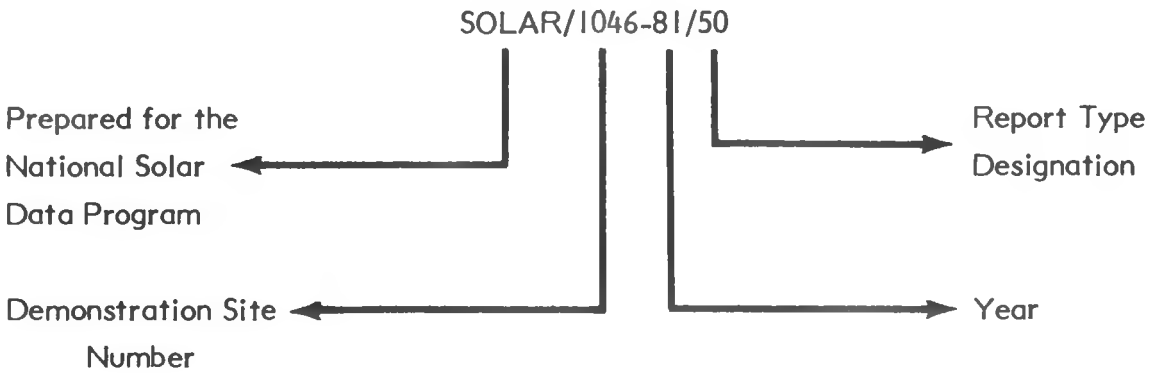
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Living Systems project site is designated as SOLAR/1046-81/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The Living Systems (Grant H-8211) site is a single-family residence in Davis, California. The home is approxmiately 1,700 square feet of conditioned space. The solar energy system consists of two independently controlled systems: a passive system for space heating the home and an active system for preheating domestic-hot-water (DHW).

The dwelling has been fully instrumented for performance evaluation since June 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.

PASSIVE SPACE HEATING SYSTEM

The following are the major solar energy descriptors:

- Collector Type -- Direct gain
- Freeze Protection -- None required
- Application -- Heat
- Storage -- Steel tubes
- New or Retrofit -- New
- Performance Evaluation Instrumentation -- Yes
- Site-Specific Features -- Passive system

The passive solar space heating system is of the direct-gain type illustrated schematically in figure IV-A-1. Incident solar energy is admitted to the building through both the large south-facing vertical windows (approximately 200 square feet) and the overhead skylight (approximately 80 square feet at 60 degrees from the horizontal). Manually-operated insulated curtains provide insulation during the night and sunless days for the south-facing collector windows. Manually-operated insulating shutters also provide reflection on the space below when open. Solar

energy is stored in steel tubes that contain approximately 3,600 gallons of water. The tubes are painted blue and placed near the window wall and under the skylight. Additional storage is provided by the 6-inch-thick concrete slab floor of the building which is covered by brown ceramic tile. Collected solar energy is distributed by natural convection, by conduction through the slab floor, and by radiation. Floor covering is minimal: linoleum in the kitchen and eating area and tan pile rugs in two bedrooms. The building envelope is well insulated in order to ensure energy conservation, with R-19 insulation in the walls and R-30 insulation in the roof. The effective R-values of the windows are in the range of R-2 to R-10 (uncovered and covered with curtains and shutters). All glass surfaces are double-glazed with minimum window area in nonsouth-facing walls. Auxiliary space heating is provided by a wood-burning stove or a gas-fired wall furnace which distributes the energy by natural convection.

The building has summer overheat protection which is provided by several means: Roof overhangs above the south-facing glazed areas provide shading; operable windows in the south wall and a vent in the north wall provide cross-ventilation of the house at night, cooling the solar storage mass and moderating daytime building temperatures; the curtains and shutters over the windows prevent collection of incident solar energy during the day; and a ceiling fan assists the heat distribution and the venting process.

ACTIVE DHW SYSTEM

The following are the major solar energy descriptors:

- Collector Type -- Liquid flat-plate
- Freeze Protection -- Controller system with drain down
- Application -- Domestic hot water
- Storage -- 82-gallon tank
- New or Retrofit -- New
- Performance Evaluation Instrumentation -- Yes

Solar energy is collected by an array of liquid flat plate collectors with a gross area of 53 square feet. The collector banks are mounted on the roof of the house and face due south at an angle of 45 degrees to the horizontal optimizing solar energy collection.

Solar energy is transferred from the collector array to an 82-gallon storage tank. Water is used as the heat collection, transfer, and storage medium. Freeze protection is accomplished by an automatic controller which drains the collectors.

When the water, preheated by solar energy, is not sufficient to satisfy the heat load, a natural gas burner in the DHW tank provides auxiliary energy for water heating.

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

The Living Systems passive solar space heating system provides space heating for a 1,700 square foot single family dwelling. The large south facing window wall and clerestory skylight permit direct winter sun to enter the house. Solar energy thermal storage is provided by both water filled tubes and the concrete slab floor. Movable shutters and insulating curtains provide capability to reduce night heat losses. Summer overheat protection is provided by roof overhangs and by natural ventilation. Auxiliary space heat is provided by a natural gas furnace.

- Building type - Single family dwelling
- Latitude - 38^{o}
- Longitude - 121^{o}
- Altitude - 17 ft

HEATING DESIGN TEMPERATURES

- Outdoor - 32.0^{o} F DB
- Indoor - 68.0^{o} F DB

BUILDING

- Building faces - South
- Average stories above ground - 1
- Average stories below ground - 0
- Height above grade - 18 ft
- Conditioned floor area - 1650 ft^2
- Roof type - Sloped with 14^{o} pitch angle

DESIGN HEAT LOSS/LOAD

- Heat Loss - 30,682.8 Btu/hr
- Heat gain - 12,298 Btu/hr
- Shading
    - Heating season -

- Cooling season -
- Appliance, lighting and equipment load - 600 Btu/hr
- Average horizontal insolation
  - January - 596.9 Btu/ft^2
  - July - 2,688 Btu/ft^2
- Annual degree days
  - Heating - 2,843
  - Data location - Sacramento, California
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

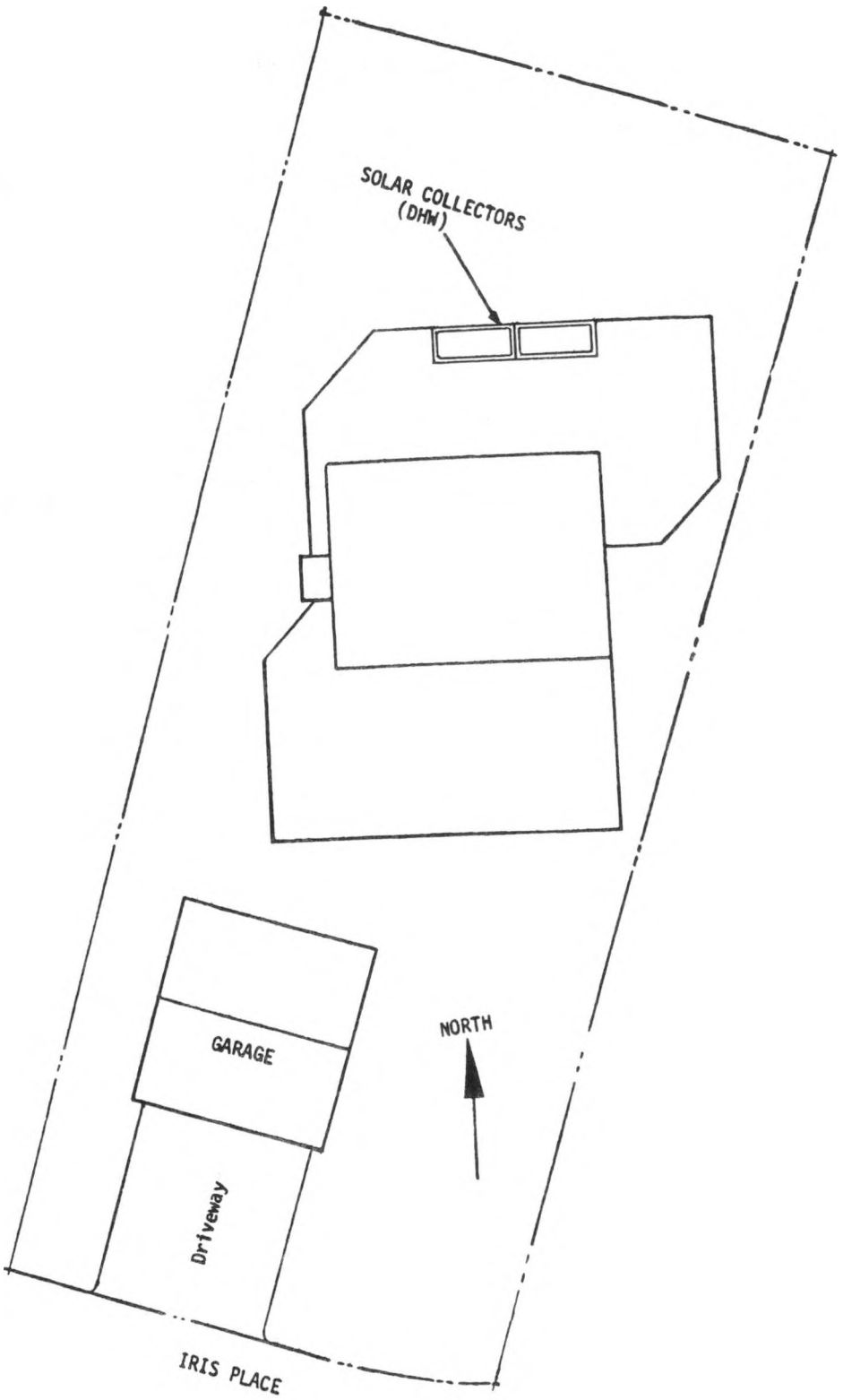


Figure III-1. Site Plan

PASSIVE SPACE HEATING SYSTEM

MECHANICAL SYSTEM

- Heating
  - Solar - Air and radiant passive, window type, directly irradiated storage
  - Auxiliary - Gas-fired wall furnace & wood burning stove
  - Distribution - Natural convection and radiation

GENERAL DATA

- Manufacturer - Site built
- Model name/number - No model number
- Type of system - Air radiant, passive

SYSTEM AND COMPONENT SUMMARY

- Collector types - 2
- Radiant fields - 3
- Thermal storage units - 2
- Operational modes - 3
- Blowers - 1
- Dampers - 3

ACTIVE DHW SYSTEM

The active solar DHW system has an array of flat-plate collectors with a gross area of 53 square feet. The array faces south at an angle of 45 degrees to the horizontal. Potable city water is the transfer medium used throughout the system. In the event of freezing temperatures and no insolation, the controller drains the water from the collectors. When water in the collector is sufficiently warmer than the water in the preheat storage tank, the controller starts the circulation between the preheat tank and the collector. The preheat tank holds 82 gallons of water which is supplied, on demand, to a conventional 20-gallon DHW tank. When the water, preheated by solar energy, is not hot enough to satisfy the hot water load, a natural gas burner in the DHW tank provides auxiliary energy for water heating.

DOMESTIC HOT WATER

- Daily water demand - 40 gal/day
- Solar - Liquid flat-plate
- Auxiliary - Gas-fired DWH

GENERAL DATA - COLLECTOR

- Manufacturer - Natural Heating Systems
- Model name/number - 82 PD
- Type of system - Liquid active

SYSTEM AND COMPONENT SUMMARY

- Collector types - 1
- Circulation loops - 2
- Thermal storage units - 1 (TSU-2)
- Operational modes - 2
- Pumps - 1
- Valves - 10
- Sensors - 3

- Flow regulators - 1
- Pressure regulators - 2
- Fail safe controls - 4

IV. SOLAR SYSTEM DESCRIPTION, PASSIVE SPACE HEATING

A. General Overview (See figure IV-A-1)

This residential solar demonstration project (Living Systems Grant H-8211) located at Davis, California has an air passive solar energy system utilized for space heating, and an active solar domestic hot water system. Auxiliary space heating is provided by a gas-fired wall furnace and a wood-burning stove.

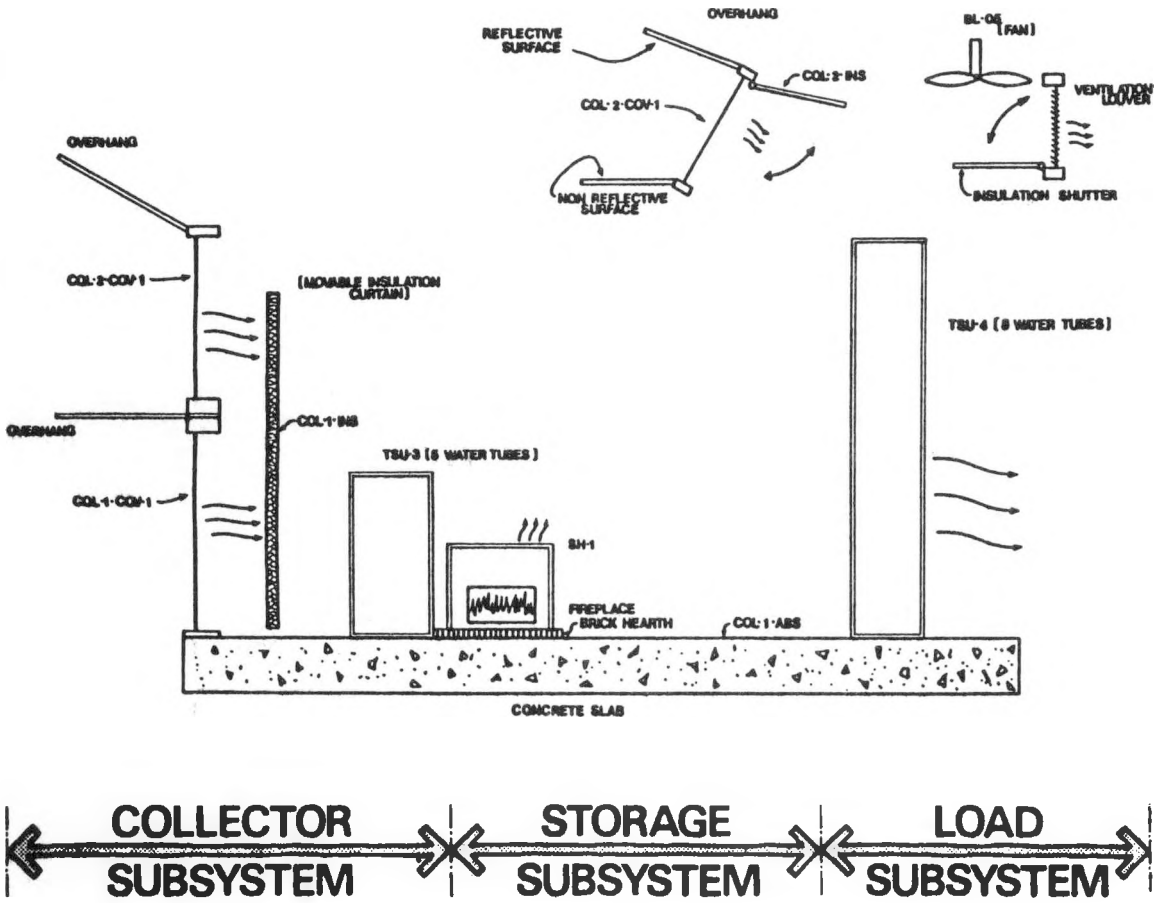


Figure IV-A-1. General Overview

Subsequent sections describe solar energy collection, storage, energy-to-load, and auxiliary subsystems. Specific details of the operating modes and controls are described in the final section.

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

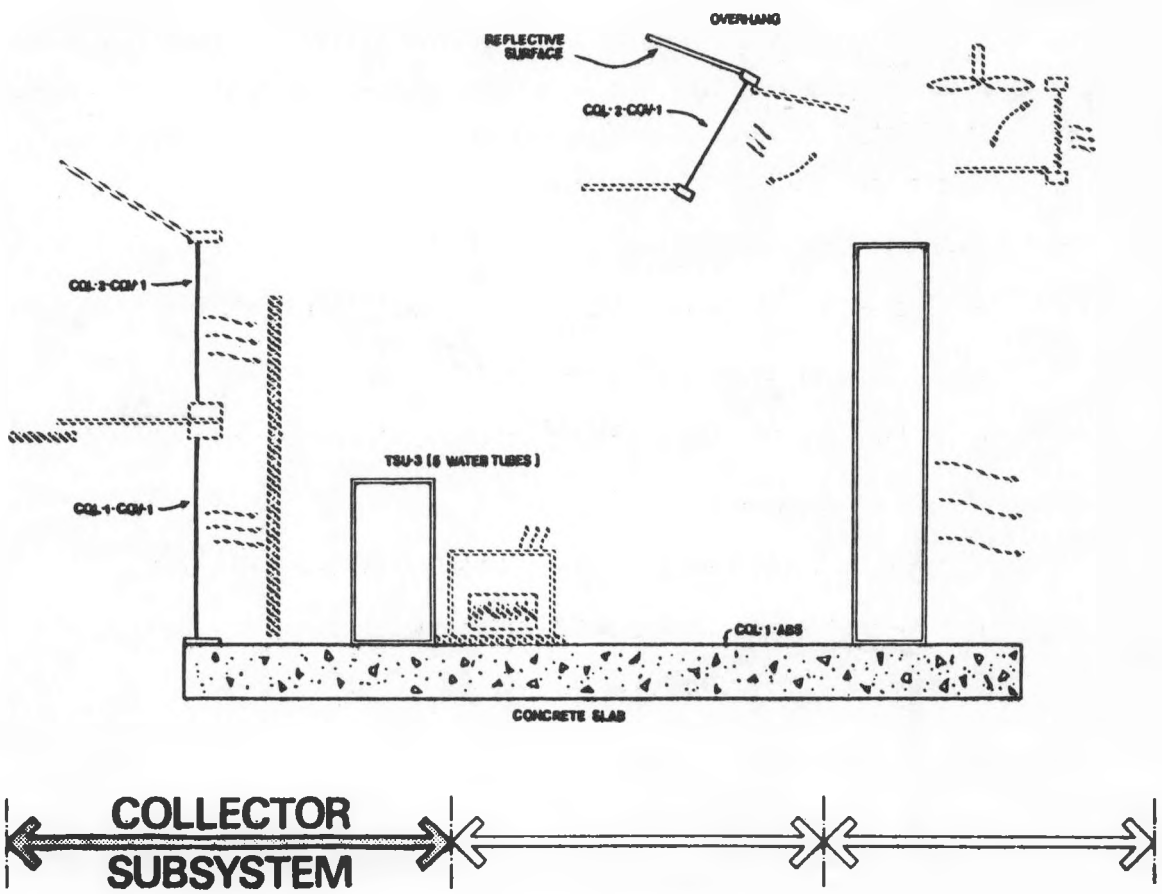


Figure IV-B-1. Collector Subsystem, Passive

Collector array system consists of large double paned windows on the south side and water filled tubes that receive short wave radiant energy from the sun. Radiant energy is also absorbed by the 6-inch thick concrete slab floor.

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

- Manufacturer - Site built
- Model name/number - None
- Type - Glass windows, water tubes
- Location - Windows and inside rooms
- Orientation - 0^{o} East of South
- Tilt angle - 90^{o} from horizontal
- Collector characteristics
  - Number of panels - (No panels as such, "window") 1
  - Total gross area of array - 50 ft^2
  - Net aperture area - 50 ft^2 (opening of window onto water tubes)
  - Net absorber area - 55 ft^2
  - Weight of filled array and support structure - 4012 lbs
  - Panel length - (window) 72.0 inches
  - Panel width - (window) 96.0 inches
  - Frame depth - 5.5 inches
  - Standoff height - 0
- Collector shading - Absorber (water tube surface) shaded
  - Area shaded in June 21 - 100% between 10 am and 2 pm, solar time-
  - Area shaded in December 21 - 35% between 10 am and 2 pm solar time
  - Maximum shade during functional season - 35% of aperature
  - Method of determining shaded area - Sun angles plotted on plan and section by DIM Sun angle data interpolated from tables 3 & 4 for 38^{o} N Latitude from Chapter 22 ASHRAE Handbook of Fundamentals. (See figure V-B-3)
  - Cause of shading - Building

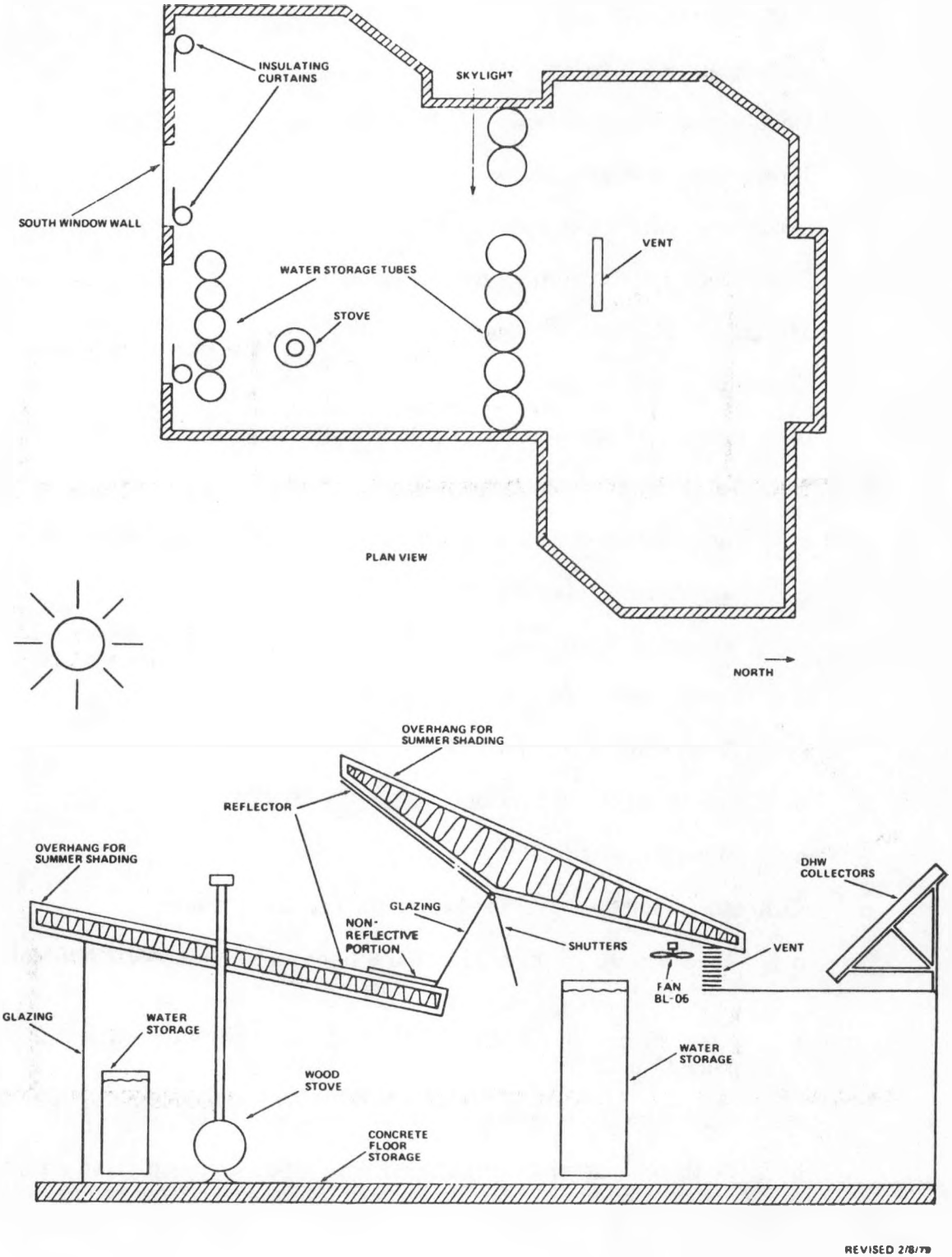
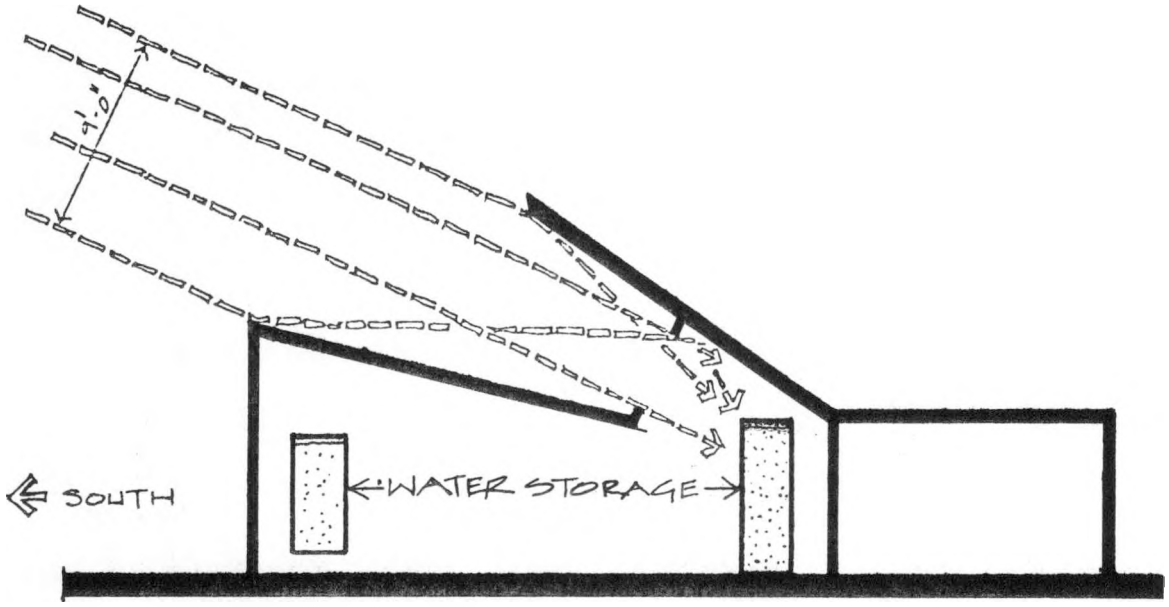
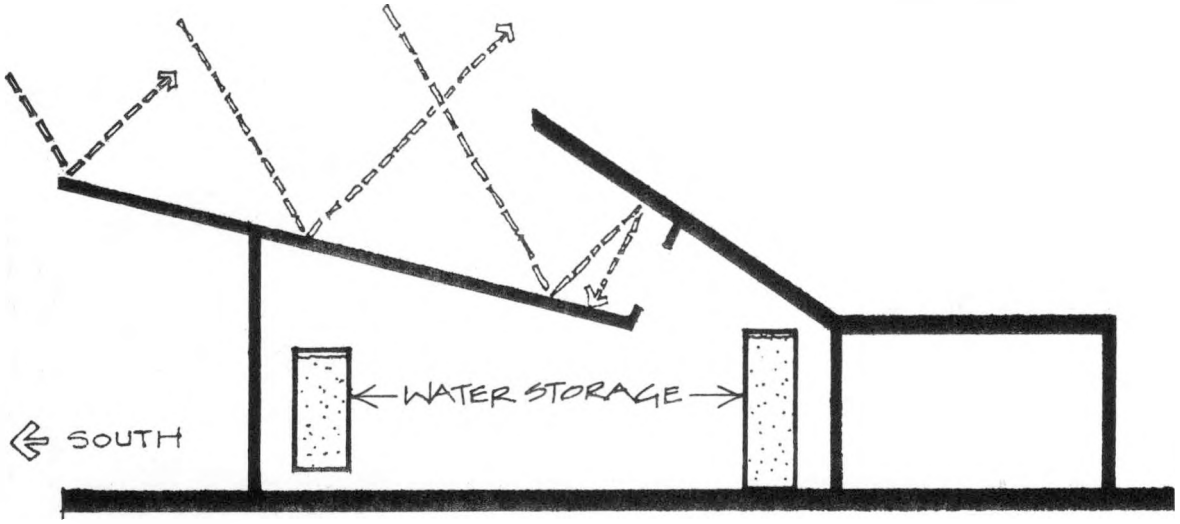


Figure IV-B-2. Solar Collector System, Passive



DECEMBER 21, 12:00 - 26° SUN ANGLE

WINTER RADIANT GAINS CAN BE APPROXIMATELY DOUBLED THROUGH THE "SUNCATCHER" SCOOP BY THE USE OF REFLECTIVE SURFACES ON THE ROOF BELOW AND THE EAVE ABOVE THE WINDOW. THE WINDOW IS SHUTTERED TO PREVENT NIGHT HEAT LOSS.



AUGUST 21, 12:00 - 62° SUN ANGLE

SUMMER HEAT GAINS ARE MINIMIZED. THE OVERHANG SHADES THE WINDOW FROM DIRECT SOLAR RADIATION, AND THE GEOMETRY OF THE "SUNCATCHER" PREVENTS SUNLIGHT REFLECTED OFF OF THE ROOF FROM ENTERING THE WINDOWS. IN ADDITION, THE WINDOW IS SHUTTERED TO REDUCE CONDUCTED HEAT GAIN.

Figure IV-B-3. Sun Angles

- Cover plates
  - Number of cover plates - 1
- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer - Blomberg
  - Product name/number - HP 680 double pane glass
  - Material - Glass, normal iron content
- Absorber - 5 water tubes
  - Manufacturer - Armco
  - Model name/number - Helcor copper/steel culvert
  - Material - Copper/steel
  - Substrate material dimension
    - Thickness - 0.062 inch
    - Length - 42 inches
    - Width - 37.5 inches
  - Number of absorbers per collector - 5 (tubes)
- Coating
  - Manufacturer - Dunn-Edwards
  - Model name/number - Decovel velvet flat W/401 series
  - Coating material - Medium value blue flat paint
  - Method of application - Painted
- Absorber
  - 6-inch concrete slab covered by ceramic brown tiles

COLLECTOR (COL-2) (SEE FIGURE IV-B-1 and 2)

- Manufacturer - Site built
- Type - Glass windows and water tubes
- Location - Windows and inside rooms
- Orientation - 0^{o} East of South
- Tilt angle - 60^{o} from horizontal
- Collector characteristics
  - Number of panels - (no panels as such, "window") 1
  - Total gross area - 88 ft^2
  - Net aperture area - 88 ft^2 (opening of window onto water tubes)
  - Net absorber area - 314 ft^2 including water tubes
  - Length - 42 inches
  - Width - 300 inches
  - Frame - 5.5 inches
- Collector shading - Absorber (water tube surface) shaded
  - Area shaded June 21 between 10 am to 2 pm solar time - 100%
  - Area shaded Dec 21 between 10 am and 2 pm solar time - 66%
  - Method of determining shaded area - Refer to COL-1 and Figure IV-B-3

    NOTE: Aluminum reflecting surface on suffit in front of window will reflect sun on tubes. At times mentioned above, reflected radiation will strike approximately that portion of the tube being directly irradiated.
  - Cause of shading - Building itself

- Cover plates
  - Number of cover plates - 1
  - Location - Outer layer
  - Manufacturer - Blomberg
  - Product name/number - HP 680 double pane glass
  - Material - Glass, tempered
- Absorber - 8 water tubes
  - Manufacturer - Armco
  - Model name/number - Helcor copper/steel culvert
  - Material - Copper/steel
  - Substrate material dimensions
    - Thickness - 0.062 inch
    - Length - 120.0 inches
    - Width - 47 inches
  - Number of absorbers per collector - 8 (tubes)
- Coating
  - Manufacturer - Dunn-Edwards
  - Model name/number - Decovel velvet flat W401 series
  - Material - Medium value blue
  - Method of application - Painted
- Absorber
  - 6-inch concrete slab covered by ceramic brown tile
- Reflectors
  - Manufacturer - Western Metal Building Products
  - Model name/number - Aluminum roofing (on soffit)
  - Number of reflectors - 2
  - Substrate material - Wood

- Substrate material dimensions
  - Length - 300 inches
  - Width - 84 inches
- Concentration factor - 1.4
- Desiccant - No
- Freeze protection - Drainage
- Overheating protection - Cross vent from windows
- Other - Shutters and overhang

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

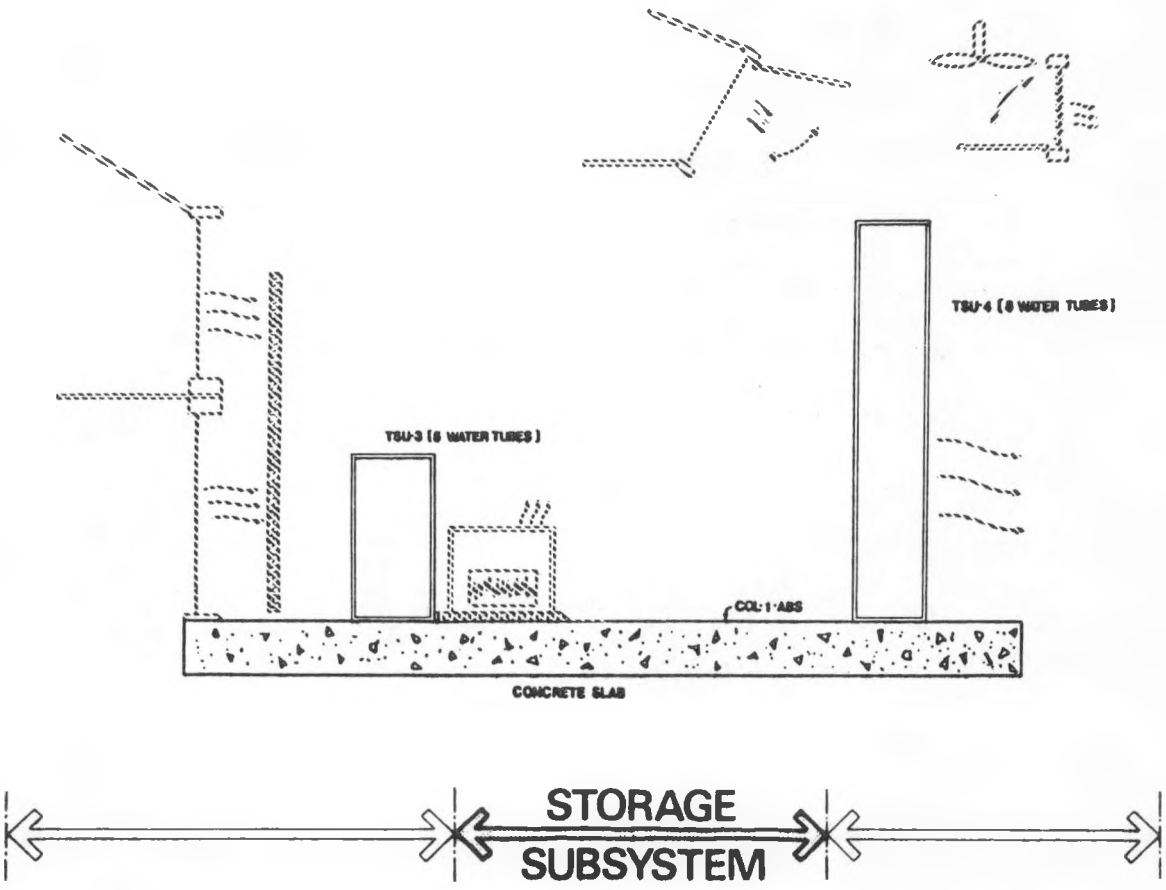


Figure IV-C-1. Storage Subsystem, Passive

Solar energy storage is provided by steel tubes containing approximately 3,600 gallons of water. The tubes are painted blue and placed near the south window wall and under the skylight. Additional storage is provided by the 6-inch-thick concrete slab floor covered by ceramic brown tiles.

THERMAL STORAGE UNIT (TSU-3)

- Manufacturer - Armco
- Model name/number - Helcor Spiral Weld Culvert/Water tubes (5 ea)
- Total storage container volume - 55 ft^3 (ea tube)
- Volume of storage medium - 55 ft^3 (ea tube)
  - Length - 10 ft (wall length)
  - Width - 2 ft (wall length)
  - Height - 3.5 ft
  - Diameter - 2.0 ft
- Maximum rated operating conditions - Not rated
- Storage medium
  - Design operating temperatures
    - Heating - 75° F Max; 65° F Min
    - Cooling - 79° F Max; 70° Min
  - 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 - Non potable
- Inhibitor - No
- Container construction
  - Manufacturer - Armco
  - Model name/number - Water Tubes (5 ea)
  - Type - Water Tube, metal galvanized, copper/steel
  - Interior lining - None

- Location - In room
- Auxiliary heaters - No
- Insulation - None
- Exterior finish - Paint, flat (Decovel)
- Filters - No
- Getters - No

THERMAL STORAGE UNIT (TSU-4)

- Manufacturer - Armco
- Model name/number - Helcor Spiral Weld Culvert (8 tubes)
- Total storage container volume - 39.2 ft^3 each tube
- Volume of storage medium - 39.2 ft^3 each tube
- Length - (wall length) - 20 ft
- Height - 10 ft
- Diameter - 2.5 ft
- Storage medium
  - Design operating temperatures
    - Heating - 75° F Max; 65° F Min
    - Cooling - 79° F Max; 70° F Min
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^2
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freeze point - 32° F
  - Toxicity - Non potable

- Container construction
  - Manufacturer - Armco
  - Model name/number - Water tube, metal, galvanized, copper/steel
  - Interior lining - None
  - Location - In room
  - Auxiliary heaters - No
  - Insulation - None
  - Exterior - Paint, flat (Decovel)

CONCRETE SLAB

- Details
  - 6-inch thick
  - Covered by brown ceramic tile

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

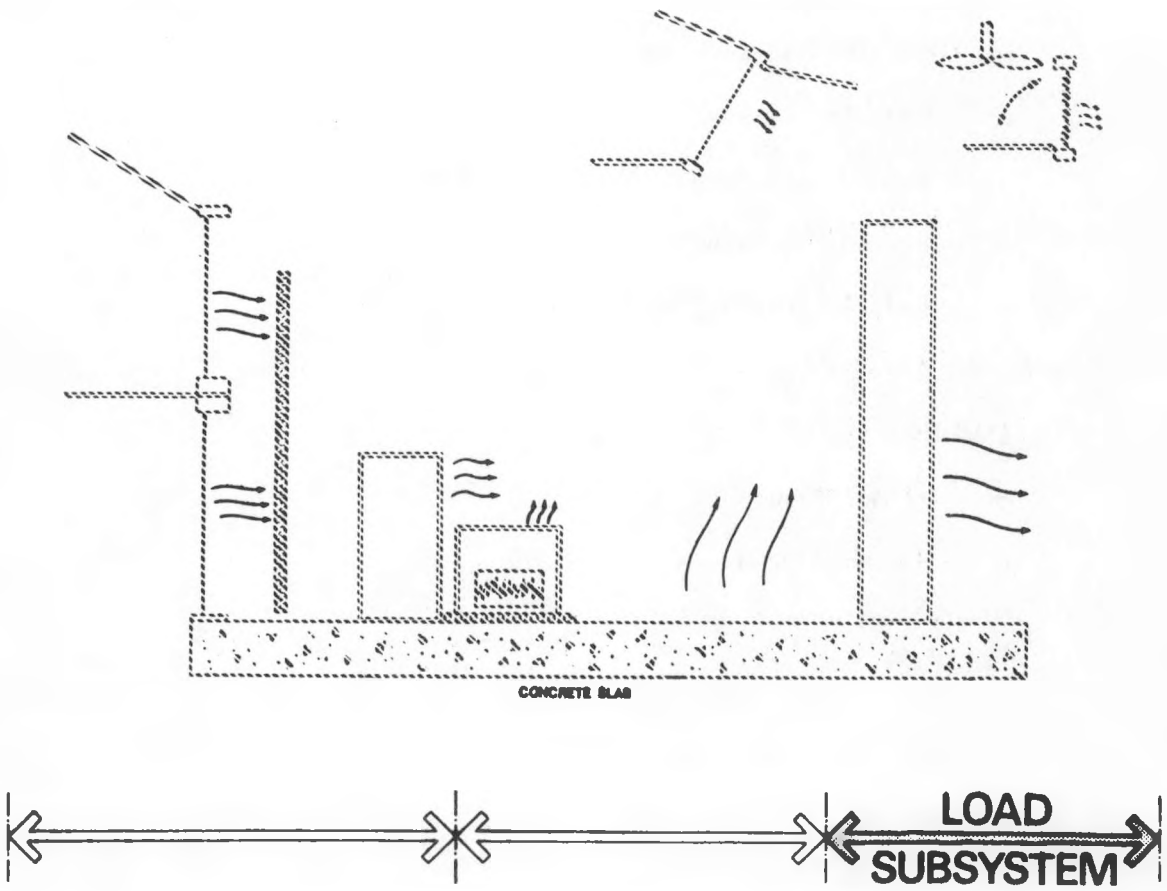


Figure IV-D-1. Energy-to-Load Subsystem, Passive

Solar energy is radiated through windows and in part is stored in the water tubes (approximately 1,300 gallons of water) and the concrete slab floor which in turn helps to meet the space heating demands by natural convection in the building. Insulated curtains and shutters prevent loss of radiant energy during cloudy periods and at night. Auxiliary space heating, supplementing this source, is provided by a wall heater and wood burning stove.

Space cooling is provided by cross ventilation and BL-5.

RADIANT FIELD - 1 (RADIATION CHARGE)

- Components within radiant field
  - Sunlight Collector(s) - COL-1, COL-2
  - Thermal storage unit(s) - TSU-3, TSU-4
  - Concrete floor
  - Other -
    - Articles exposed to sunlight
  - Location - Above grade

RADIANT FIELD - 2 (RADIATION DISCHARGE)

- Components within radiant field
  - Thermal storage unit(s) - TSU-3, TSU-4
  - Concrete floor
  - Others
    - Articles exposed to sunlight

INSULATION - (cloudy periods or night)

- Insulation, curtains
  - Layer one - sides
    - Manufacturer - Site built
    - Product name/number - Insulated curtains
    - Material - 2-ply polyester
    - Thermal resistance - R-4
  - Desiccant - No
  - Overheating protection - Cross vent from windows
  - Other - Overhand and curtain
- Insulation, shutters
  - Layer one - Overglass
  - Product name/number - Insulated shutters on windows

- Material - Polyurethene, CO_2 blown
- Thermal resistance - R-7

- Frame - For insulated shutters
  - Manufacturer - Site built
  - Product name/number - Wood
  - Material - Douglas Fir
  - Protective coating - None

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

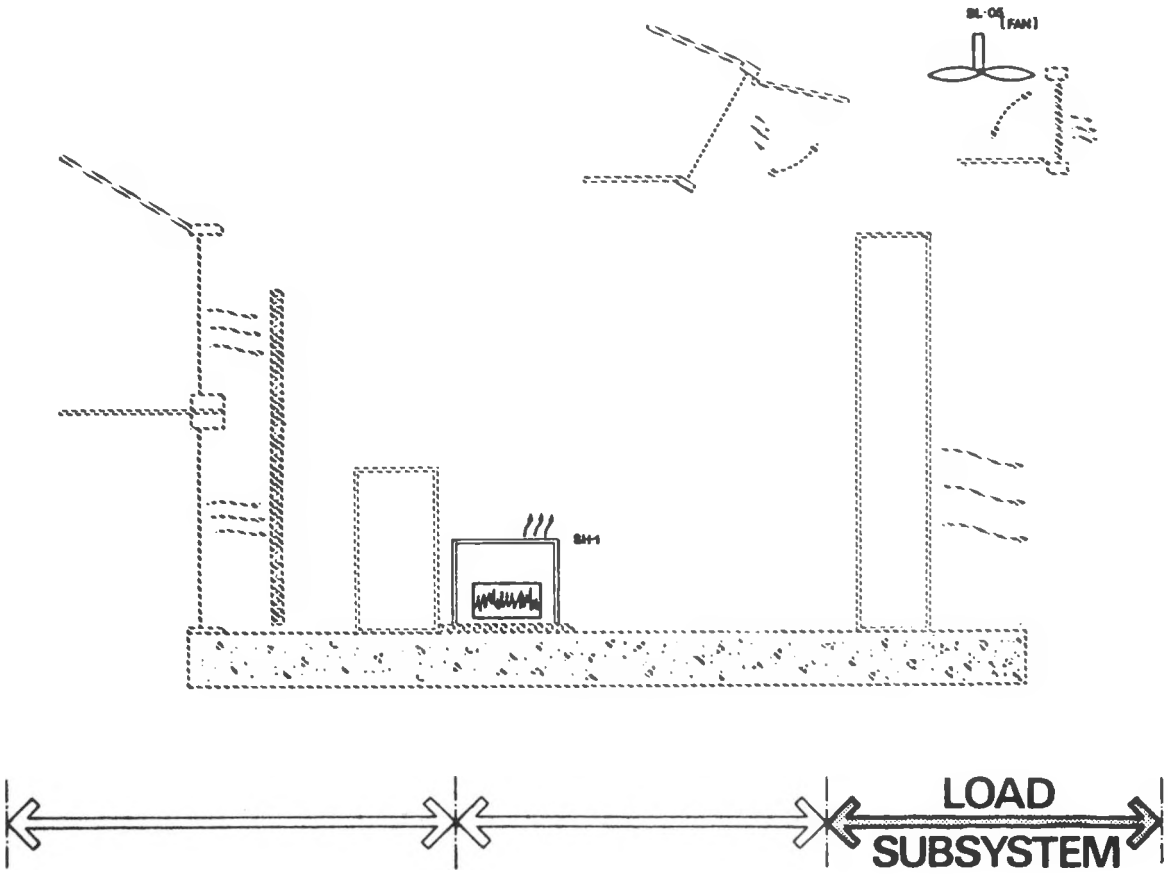


Figure IV-E-1. Auxiliary-to-Load Subsystem, Passive

The auxiliary subsystems including the furnace and a fan (BL-5) and Wood stove (SH-1), mentioned in the foregoing Energy to Load Subsystem, have been grouped in this section for descriptive purposes, their function and purpose have been previously described.

AUXILIARY SUBSYSTEMS

- Components
  - Furnace
  - Blower - BL-5
  - Wood stove - SH-1
- Furnace
  - Manufacturer - Westwood
  - Model name/number - B50D (2)
  - Energy source - Natural gas
  - Energy input - 50,000 Btu/hr
  - Energy output - 35,000 Btu/hr
  - Burner ignition method - Gas pilot, on continuously
  - Flue vent - Automatic
- Distribution Blower (BL-5)
  - Manufacturer - Emerson/Grainger
  - Model name/number - CF363L Ceiling Fan (4C353 Grainger stock number)
    - Type - Ceiling Fan, 36" dia. horizontal
    - Motor size - 0.11 hp; 120 V; 1 Phase; 60 Hz
    - Maximum motor speed - 330 rpm
    - Drive - Direct
    - Speed - Multiple (2 speed)
  - Design conditions at low speed
    - Impeller speed - 235 rpm

	Low Static Mode
- Circulating volume	2848 cfm
- External static pressure	None (free air operation)
- Motor operation	0.11 bhp

- Design conditions at high speed
  - Impeller speed - 330 rpm

	Low Static Speed
- Circulating volume	4000 cfm
- External pressure	None (free air operation)
- Motor operation	0.11 bhp

- Supplementary Heater (SH-1)
  - Manufacturer - Living Systems
  - Product name/number - "Black Body" stove
  - Energy source - Wood
  - Description - Spherical fireplace, 30,000 Btu/hr output

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

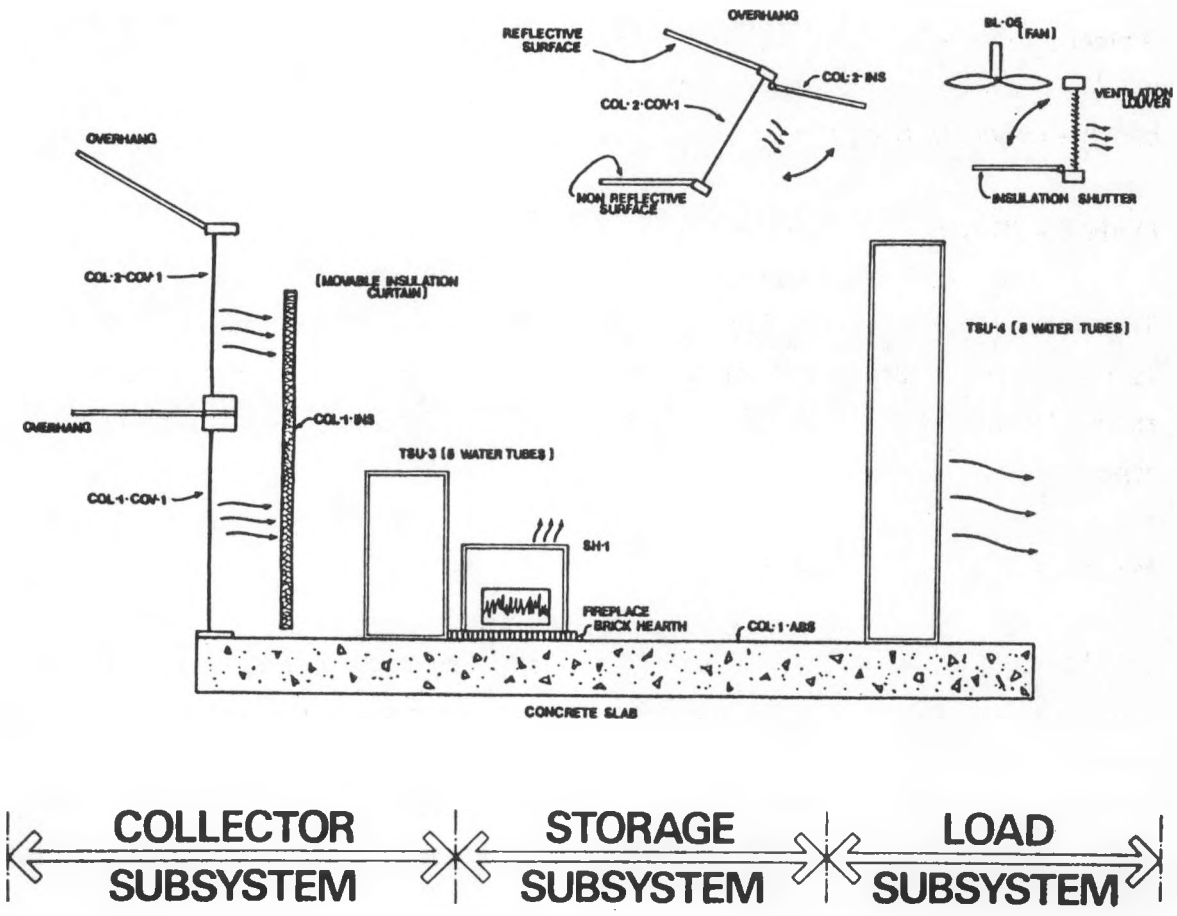


Figure IV-F-1. Controls Diagram, Passive

The Living Systems solar project controls include drapes, shutters, and operable windows shown in figure IV-F-1. The system consists of the following four subsystems: a) Collector, b) storage, c) load (heating) and d) auxiliary loads subsystems.

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

Mode 1 - Collector-to-Storage

Incident solar energy "direct gain type" is admitted through both large south facing windows and an overhead skylight. The energy is transferred to the water tubes and the concrete floor for storage.

Mode 2 - Storage-to-Space Heating

The water tubes, concrete floor and other items exposed to sunlight radiate energy to the heating space and heat by natural convection. As required, warm air is recirculated by the BL-05 fan. Additional heat may be provided as required by the supplementary heater (SH-1); or the main furnace.

Mode 3 - Over Heat Protection

The BL-05 fan, although it does not actually lower air temperature, provides a cooling effect by circulating room air causing air motion around a human body. The roof overhangs (on all south glass) as well as insulated drapes (COL-1-INS) and shutters block direct solar radiation into the house. Cross ventialtion is accomplished by operation of (COL-1-INS) insulating window drapes and the insulating shutter over the north louvers.

V. SOLAR SYSTEM DESCRIPTION, ACTIVE DHW

A. General Overview

This residential solar demonstration project (Living Systems Grant H-8211) located at Davis, California is a liquid active system utilized for domestic hot water. The DWH is gas-fired for auxiliary energy.

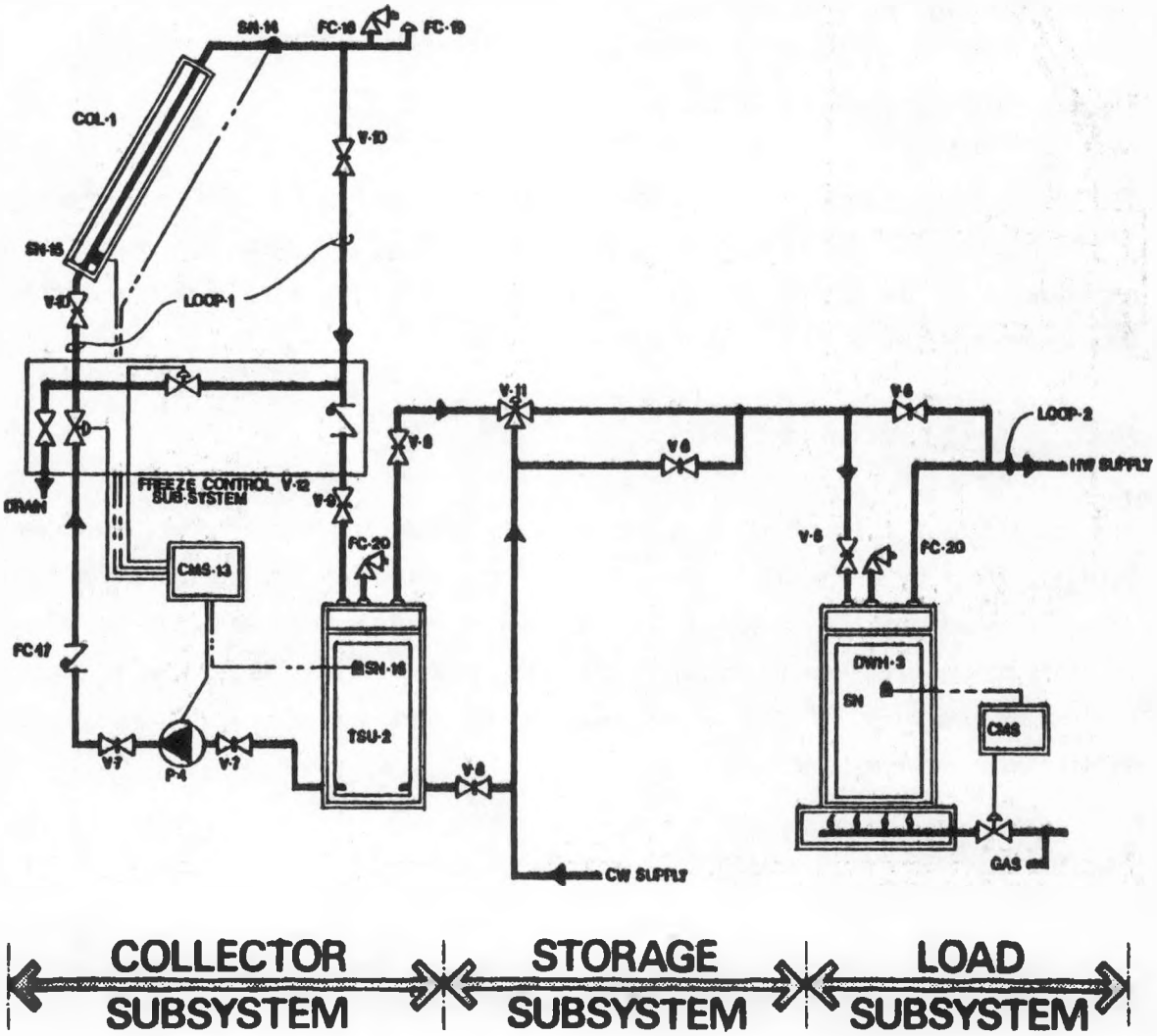


Figure V-A-1. General Overview, Active

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

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

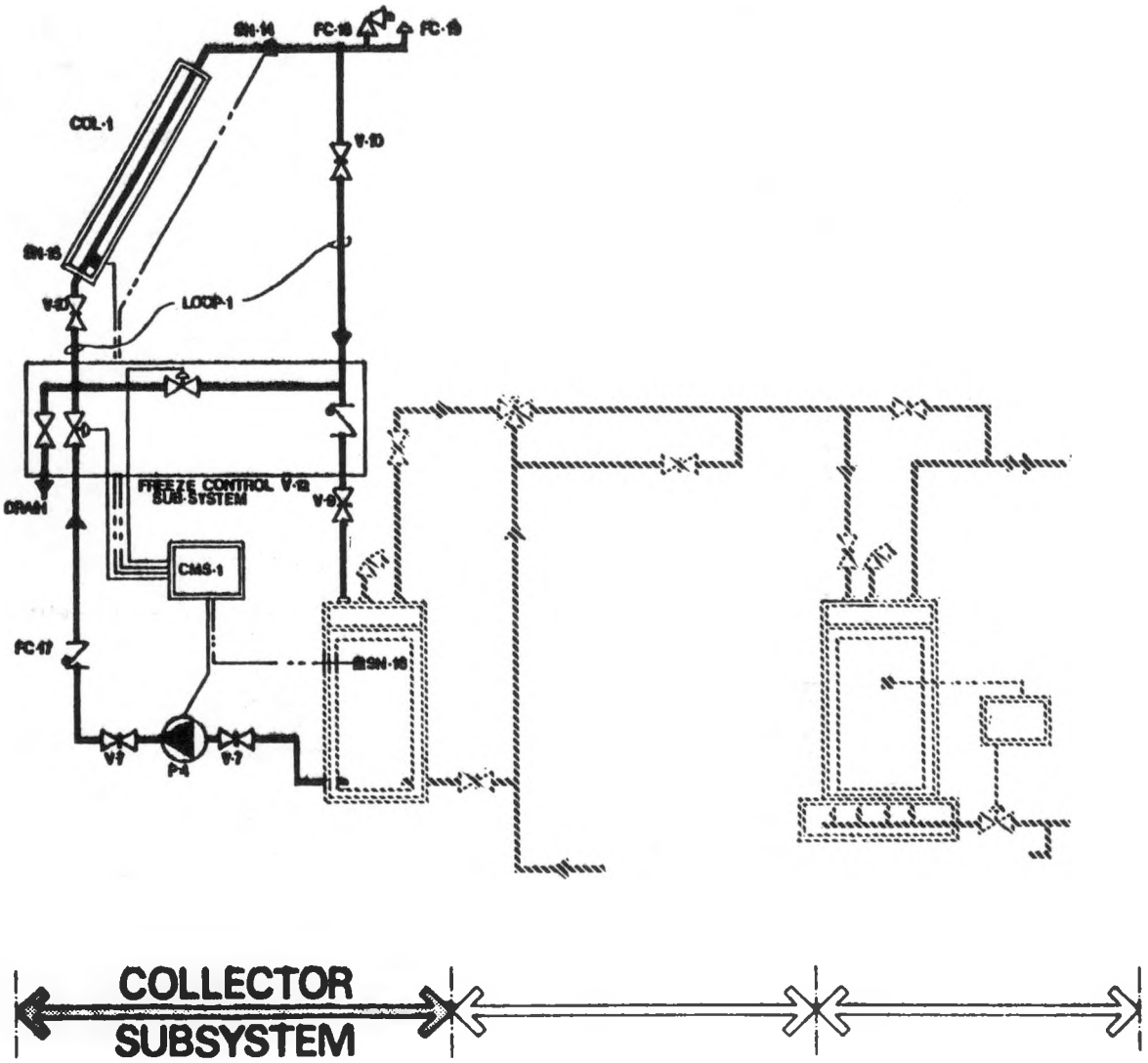


Figure V-B-1. Collector Subsystem, Active

Collector array system consists of two liquid flat-plate collector panels. Freeze protection is provided by a freeze-control subsystem and drain down.

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

- Manufacturer - Sunburst Collector
- Model name/number - All copper (No model number)
- Type - Liquid flat-plate tube & plate
- Location - Roof
- Orientation - 0^{o} East of South
- Tilt angle - 45^{o} from horizontal
- Collector characteristics
  - Number of panels - 2
  - Total gross area of array - 53 ft^2
  - Net aperture area - 37 ft^2
  - Net absorber area - 37 ft^2
  - Weight per panel, empty - 185 lb
  - Weight per panel, full - 196 lb
  - Weight of filled array and support structure - 392 lb
  - Panel length - 121 inches
  - Panel width - 22.02 inches
  - Frame depth - 5.5 inches
  - Standoff height - 34 inches
- 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 - 1

Illustration Unavailable

Figure V-B-2. Solar Collector, Active

- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer - Blomberg
  - Product name/number - 3/16 inch tempered
  - Material - Glass, tempered
  - Thickness - 0.187 inch
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	86%	
- Reflectance -		
- Emittance -		

  - Edge or surface treatment, other than coating - None
  - Coating on cover plate material - None
- Absorber
  - Manufacturer - Natural Heating Systems
  - Model name/number - Site Built
  - Material - Copper
  - Substrate material dimension
    - Thickness - 0.007 inch
    - Length - 121.0 inches
    - Width - 22.2 inches
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - Hughson Chemical Corp
  - Model name/number - Chemglaze Z306
  - Coating material - Flat black paint with Polyurethene

	(solar region)	(infrared region)
o Absorptance -	No information available	
o Reflectance -	No information available	
o Emittance -	No information available	

- o Heat transfer fluid passages
  - o Location - On absorber
  - o Pattern - Parallel
  - o Materials - Copper
  - o Protective coating inside fluid passage - None
- o Insulation - None
  - o Layer one - back
    - Manufacturer - Owens-Corning
    - Product name/number - Batts
    - Material - Glass fiber
    - Thermal resistance - R-19
- o Gaskets and sealants
  - o Inner cover - Silicone
- o Frame
  - o Manufacturer - Site built
  - o Product name/number - None
  - o Material - Wood
  - o Protective coating - Stain
  - o Standoffs used - Yes
  - o Number of structure attach points per module to building - Continuous

- Reflectors - None
    - Desiccant - No
    - Freeze protection - Drain down
    - Overheating protection - Temperature & pressure valves on tanks
- Collector performance - No testing accomplished

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

- Maximum design operating temperature - 210° F
- Maximum design operating pressure - 150 psi
- Heating design liquid flow - 4.0 gpm
- Pump speed - 2620 gpm
- Heat transfer medium:
    - Volume of liquid in loop - 106.4 gal
    - Anticipated liquid temperatures - Maximum 180° F; Minimum 50° F
    - Provisions for expansion - No
    - 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
    - Maximum recommended use temperature - 150° F
    - Toxicity - Potable
    - pH factor - 7
    - Chemical feeder to maintain pH factor - No
    - Inhibitor - No

- Components within circulation loop
  - Pump(s) - 1 (P-4)
  - Thermal storage unit(s) - TSU-2
  - Collector(s) - COL-1
  - Valve(s) - V-7, V-9, V-10, V-12
- Piping
  - Rigid - Copper, type M
  - Piping insulation - Polyurethane
  - Location - Above grade
- Circulator pump (P-4)
  - Manufacturer - Grundfos
  - Model name/number - UP 25-42 SF W/Isol valves
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 150 psi
    - Dynamic pressure - 5 psi
    - Temperature - 210° F
  - Material exposed to heat transfer fluid - Type 316 Stainless steel
  - Motor size - 0.05 HP; 115 V; 1 Phase; 60 Hz
  - Maximum motor speed - 2620 rpm
  - Drive - Direct
  - Speed - Multiple (2 speed)
  - Circulating volume, Low head mode - 4.0 gpm
  - Operating head (dynamic), Low head mode - 4.98 psi
  - Motor operation - 0.05 bhp

- Distribution Valve (V-7)
  - Manufacturer - Norca
  - Model name/number - Gate
  - Function - Isolation
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Bronze
- Distribution Valve (V-9)
  - Manufacturer - Alps
  - Model name/number - Gate
  - Function - Isolation
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid - Bronze
- Distribution Valve (V-10)
  - Manufacturer - WOG
  - Model name/number - Gate
  - Function - Flow switching
  - Operation - Manual
  - Type - Gate
- Distribution Valve (V-12)
  - Manufacturer - Richdel
  - Model name/number - R797
  - Function - Drain/shut-off isolation
  - Operation - Automatic, motorized

- Type - Ball and diaphram
- Pressure - 100 psi
- Temperature - 200° F
- Materials exposed to heat transfer fluid - Glass filled polysulfone

Control Mode Selector (CMS-13)

- Manufacturer - Helithope General
- Model name/number - DTT-690
- Modes controlled
  - Collector to storage -
    - ON - (SN-14) > (SN-16) + 9°
    - OFF - (SN-14) < (SN-16) + 3°
  - Drain down
    - ON - (SN-15) < 42°
- Sensors (SN-14) and (SN-15) and (SN-16)
  - Manufacturer - Heliothrope
  - Model name/number - Tes - 1
  - Type - Temperature and Bl metalic freeze sensor
- Fail Safe Control (FC-17)
  - Manufacturer - Red-White
  - Model name/number - Reverse flow check
  - Type - Check valve
- Flow Control (FC-18)
  - Manufacturer - Watts
  - Model name/number - Unknown
  - Type - Relief valve

- Flow Control (FC-19)
  - Manufacturer - Watts
  - Model name/number - Unknown
  - Type - Air vent

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

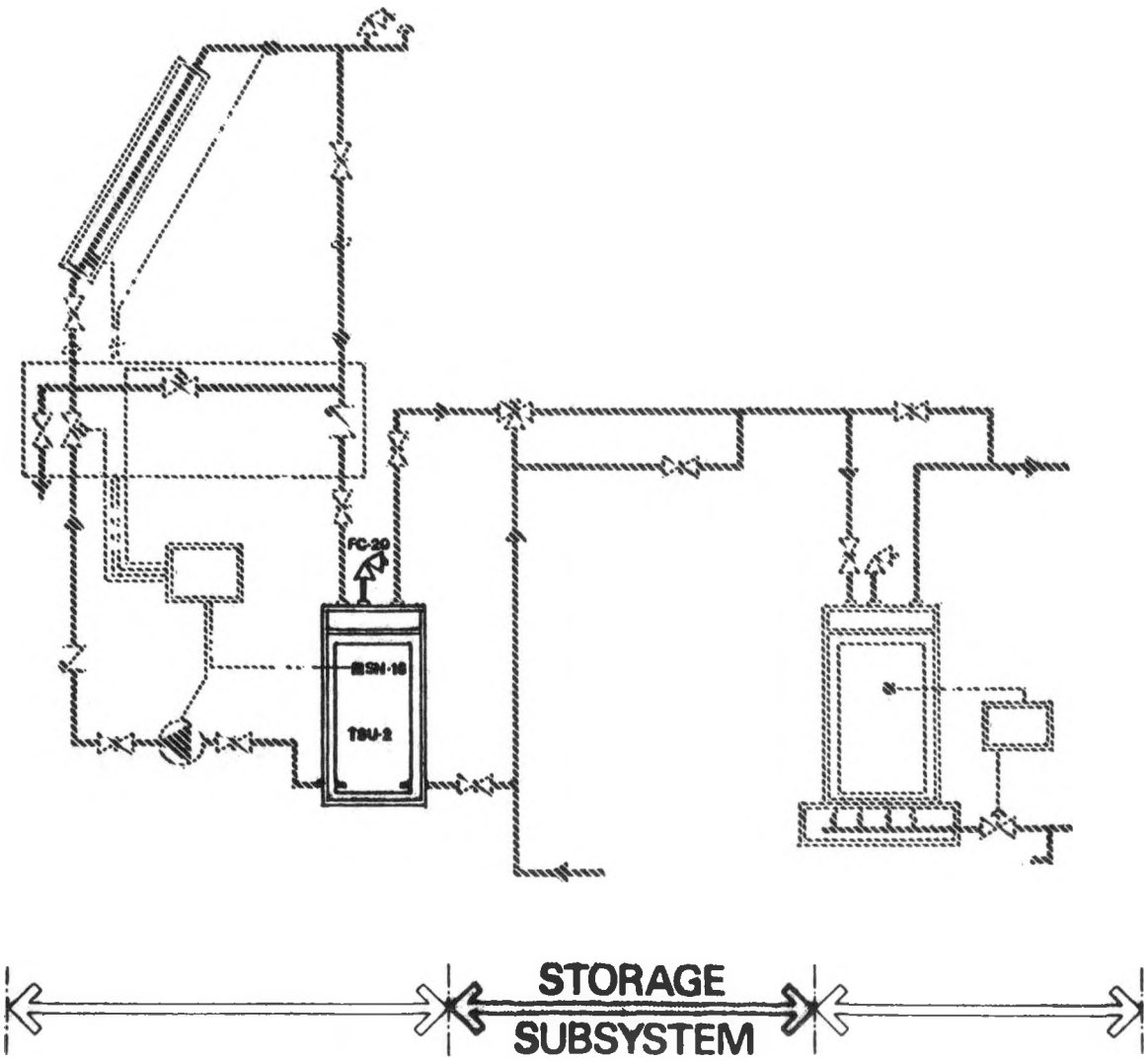


Figure V-C-1. Storage Subsystem, Active

Solar energy storage is provided by an 82-gallon storage tank. This tank is made of metal with an interior lining of glass. It measures 5.0 ft in height and 2.2 ft diameter.

THERMAL STORAGE UNIT (TSU-2)

- Manufacturer - Rheem
- Model name/number - Solaraid/688-82-T
- Total storage container volume - 19 ft^3
- Volume of storage medium - 19 ft^3
  - Height - 5.0 ft
  - Diameter - 2.2 ft
- Maximum rated operating conditions
  - Temperature - 212° F Maximum
  - Pressure - 150 psi
- Storage medium
  - Design operating temperatures
    - Heating - 190° F Maximum; 34° F Minimum
  - 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 - 150° F
- Toxicity - Potable
- pH Factor - 7
- Inhibitor - No
- Container construction
  - Type - Metal
  - Interior lining - Porcelain Formula Glass

- Location - In room
- Auxiliary heaters - No
- Insulation - Glass fiber
- Exterior finish - Paint, baked enamel
- Filters - No
- Getters - No

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

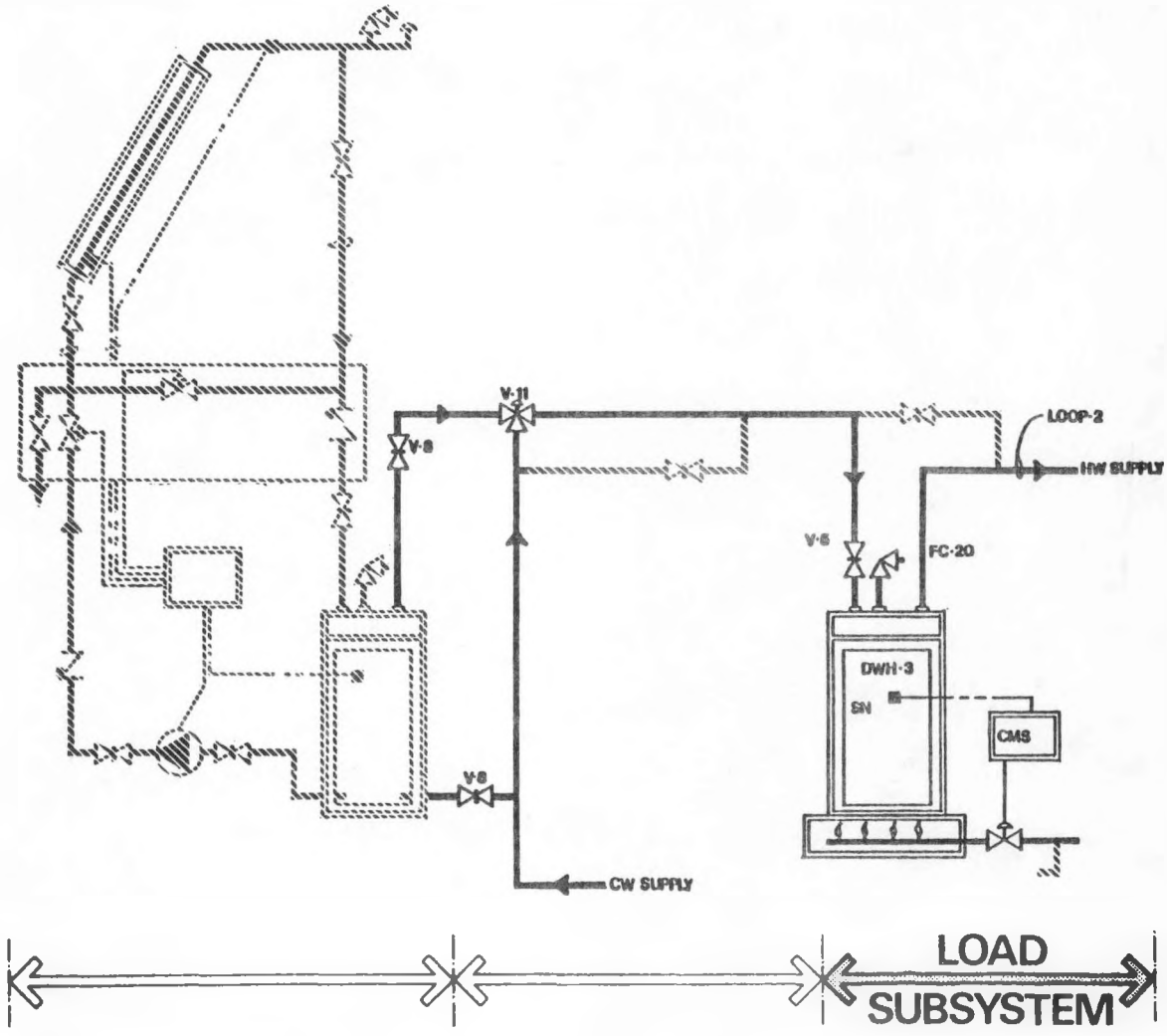


Figure V-D-1. Energy-to-Load Subsystem, Active

The active solar DHW system has an array of flat-plate collectors with a gross area of 53 square feet. The array faces south at an angle of 45 degrees from the horizontal. Potable city water is the transfer medium used throughout the system. In the event of freezing and no insolation, the controller drains the water from the collectors. When water in the collector is sufficiently warmer than the water in the preheat storage tank, the controller starts the circulation between the preheat tank and the collector. The preheat tank holds 82 gallons of water which is supplied, on demand, to a conventional 20 gallon DHW tank. When the water preheated by solar energy is not hot enough to satisfy the hot water load, a natural gas burner in the DHW tank provides auxiliary energy for water heating.

LIQUID CIRCULATION LOOP NO. 2 (TSU-2 TO DWH TO HW)

- Design maximum operation temperature - 180° F
- Design maximum operation pressure - 150 psi
- Heating
  - Design liquid flow - 4.0 gpm
- Heat transfer medium
  - Volume of liquid in loop - 106.4 gal
  - Anticipated liquid temperatures
    - Maximum - 180° F
    - Minimum - 50° F
  - Provisions for expansion - Not required
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Medium manufacturer's recommended use temperature -
    - Maximum - 180° F
  - Toxicity - Potable
  - pH factor - 7
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Components within circulation loop
  - Domestic water heater(s) - DWH-3
  - Valve(s) - V-5, V-6, V-8, V-11

- Distribution Valve (V-5) (V-6)
  - Manufacturer - Norca
  - Model name/number - Gate
  - Function - Flow switching
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Bronze
- Isolation Valve (V-8)
  - Manufacturer - Toya
  - Model name/number - Gate
  - Function - Isolation
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Bronze
- Distribution Valve (V-11)
  - Manufacturer - Watts
  - Model name/number - 70-A
  - Function - Tempering
  - Operation - Automatic, non-motorized
  - Type - Thermostat
  - Materials exposed to heat transfer fluid - Bronze
- Piping
  - Rigid - Copper, type M
  - Interior coating - None
  - Insulation - Polyurethane
  - Location - Above grade
  - Filters - No
  - Getters - No

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

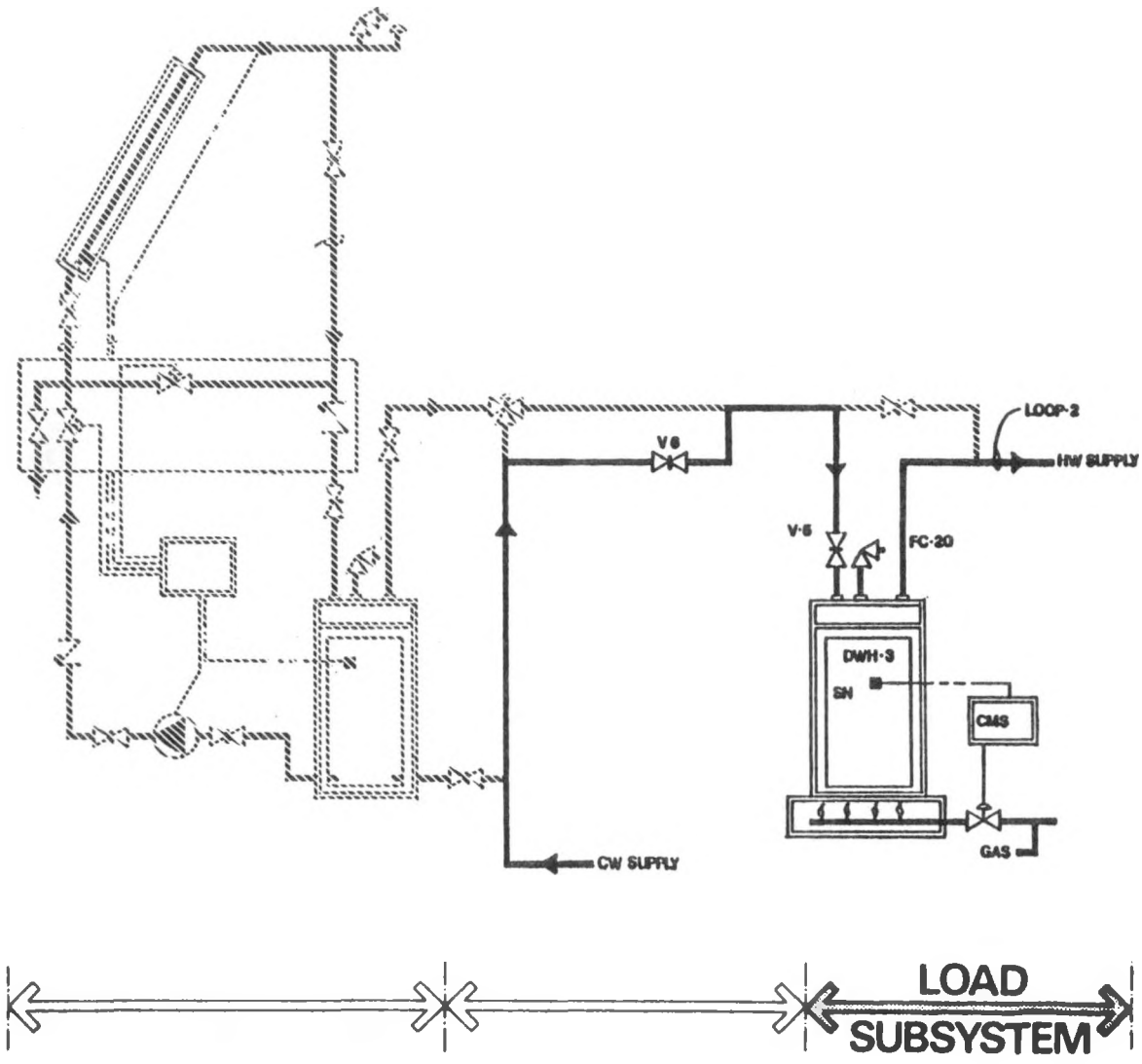


Figure V-E-1. Auxiliary-to-Load Subsystem, Active

The auxiliary subsystem, DWH-3 mentioned in the foregoing Energy to Load Subsystem is in this section for descriptive purposes, the function and purpose has been previously described.

AUXILIARY LOADS

- Domestic Water Heater (DWH-3)
  - Manufacturer -Hoyt
  - Model - Hitest Glass lined 20 gallon
  - Energy source - Natural gas
  - Tank volume - 20 gallon
  - Energy input - Not available
  - Energy output - Not available
  - Maximum pressure rating - 150 psi
  - Maximum temperature rating - 200° F
  - Design operating pressure - 150 psi
  - Heating stages - Single
  - Design energy at highest heat
    - Input - 29,000 Btu/hr
    - Output - 21,750 Btu/hr
  - Maximum recovery rate - 24 gal/hr
  - Yearly average inlet temperature - 50° F
  - Design output temperature - 140° F
  - Thermal resistance - Unknown
  - Corrosion protection anodes - Magnesium
  - Burner ignition method - Automatic pilot
  - Flue vent - Yes

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

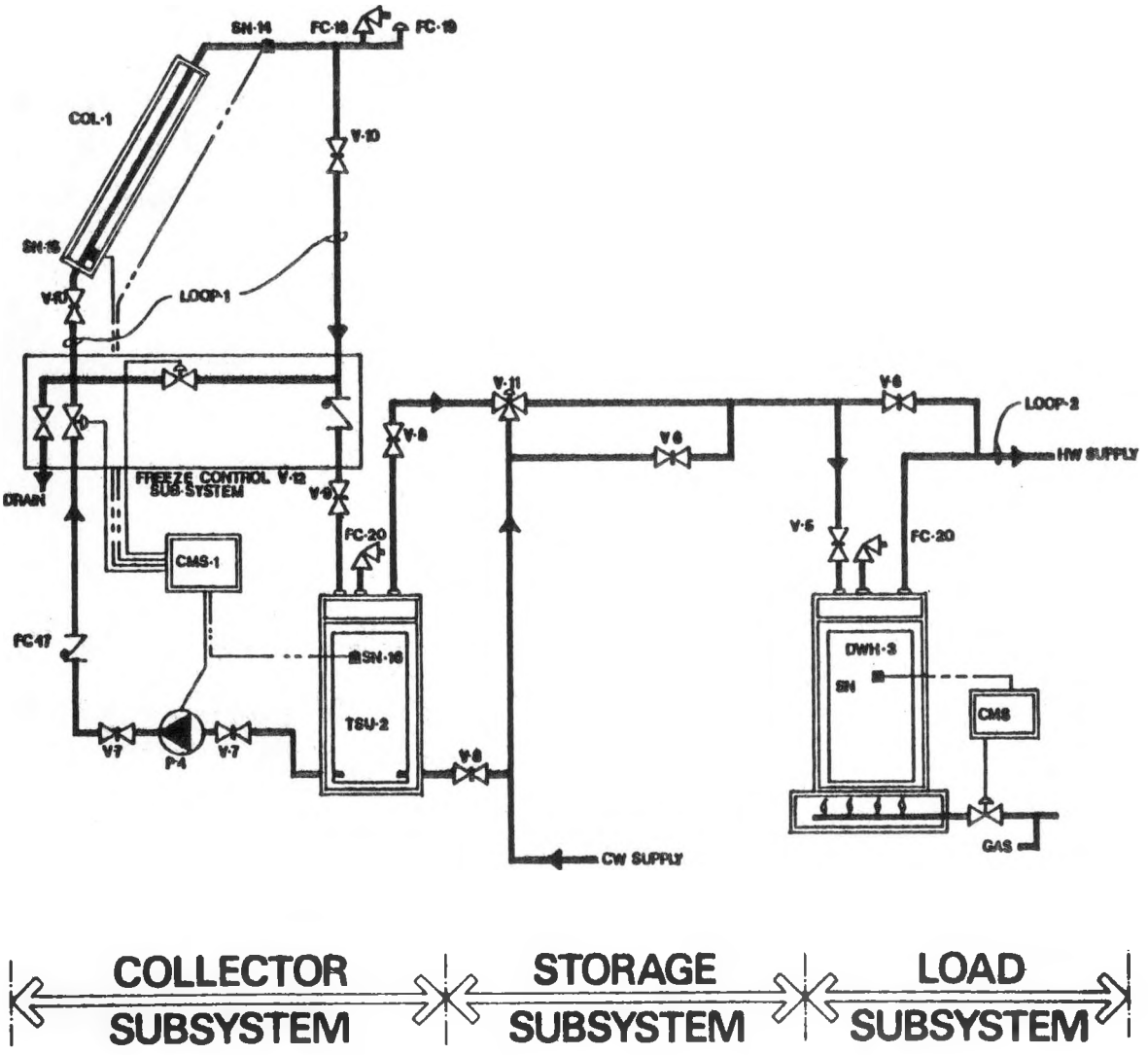


Figure V-F-1. Controls Diagram, Active

The Living Systems solar project is shown on Figure V-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 subsystems may involve one or more of the two modes of operations described below.

Mode 1 - Collector-to-Storage-to-DHW

This is an open system and the solar heated water is stored in an 82-gallon preheat tank. When the water preheatead by solar energy is not hot enough to satisfy the hot water load, a natural gas burner in the DHW tank provides auxiliary energy for water heating.

Mode 2 - Freeze Protection

An automatic freeze control will be activated should outside temperature sense less than 42° F. The control should cause drain down of the collectors.

VI. PERFORMANCE EVALUATION INSTRUMENTATION

A. The National Solar Data Network

The National Solar Data Network (see figure VI-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.

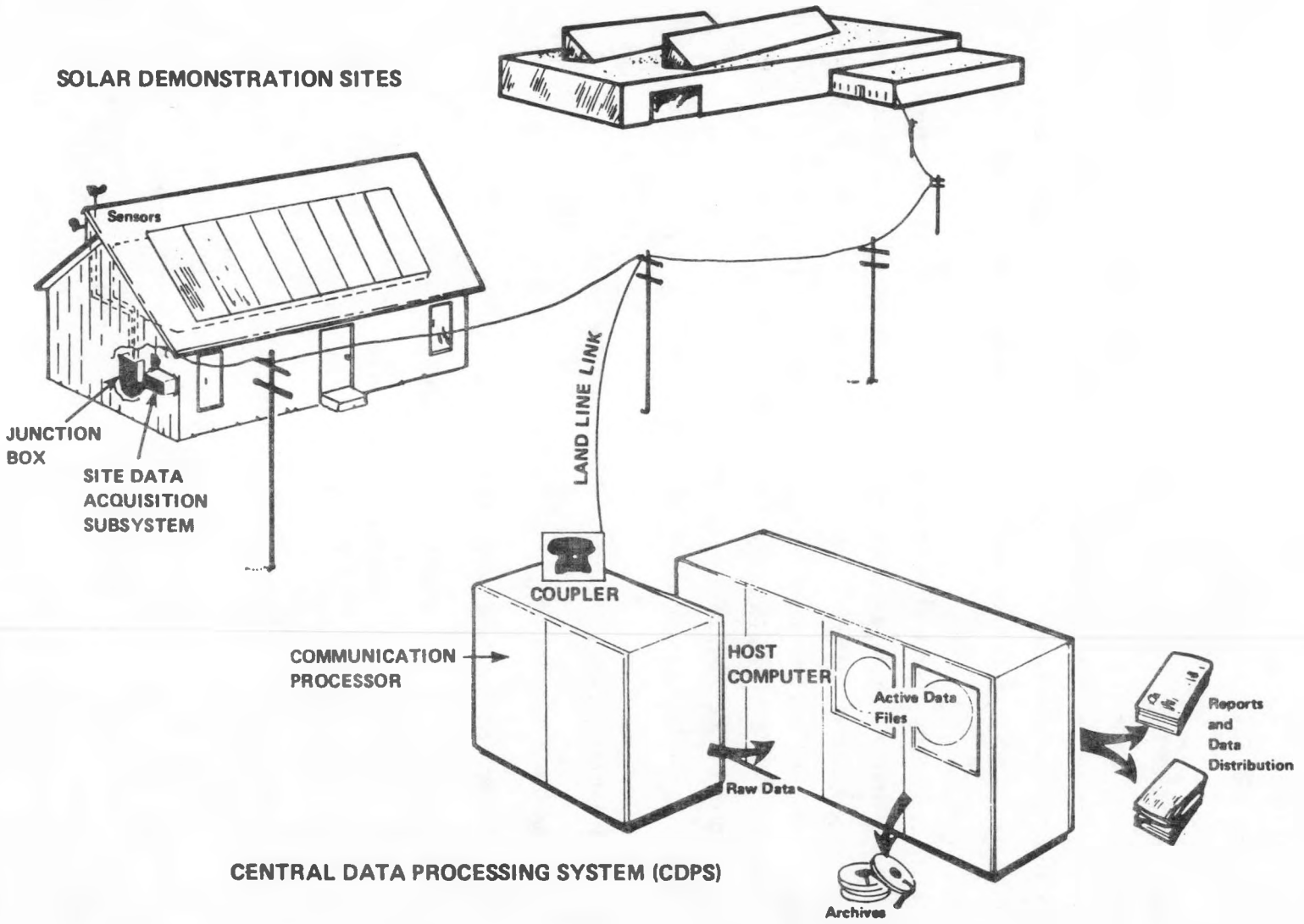


Figure VI-A-1. The National Solar Data Network

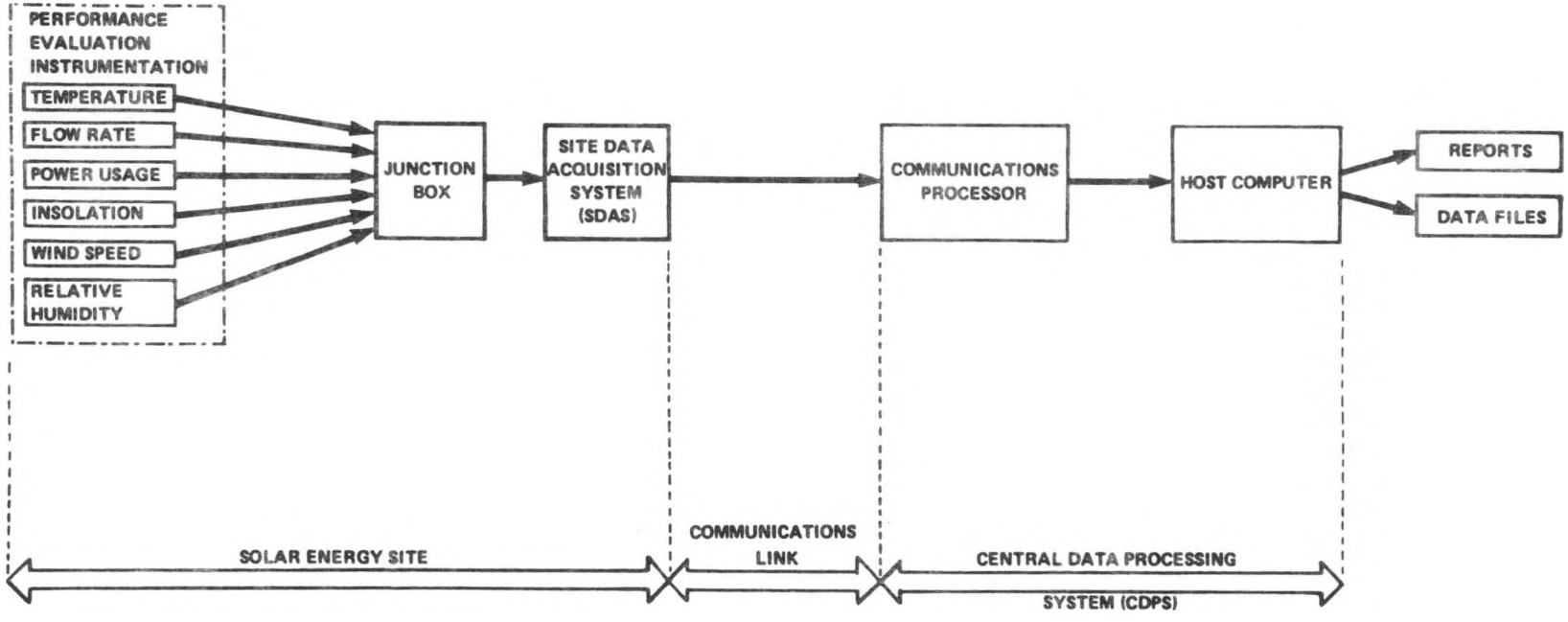


Figure VI-A-2. Data Flow Path for the National Solar Data Network

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 textual site identification; and specific site data used in generating the performance factors.

B. On-Site Instrumentation

PASSIVE SPACE HEATING SYSTEM

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 VI-A-1 and VI-A-2). Specific information for temperature, flow, power and miscellaneous sensors are presented in tabular form. Critical sensor locations are shown in figure VI-B-1.

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Insolation, total	Eppley PSP
T001	Temperature, outside ambient	S53P-60,IS2
RH001	Humidity, Outdoor	WM, HM-111-P
WV001	Velocity, wind	WM, W-101-P-DC/360
WD001	Direction, wind	Part of above
D501	Displacement, East window	RI 4040-5
D502	Displacement, Center window	RI 4040-4
D503	Displacement, West window	RI 4040-4
D101	Displacement, East curtain	RI 4040-10
D102	Displacement, Center curtain	RI 4040-8
D103	Displacement, West curtain	RI 4040-8
D104	Displacement, East shutter	
D105	Displacement, Center shutter	
D106	Displacement, West shutter	
T271	Temperature, storage tank, top	Minco S32B
T272	Temperature, storage tank, center	Minco S32B
T273	Temperature, storage tank, bottom	Minco S32B
T281	Temperature, storage tank, top	Minco S32B
T282	Temperature, storage tank, center	Minco S32B
T283	Temperature, storage tank, bottom	Minco S32B
T604	Temperature, room gradient, top	Minco S32B
T605	Temperature, room gradient, center	Minco S32B
T606	Temperature, room gradient, bottom	Minco S32B
T231	Temperature, storage tank, top	Minco S32B
T232	Temperature, storage tank, center	Minco S32B
T233	Temperature, storage tank, bottom	Minco S32B
T241	Temperature, storage tank, top	S32B
T242	Temperature, storage tank, center	S32B
T243	Temperature, storage tank, bottom	Minco S32B
D500	Displacement, shutter	I
F400	Fuel flow, dom. furnace	AC-175
EP500	Power, "Casa Blanca" fan	PC5-103

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
T601	Temperature, room	S53P-28
T602	Temperature, room	S53P-28
T603	Temperature, room	S53P-28
T201	Temperature, slab	S53P-28
T202	Temperature, slab	S53P-28
T203	Temperature, slab	S53P-28
T204	Temperature, slab	S53P-28
T205	Temperature, slab	S53P-28
T206	Temperature, slab	S53P-28
T207	Temperature, slab	S53P-28
T208	Temperature, slab	S53P-28
T212	Temperature, slab	S53P-28
T213	Temperature, slab	S53P-28
T217	Temperature, slab	S53P-28
T218	Temperature, slab	S53P-28
T219	Temperature, slab	S53P-28
T220	Temperature, slab	S53P-28
T221	Temperature, slab	S53P-28
T222	Temperature, slab	S53P-28
T209	Temperature, slab	S53P-28
T210	Temperature, slab	S53P-28
T211	Temperature, slab	S53P-28
D600	Displacement, switch #30002-000	Fenwall, Inc.,
T214	Temperature, slab	S53P-28
T215	Temperature, slab	S53P-28
T216	Temperature, slab	S53P-28
RH600	Humidity, relative, indoor	WM, HM-11P
T600	Temperature, indoor	S53P-28
I002	Insolation, passive collector	Eppley PSP

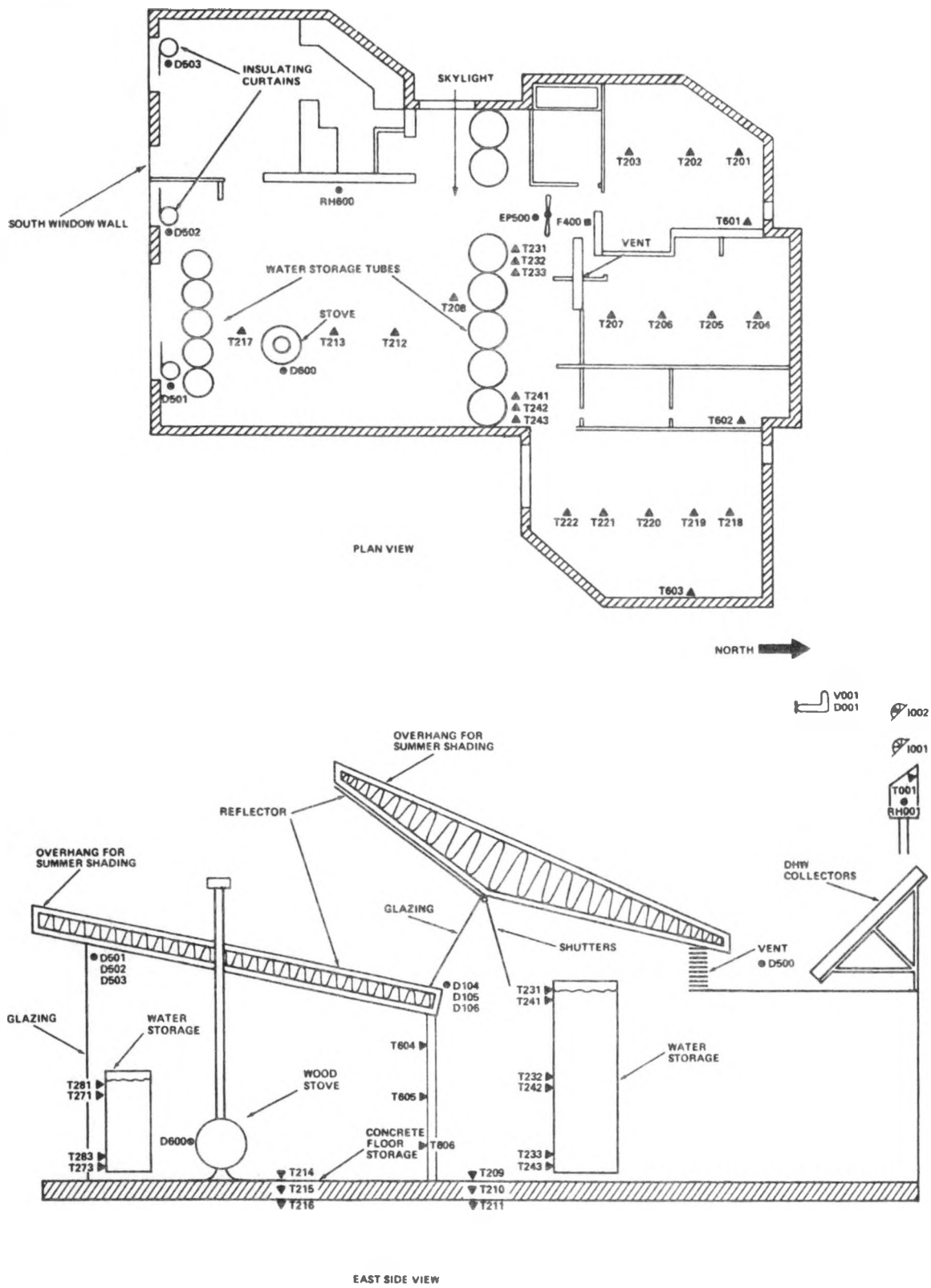


Figure IV-B-1. Sensor and Control Diagram, Passive

ACTIVE DHW SYSTEM

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 VI-A-1 and VI-A-2). Specific information for temperature, flow, power and miscellaneous sensors are presented in tabular form. Sensor locations are shown in figure VI-B-2.

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
T100	Temperature, collector return	S57P-60
T150	Temperature, collector, high	S53P-60
W100	Flow, collector	MKV-1,1-10GPM
EP100	Power,collector pump	PC5-106
T300	Temperature, cold water supply	S57P-60
T350	Temperature, supply from storage	S57P-60
T351	Temperature, storage to DHW supply tank, high	S57P-60
T352	Temperature, DHW tank, high	S53P-60
W300	Flow, totalizer, CW supply	Hersey 430
F300	Fuel flow, DHW tank	AC-175
T291	Temperature, Ext., storage tank	S32B

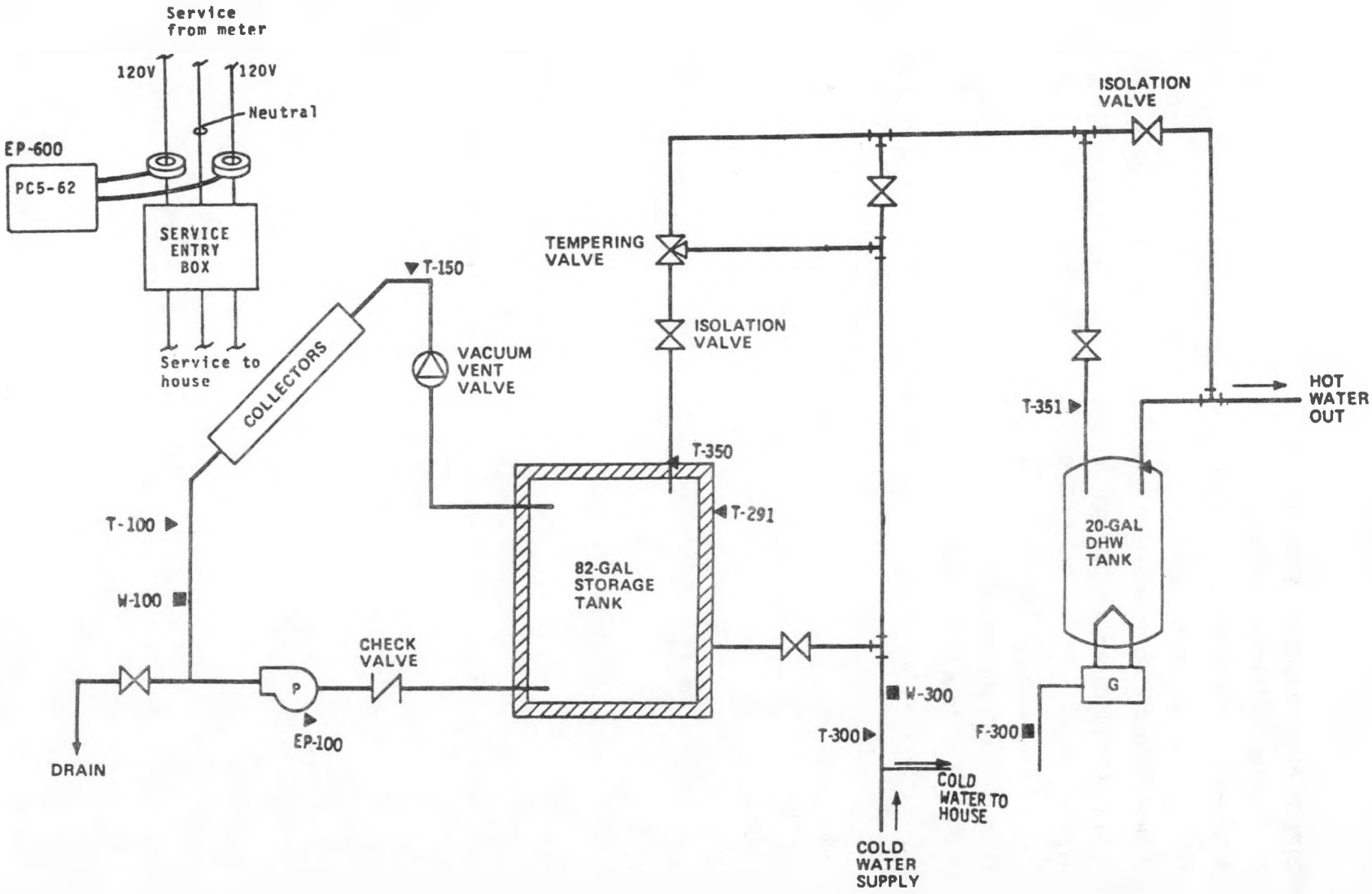


Figure VI-B-2. Sensor and Control Diagram, Active

VII. COST DATA

PASSIVE SPACE HEATING SYSTEM

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(Glazing)	$1,500	$
Energy Storage	2,200	
Distribution and Controls	1,280	
Installation		
Other		
Total	$4,980	$4,980

C. Construction Period: September 1977 through June 1978

VII. COST DATA - continued

ACTIVE DHW SYSTEM

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	$ 390	
Energy Storage	168	
Distribution and Controls	215	
Installation	390	
Other	770	
Total	$1,933	

C. Construction Period: September 1977 through June 1978

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.

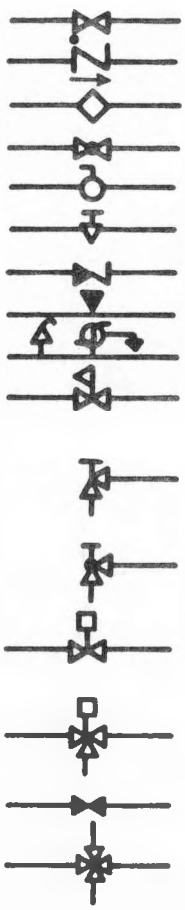
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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.

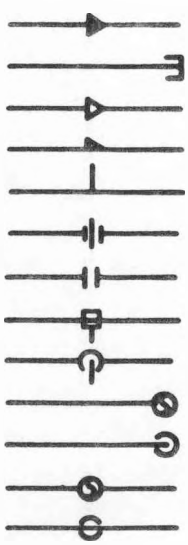
B. Legend For Solar System Schematics

VALVES



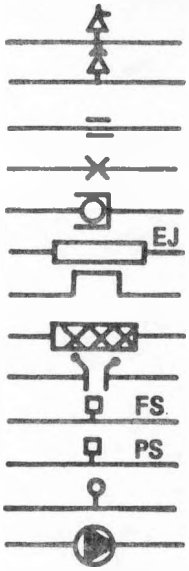
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

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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