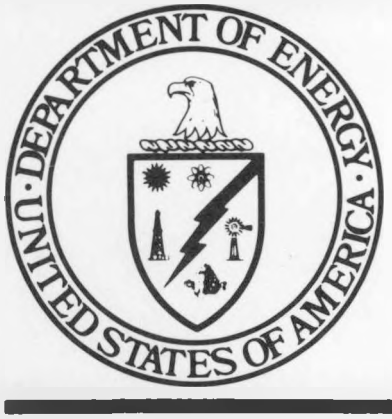
SOLAR/1004-81/50
(DE81025175)

Solar Project Description

JOHN BYRAM, JR. SINGLE-FAMILY RESIDENCE Shawnee Mission, Kansas July 2, 1981



U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1004-81/50
(DE81025175)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
JOHN BYRAM, JR.
SINGLE-FAMILY RESIDENCE; SHAWNEE MISSION, KANSAS

Department of Housing and Urban Development

Under Contract Number

H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

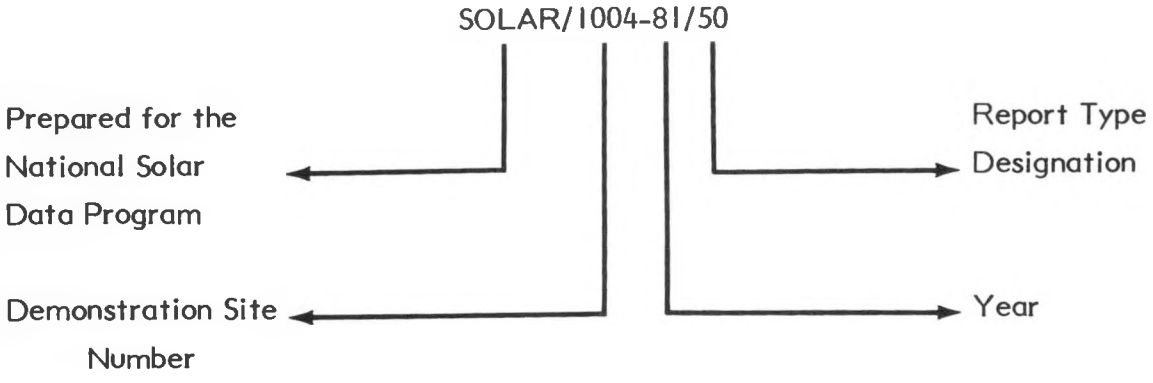
The Boeing Company
David Beers, Program Manager

TABLE OF CONTENTS

LIST OF FIGURES

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 John Byram, Jr. project site is designated as SOLAR/1004-81/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type -- Air Flat-Plate, Active
- o Freeze Protection -- Not required
- o Application -- Space heating and DHW
- o Storage -- 172 ft^3 bin containing 17,200 lbs rock, 120-gallon preheat tank and greenhouse floor
- o New or Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- Utilizes both active and passive systems

The John Byram, Jr. solar energy system (Grant H-2775) is installed in a single family residence located in Shawnee Mission, Kansas. The system is designed to provide solar energy for space heating and domestic hot water.

ACTIVE SOLAR HEATING SYSTEM

The active solar heating system includes the roof-mounted flat plate solar collector panels which are connected to the air handler (fan) and a pebble bed heat storage unit. There are 312 square feet of solar collector panels which are sloped at 54 degrees and have a south facing orientation. Air passing through these solar collectors is heated by the sun and routed through ductwork to the basement where it can be distributed throughout the house if heat is needed or stored in the pebble bed. Heat stored in the pebble bed can be used at night or during extended cloudy periods.

Water for domestic use is heated year round by a heat exchanger coil located in the solar air duct. This solar heated hot water is stored in a 120 gallon tank with a 4.5 kW heater. There is also a 40 gallon auxiliary tank (gas fired) for extended cloudy periods.

PASSIVE SOLAR HEATING SYSTEM

The main entrance to the house is through a small room with a cobblestone floor and large, south-facing glass windows. The floor of this room is 16 inches thick and made of reinforced concrete. The partition between this room and the main living area is constructed of brick and double hung windows. Although this area serves as a greenhouse, sun room, etc., it also functions in the winter as a passive solar space heating system.

Solar heat passing through the exterior windows is collected and stored in the greenhouse floor. Heat is provided to the main living areas either by opening the interior set of windows and door, or by turning on a low wattage fan which blows hot air from the greenhouse through a ceiling duct into the Great Room. Shade from deciduous trees in the front yard prevents this room from overheating in the summer. See section V for data concerning the passive system.

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)

- Building type - Single family detached
- Latitude - 39°
- Longitude - 94°
- Altitude - 742 ft
- Average summer temperature - 91° F
- Average winter temperature - 44° F

HEATING DESIGN TEMPERATURES

- Outdoor - 6° F DB
- Indoor - 75° F DB

BUILDING

- Building faces - South
- Average stories above ground - 1
- Average stories below ground - 1
- Height above grade - 20 ft
- Conditioned floor area - 1675 ft^2
- Roof type - Sloped

DESIGN HEAT LOSS/LOAD

- Heat Loss - 36,556 Btu/hr
- Heat gain - Unknown
- Shading
  - Heating season - 10%
  - Cooling season - 10%

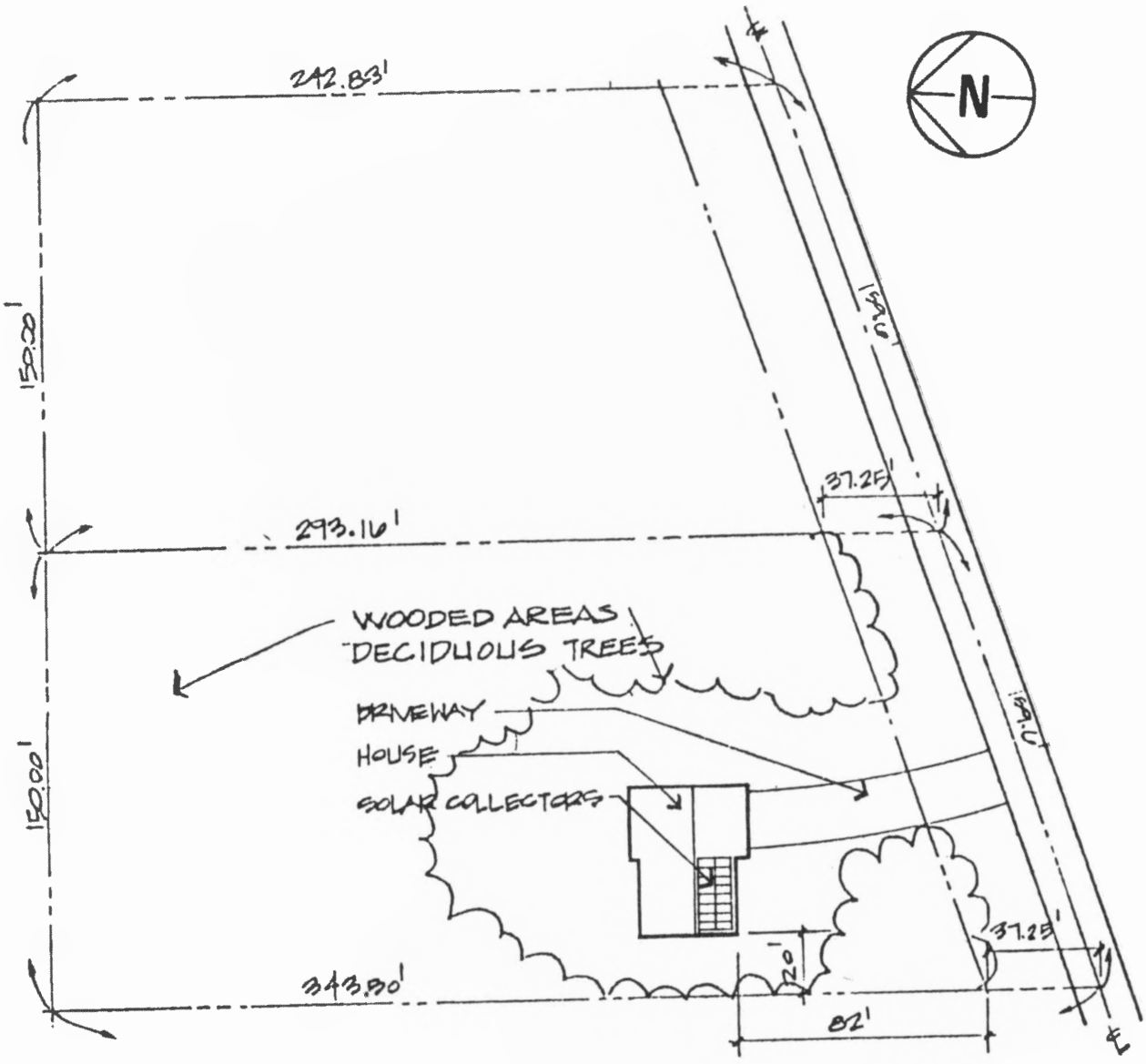


Figure III-1. Site Plan

- Appliance, lighting and equipment load - Unknown
- Average horizontal insolation
  - January - 647 Btu/ft^2/day
  - July - 2102 Btu/ft^2/day
- Annual degree days
  - Heating - 5357 DD
  - Data location - Kansas City, MO
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

MECHANICAL SYSTEM

- Heating
  - Solar - Air flat-plate collectors
  - Auxiliary - Gas fired furnace
  - Distribution - Air handling system

DOMESTIC HOT WATER

- Daily water demand - 100-gallons
- Solar - Air flat-plate collectors
- Auxiliary - Gas fired DWH-1

GENERAL DATA - COLLECTOR AND AIR HANDLER

- Manufacturer - Solaron
- Model name/number - 2000 Series Collector and model AU400 Air Handler
- Type of system - Air (active) and Greenhouse (passive)

SYSTEM AND COMPONENT SUMMARY

- Collector types - 2 (COL-1, COL-2)
- Circulation loops - 6
- Thermal storage units - 3
- Operational modes - 4 (active system) and 2 (passive system)

- Pumps - 1 (P-1)
- Valves - 2 (V-1, V-2)
- Blowers - 3 (BL-1, BL-2 for active system and BL-3 used in Greenhouse)
- Dampers - 8 (MD-1, -2 and -3; D-1, D-2 and D-3; BD-1 and BD-2)
- Sensors - 7
- Flow regulators - 0
- Pressure regulators - 1
- Fail safe controls - 1

IV. SOLAR SYSTEM DESCRIPTION, ACTIVE

A. General Overview

This residential solar demonstration project (John Byram, Jr., Grant H-2775) located at Shawnee Mission, Kansas is an air active system utilized for space heat and DHW. A gas-fired furnace is utilized for auxiliary space heating and a gas-fired DWH is used for hot water. A passive system (greenhouse) is also utilized for space heating primarily during the winter season when the leaves from the decidious trees have fallen. See section V.

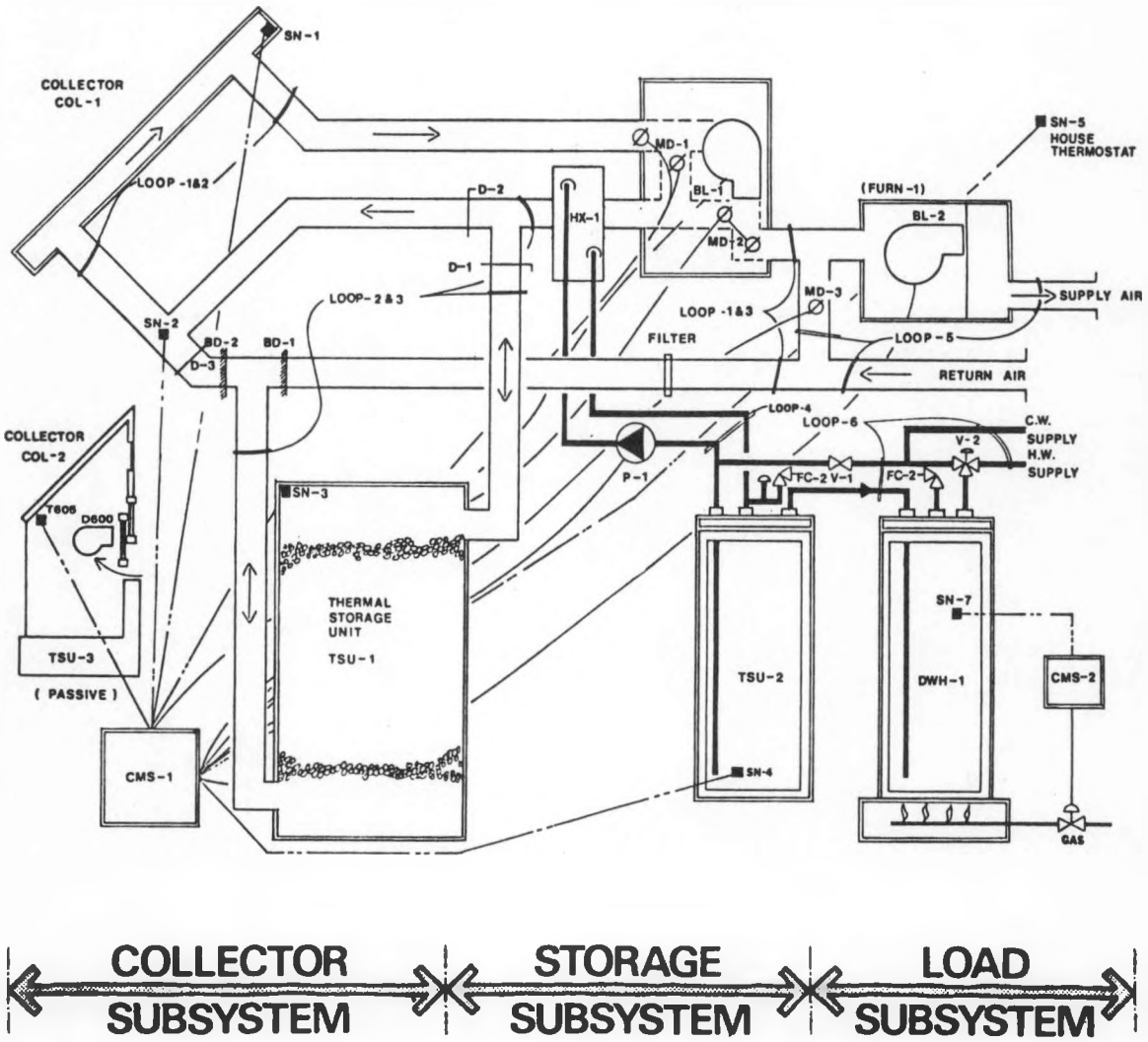


Figure IV-A-1. General Overview

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

B. Collector Subsystem (See Figures IV-B-1 and IV-B-2)

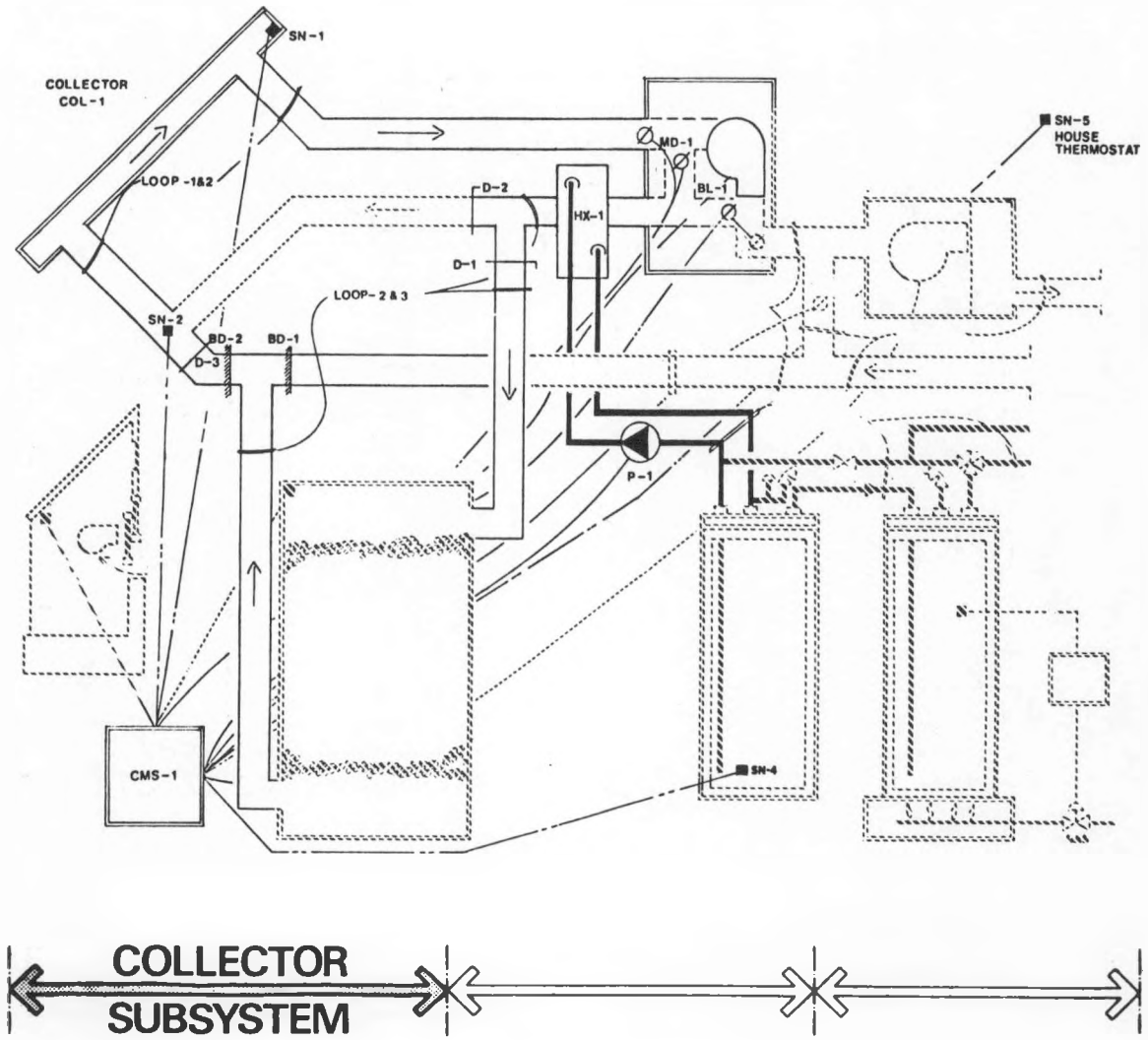


Figure IV-B-1. Collector Subsystem, Collector-to -Storage and DHW Preheating

Collector (COL-1) array for the active system consists of 16 air flat plate collector panels. Panels are attached to the roof structure and each are 3 feet wide by 6½ feet long. Freeze protection is not required.

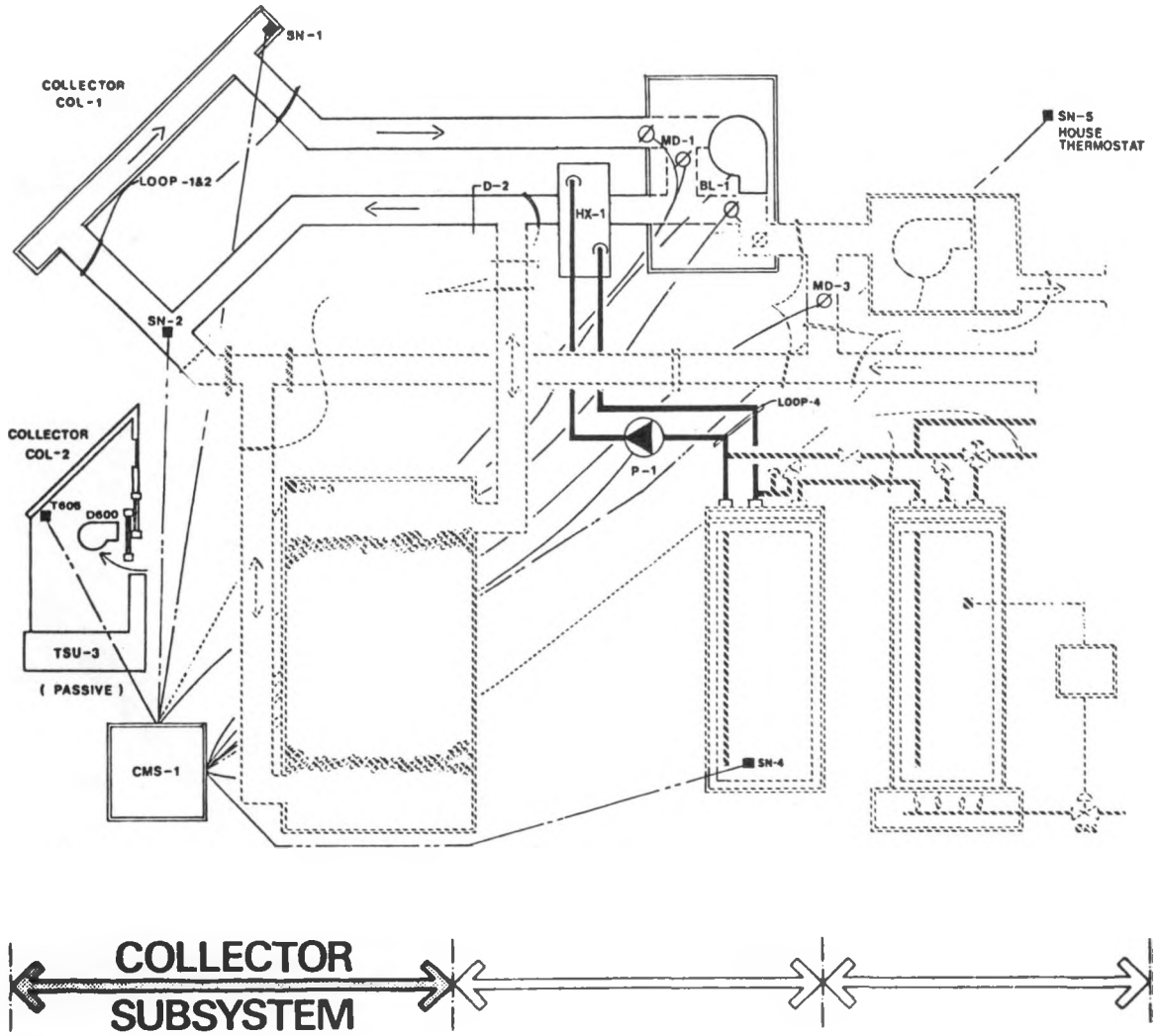


Figure IV-B-2. Collector Subsystem, Summer Mode-DHW Preheating

This mode activates when there is a DHW preheat demand, the collectors are operating and there is no demand for space heating or storage preheat.

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

- o Manufacturer - Solaron
- o Model name/number - Solaron 2000 Series
- o Type - Air flat plate with black non-reflective surface
- o Location - Roof
- o Orientation - Due South
- o Tilt angle - 54° from horizontal

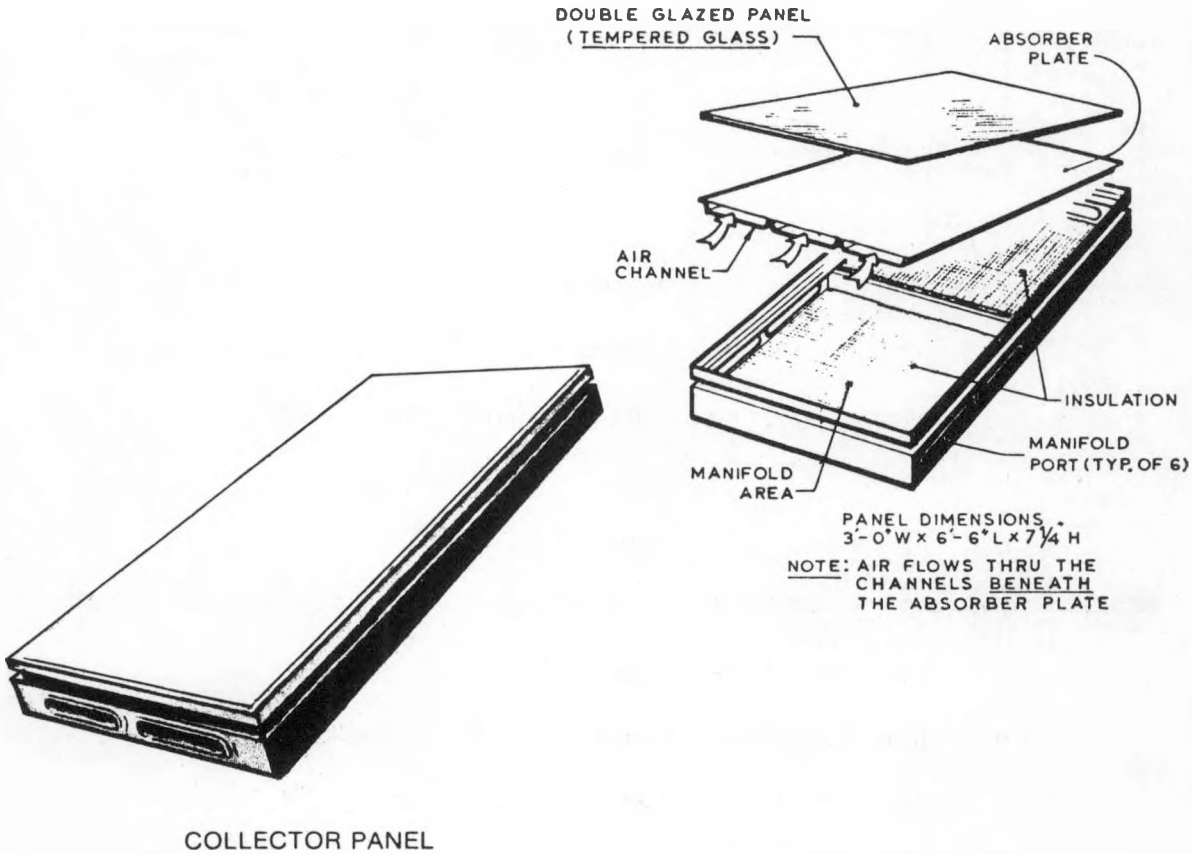


Figure IV-B-3. Solar Collector

- Collector characteristics
  - Number of panels - 16
  - Total gross area of array - 312 ft^2
  - Net aperture area - 285 ft^2
  - Net absorber area - 312 ft^2
  - Weight per panel, empty - 153 lb
  - Weight per panel, full - 153 lb
  - Weight of filled array and support structure - 2695 lb
  - Panel length - 78.0 in
  - Panel width - 36.0 in
  - Frame depth - 7.3 in
  - Standoff height - 0
- Collector shading -
  - Area shaded in June - 10%
  - Area shaded in December - 0
  - Maximum shade during functional season - 10%
- Cover plates
  - Number of cover plates - Two
- Cover plate No. 1
  - Location - Outer layer
  - Manufacturer - ASG Industries
  - Product name/number - Tru-Temp Glass
  - Material - Low iron tempered glass
  - Thickness - 0.125 in

- Optical properties

	(solar region)	(infrared region)
- Transmittance -	89%	0
- Reflectance -	8%	12%
- Emittance - 3%		

  - Edge or surface treatment, other than coating - Mechanical, ground
  - Coating on cover plate material - None
- Cover plate No. 2
  - Location - Inner layer
  - Manufacturer - ASG Industries
  - Product name/number - Tru-Temp
  - Material - Low iron tempered glass
  - Thickness - 0.125 in
  - Optical properties

	(solar region)	(infrared region)
- Transmittance	89%	0
- Reflectance	8%	12%
- Emittance - 3%		

  - Edge treatment - Mechanical, ground
  - Coating - None
- Absorber
  - Manufacturer - Solaron
  - Model name/number - Series 2000 Absorber
  - Material - Cold Rolled Steel
  - Substrate material dimension
    - Thickness - 0.015 in
    - Length - 78 in
    - Width - 36 in
  - Number of absorbers per collector - 1

- Coating
  - Manufacturer - Alliance Wall
  - Model name/number - Porcelain Enamel
  - Coating material - Ceramic enamel

	(solar region)	(infrared region)
Absorptance -	94%	89%
Reflectance -	6%	11%
Emittance -	94%	89%

  - Method of coating application - Baked
- Heat transfer fluid passages
  - Location - Beneath absorber
  - Pattern - Parallel
  - Materials - Steel
  - Wall thickness - 0.015 in
  - Internal diameter - 1.18 in
  - Maximum operating conditions
    - Temperature - 200° F
  - Fluid passage bond to substrate - None
  - Protective coating inside fluid passage - Paintlok
- Insulation - None
  - Layer one - back
    - Manufacturer - Owens-Corning
    - Product name/number - Fiberglas
    - Material - Glass fiber
    - Thermal resistance - R-12

- Gaskets and sealants
  - Inner cover - Butyl
  - Outer cover - Butyl
  - Backing plate - Silicone 732 (Dow Corning)
  - Penetrations - EPDM (Pawling Rubber)
- Frame
  - Manufacturer - Solaron
  - Product name/number - Series 2000 Frame
  - Material - Steel, standard sheet metal
  - Protective coating - Painted (Paintlock/Paint)
  - Standoffs used - No
  - Number of structure attach points per module to building - 6
- Reflectors - None
  - Desiccant - Yes, Silica Gel
  - Freeze protection - None
  - Overheating protection - None
- Collector performance
  - Method of evaluation - $\frac{t_i - t_a}{I_t}$ (ASHRAE)
  - y intercept $F_R(\tau\alpha)_\eta$ - 0.48
  - Slope - $F_R U_L$ - 0.85

Point Number	1	2	3	4
n = Collector thermal efficiency (η %) -	44.3	39.4	32.2	14.4
t_i or t_f = collector inlet temperature (^{o} F) -	107	124	152	209
t_a = ambient air temperature (^{o} F) -	74	76	66	79
I_t = insolation intensity Btu/hr ft^2 -	339	330	334	338
ASHRAE $(t_i-t_a)/I_t$ -	0.10	0.15	0.26	0.39

Where

- η = collector thermal efficiency
- U_L = collector heat loss factor
- F_R = collector heat removal factor
- t_a = ambient air temperature, ^{o} F
- $(\tau\alpha)_{\eta}$ = Transmissivity-absorptivity product at normal incidence
- t_i = collector inlet temperature, ^{o} F
- t_f = average fluid temperature, ^{o} F
- I_t = radiation (insolation) intensity on collector, Btu/hr.ft^2
  - Test flow rate - 80.8 ft^3/min
  - Heat loss coefficient 1.32 Btu/hr/ft^2/^{o} F
  - Test wind speed - 5 mph
  - Test collector area:
    - Gross - 19.2 ft^2
    - Net - 17.0 ft^2
    - Thermal response time - 6 min
  - Incidence angle modifier:
    - 45^{o}:0.94
    - 60^{o}:0.88
    - 75^{o}:0.67
  - Fluid specific heat - 0.24 Btu/lb/^{o} F
  - Test fluid medium - Air

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

- Heating
  - Maximum design operating temperature - 250^{o} F
  - Heating design air flow - 780 cfm

- Components within circulation loop
  - Blower(s) - BL-1
  - Thermal storage unit(s) - TSU-1
  - Damper(s) - MD-1, MD-2, D-1, D-2, D-3, BD-1 and BD-2
  - Heat exchanger(s) - HX-1
- Ducting
  - Type - Glass fiber
  - Location - Above grade
  - Maximum operating temperature - 250° F
  - Thermal resistance - Unknown
  - Insulation - Glass fiber
- Blower (BL-1)
  - Manufacturer - Solaron
  - Model name/number - AU-40
  - Type - Squirrel cage
  - Motor size - 0.33 HP; 115 V; 1 phase; 60 Hz
  - Design conditions

	Low Static Mode	High Static Mode
- Circulating volume	800 cfm	
- Motor operation	0.33 bhp	
- Ext static pressure	13.8 in wg	

- Dampers (MD-1 and MD-2)
  - Manufacturer - Solaron
  - Model name/number - AU-40
  - Function - Flow switching
  - Type - Opposed blade
  - Operation - Automatic, motorized
  - Blade edges - No gasket/seal
  - Blade/Frame contact - Neoprene
- Dampers (D-1, D-2 and D-3)
  - Manufacturer - Duro-Dyne
  - Model name/number - Unknown
  - Function - ON/OFF
  - Operation - Manual
- Dampers (BD-1 and BD-2)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Function- ON/OFF
  - Type - Backdraft
  - Operation - Automatic, non-motorized

LIQUID CIRCULATION LOOP NO. 4 (HX-1 TO TSU-2)

- Design operating temperature - 140^{o} F
- Heating
  - Design liquid flow - Unknown
  - Design pump speed - 1750 rpm
- Heat transfer medium
  - Volume of liquid in loop - Unknown

- Anticipated liquid temperature
  - Maximum - 250° F
  - Minimum - 140° 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
- Medium manufacturer's recommended use temperature
  - Maximum - 140° F
  - Minimum - 90° F
- Toxicity - Potable
- pH factor - 7.0
- Chemical feeder - No
- Inhibitor - No

- Components within circulation loop
  - Heat exchanger - HX-1
  - Circulator pump - P-1
  - Thermal storage unit - TSU-2
- Piping
  - Rigid - Copper
  - Insulation - None
  - Location - Above grade

- Heat Exchanger (HX-1) Air to Liquid
  - Manufacturer - Solaron
  - Model name/number - LAU
  - Type of flow - Cross
  - Heat exchanger design - Fin coil

	Air Side	Liquid Side
o Convection:	Forced	Forced
o Part of circulation loop:	2	4
o Maximum manufacturer's rated -		
- Temperature -	250° F	180° F
o Material	Copper	Aluminum

- Heating
  - Effectiveness - 27%

	Air Side	Liquid Side
o Design flow quantity -	800 cfm	
o Related pump no. -	BL-1	P-1
o Temperatures:		
- Entering -	Unknown	Unknown
- Leaving -	Unknown	Unknown

- Circulator pump (P-1)
  - Manufacturer - March
  - Model name/number - 809-3
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 125 psi
    - Temperature - 250° F
  - Material exposed to heat transfer fluid - Bronze

- Motor size - 0.01 HP; 115 V; 1 phase; 60 Hz
- Maximum motor speed - 1750 rpm
- Drive - Direct
- Speed - Single
- Pump speed - Variable
- Circulating volume - Low head mode - Unknown
- Operating head (dynamic) - Low head mode - Unknown
- Motor operation - 0.01 bhp

CONTROL MODE SELECTOR (CMS-1)

- Manufacturer - Solaron
- Model name/number - HC-0115
- Modes controlled
  - Collector to storage -
    - ON - (SN-5) + 2^{o} F $\geq$ Thermostat setting
      - (SN-1) > (SN-2) + 40^{o} F
    - OFF - (SN-1) < (SN-2) + 25^{o} F
  - HX-1 to TSU-2
    - ON - (SN-4) < 140^{o} F
      - (SN-5) + 2^{o} F $\geq$ Thermostat setting
      - (SN-1) > (SN-2) + 40^{o} F
    - OFF - (SN-1) < (SN-2) + 25^{o} F
- Sensors (SN-1, SN-2)
  - Type - Temperature, Thermistor
- Sensor (SN-4)
  - Type - Aquastat
- Sensor (SN-5)
  - Type - Thermostat

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

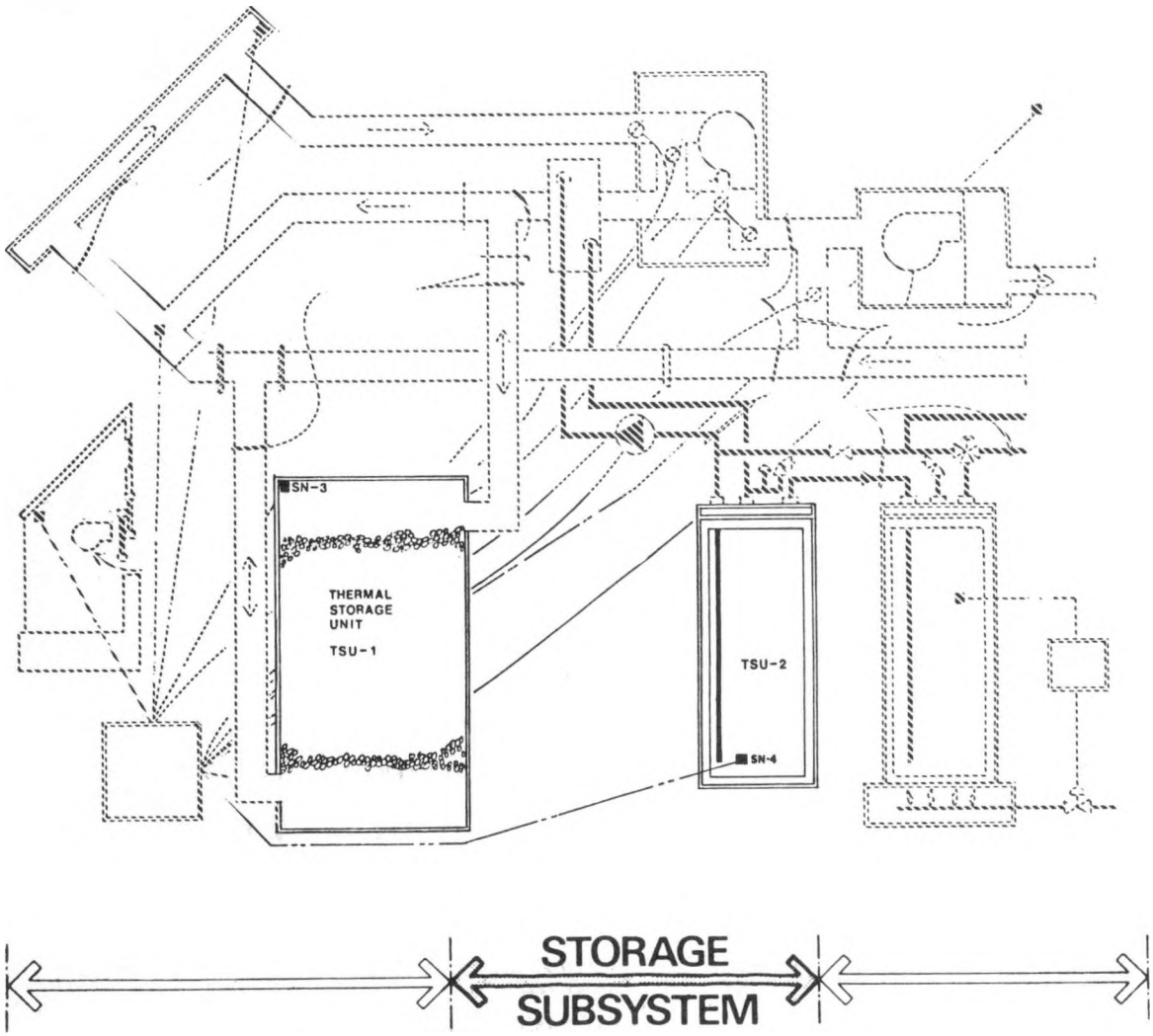


Figure IV-C-1. Storage Subsystem

Solar energy is stored in a 320 ft^3 (17,200 lbs of river rock) storage tank (TSU-1). This tank is made of concrete with ½" drywall interior. It measures 8.0 ft x 5.0 ft x 8.0 ft high and has glass fiber insulation.

TSU-2 has 14 ft^3 storage volume with 120-gal capacity used for domestic hot water. The tank is 5.0 ft high by 1.9 ft in diameter and is constructed of glass fiber lined with glass. An auxiliary heater is built in the unit.

THERMAL STORAGE UNIT (TSU-1, Space Heat)

- Manufacturer - Solaron
- Model name/number - Site built
- Total storage container volume - 320 ft^3
- Volume of storage medium - 17,200 lbs
  - Length - 8.0 ft
  - Width - 5.0 ft
  - Height - 8.0 ft
- Maximum rated operating conditions
  - Temperature - 140° F
- Storage medium
  - Design operating temperatures
    - Maximum - 250°F
    - Minimum - 40°F
  - Medium - River rocks
  - Weight per ft^3 of packed medium - 100 lbs
  - Total weight - 17,200 lbs
  - Storage medium size range - 0.8 to 1.5 in
  - Specific heat - 0.20 Btu/lb/° F
  - Heat capacity - 20.0 Btu/ft^3/° F
- Medium manufacturers recommended use of temperature -
  - Maximum - 140° F
  - Minimum - 40° F
- Container construction
  - Type - Concrete
  - Interior lining - ½" Drywall

- Location - Basement
- Auxiliary heaters - No
- Insulation - Glass fiber
- Exterior finish - None

THERMAL STORAGE UNIT (TSU-2, Domestic Hot Water Preheat Tank)

- Manufacturer - Jetglass
- Model name/number - M80SRD-2
- Total storage container volume - 10 ft^3
- Volume of storage medium - 75 gallon
  - Height - 5.0 ft
  - Diameter - 1.9 ft
- Maximum rated operating conditions
  - Temperature - 140° F
- Storage medium
  - Design heating operating temperatures
    - Maximum - 140° F
    - Minimum - 70° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
- Medium manufacturers recommended use of temperature
  - Maximum - 140° F
  - Minimum - 70° F
- Toxicity - Potable

- pH Factor - 7.0
- Inhibitor - No
- Container construction
  - Type - Glass fiber
  - Interior lining - Glass
  - Location - Basement
  - Auxiliary heaters - Yes (4.5 kW element)
  - Insulation - Glass fiber
  - Exterior finish - None
  - Filters - No
  - Getters - No

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

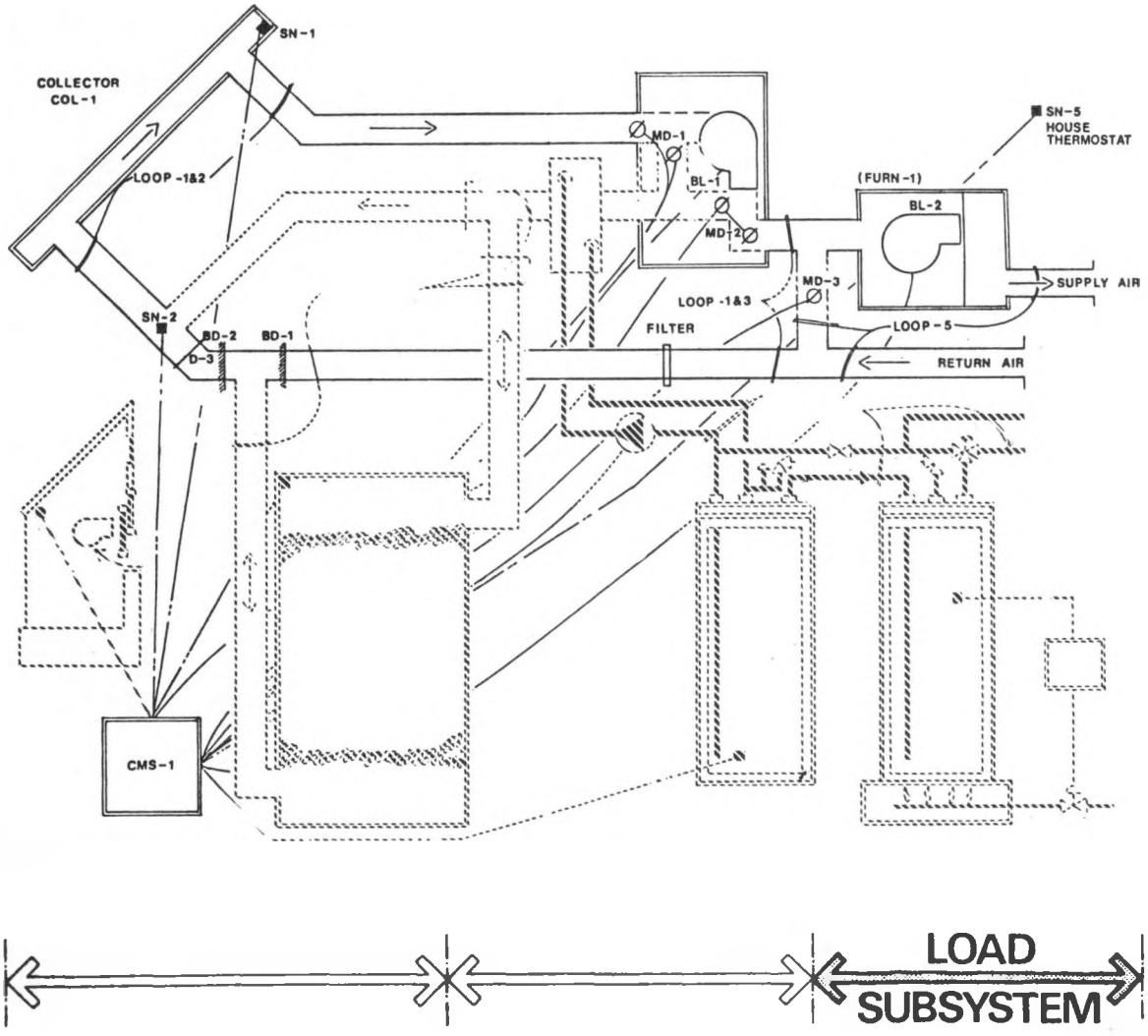


Figure IV-D-1. Energy-to-Load Subsystem, Collector-to-Space

Solar energy is transmitted when a space heating demand exists and when an adequate temperature differential exists between the solar collector inlet and outlet.

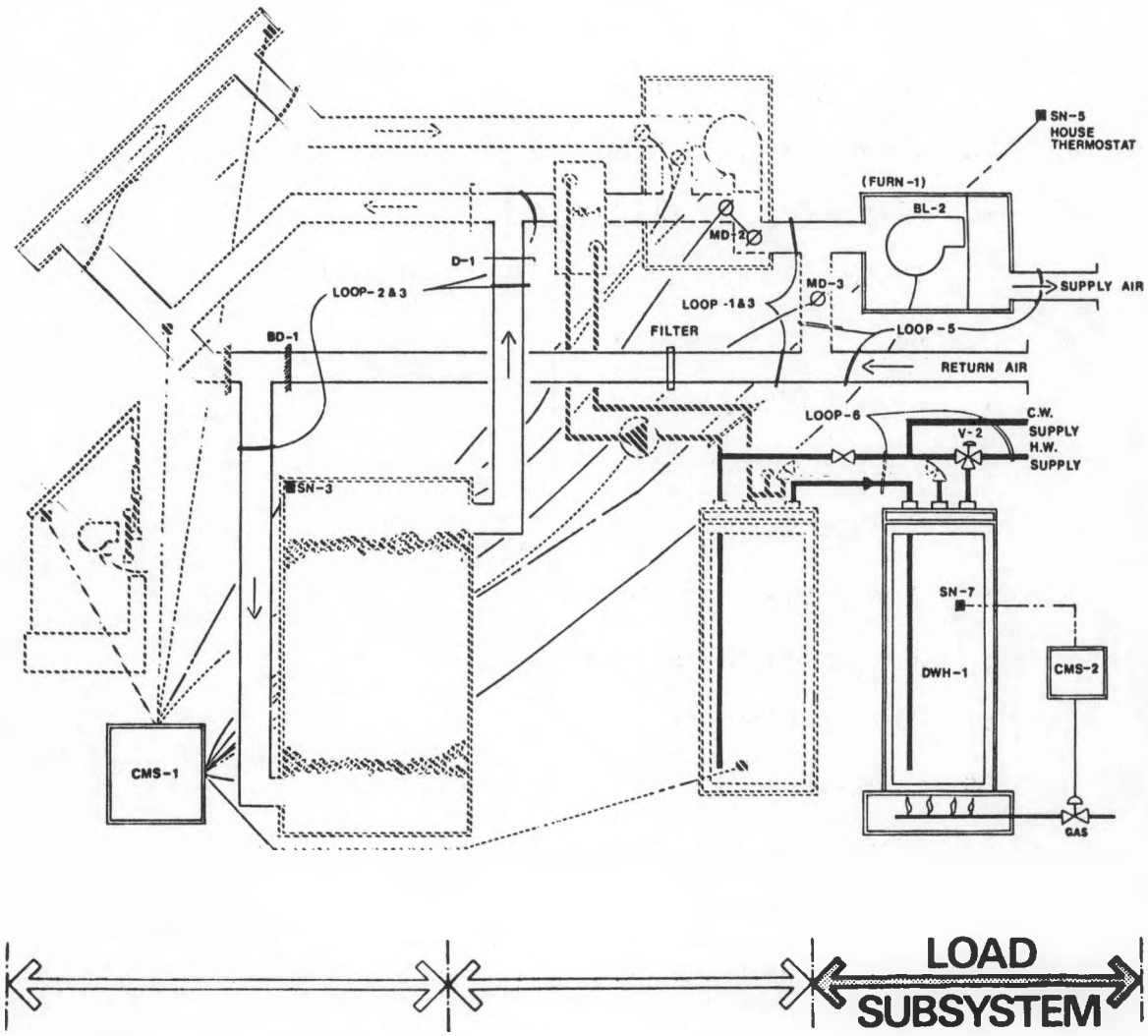


Figure IV-D-2. Energy-to-Load Subsystem, Storage-to-Space

Solar energy stored in the 320 ft^3 storage tank (TSU-1) is used to meet the space heating demands by circulating it through heating ducts in the air distribution system. Auxiliary space heating, supplementing this source, is provided by natural gas-fired furnace (FURN-1).

Water for domestic use is stored in a 120-gallon preheat tank (TSU-2). There is also a 40-gallon (DWH-1) tank which is gas-fired.

AIR CIRCULATION LOOP NO. 1 (COL-1 TO SPACE)

- Heating
  - Maximum design operating temperature - 250° F
  - Heating design air flow - 780 cfm
- Components within circulation loop
  - Blower(s) - BL-1, BL-2
  - Damper(s) - MD-1, MD-2, MD-3, BD-1 and BD-2
- Ducting
  - Type- Jacket fiber
  - Location - Above grade
  - Maximum operating temperature - 250° F
  - Insulation - Glass fiber
  - Exterior finish - Scrim Kraft (Foil)
  - Filters - Fiberglas
- Blower (BL-2)
  - Manufacturer - Carrier
  - Model name/number - Unknown
  - Type - Squirrel cage
  - Design conditions
  - Motor size - 0.33 HP; 115 V; 1 phase; 60 Hz

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

- Damper (MD-3)
  - Manufacturer - Honeywell
  - Model name/number - Unknown

- Function - ON/Off
- Operation - Automatic, motorized

AIR CIRCULATION LOOP NO. 3 (TSU-1 TO SPACE)

- Heating
  - Maximum design operating temperature - 250° F
  - Heating design air flow - 780 cfm
- Components within circulation loop
  - Blower(s) - BL-2
  - Thermal storage unit(s) - TSU-1
  - Damper(s) - D-1, D-2, MD-1, MD-2, MD-3, BD-1 and BD-2
- Ducting
  - Type - Rigid Glass Fiber
  - Location - Above grade
  - Maximum operating temperature - 250° F
  - Thermal resistance - Unknown
  - Insulation - Glass Fiber
  - Exterior finish - Scrim Kraft
  - Filter - Fiberglas

AIR CIRCULATION LOOP NO. 5 (SPACE HEAT)

- Heating
  - Maximum design operating temperature - 250° F
  - Heating design air flow - 780 cfm
- Components within circulation loop
  - Blower(s) - BL-2 (Part of FURN-1)
  - Damper(s) - MD-2 and MD-3

- Ducting
  - Type - Jacket Fiber
  - Location - Above grade
  - Maximum operating temperature - 250° F
  - Thermal resistance - R-22
  - Insulation - Glass Fiber
  - Exterior finish - Foil

LIQUID CIRCULATION LOOP 6 (HOT WATER SUPPLY)

- Design maximum operating temperature - 140° F
- Design maximum operating pressure - Unknown
- Heating
  - Design liquid flow - Unknown
  - Design pump speed - Unknown
- Heat transfer medium
  - Volume of liquid in loop - Unknown
  - Anticipated liquid temperatures
    - Maximum - 180° F
    - Minimum - 70° 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
  - Medium manufacturer's recommended use temperature
    - Maximum - 180° F
    - Minimum - 120° F

- Toxicity - Potable
- pH Factor - 7.0
- Chemical feeder - No
- Inhibitor - No

- Components within circulation loop
  - Domestic water heater(s) - DWH-1
  - Thermal storage unit(s) - TSU-2
  - Valve(s) - V-1, V-2
  - Other(s) - FC-1, FC-2
  - Piping
    - Rigid - Copper
    - Interior coating - None
    - Insulation - None
    - Location - Above grade
    - Filters - No
    - Getters - No

- Distribution Valve (V-1)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Function - ON/OFF
  - Operation - Manual
  - Type - Gate

- Distribution Valve (V-2)
  - Manufacturer - Watts
  - Model name/number - N 170 (70A)
  - Function - Flow adjusting
  - Operation - Automatic, motorized

- Type - Hot Water Tempering
- Manufacturer's rated operating conditions
  - Pressure - 150 psi
  - Temperature - 120° F to 160° F

- Flow Control (FC-1)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Pressure/Temperature Relief Valves
- Flow Control (FC-2)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Type - Pressure Relief Valve

CONTROL MODE SELECTOR (CMS-1)

- Manufacturer - Solaron
- Model name/number - HC-0115
- Modes controlled
  - Collector to space
    - ON - (SN-5) + 2° F < thermostat setting
      - (SN-1) > (SN-2) + 40° F
    - OFF - (SN-1) < (SN-2) + 25° F
  - Storage to space
    - ON - (SN-5) + 2° F < Thermostat setting
      - (SN-3) > 90° F
    - OFF - (SN-5) + 2° F $\geq$ thermostat setting
- Sensors (SN-1, SN-2, and SN-3)
  - Type - Temperature, Thermistor
- Sensor (SN-5)
  - Type - Thermostat

CONTROL MODE SELECTOR (CMS-2)

- Manufacturer - Solaron
- Model name/number - AU
- Modes controlled
  - Auxiliary heat to hot water
    - ON - (SN-7) < 140° F
- Sensor (SN-7)
  - Type - Temperature, thermistor

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

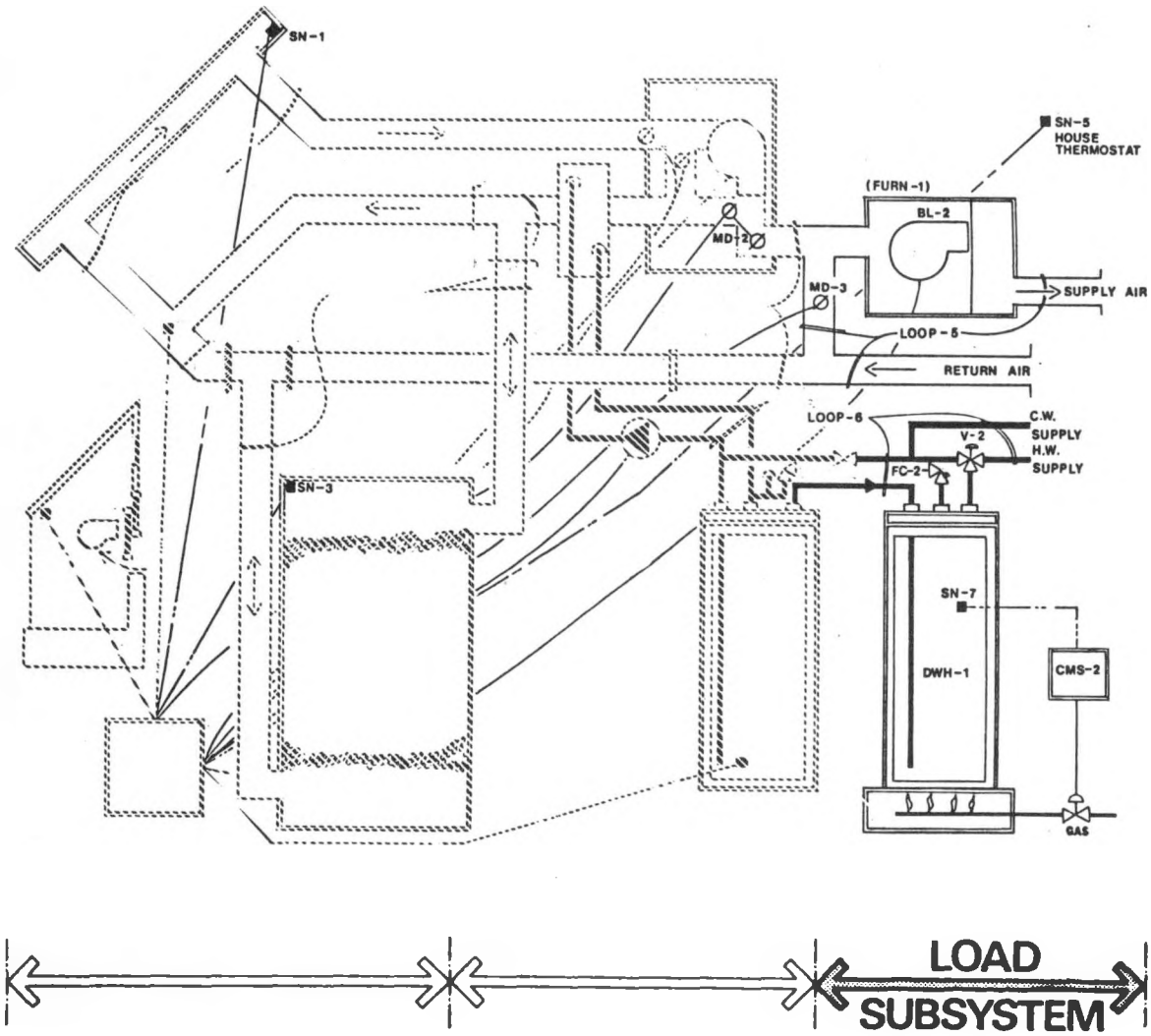


Figure IV-E-1. Auxiliary-to-Load Subsystem

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

AUXILIARY LOADS

- Domestic Water Heater (DWH-1)
  - Manufacturer - A.O. Smith
  - Model - PGC-40850
  - Energy source - Natural gas
  - Tank size - 40-gallon
  - Energy input - 32,500 Btu/hr
  - Energy output - 22,700 Btu/hr
  - Maximum pressure rating - Unknown
  - Maximum temperature rating - 200° F
  - Design operating pressure - Unknown
  - Heating stages - Single
  - Maximum recovery rate - 28 gal/hr
  - Yearly average inlet temperature - 55°F
  - Design output temperature - 140° F
  - Thermal resistance - R-18
  - Standby heat loss - 0%
  - Corrosion protection anodes - No
  - Burner ignition method - Gas pilot
  - Flue vent - Yes
- Furnace (FURN-1)
  - Manufacturer - Carrier
  - Model name/number - 58ES080-3D Series 314
  - Energy source - Natural Gas
  - Energy input - 80,000 Btu/hr
  - Energy output - 64,000 Btu/hr

- Burner ignition method - Gas Pilot
- Flue vent - Yes

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

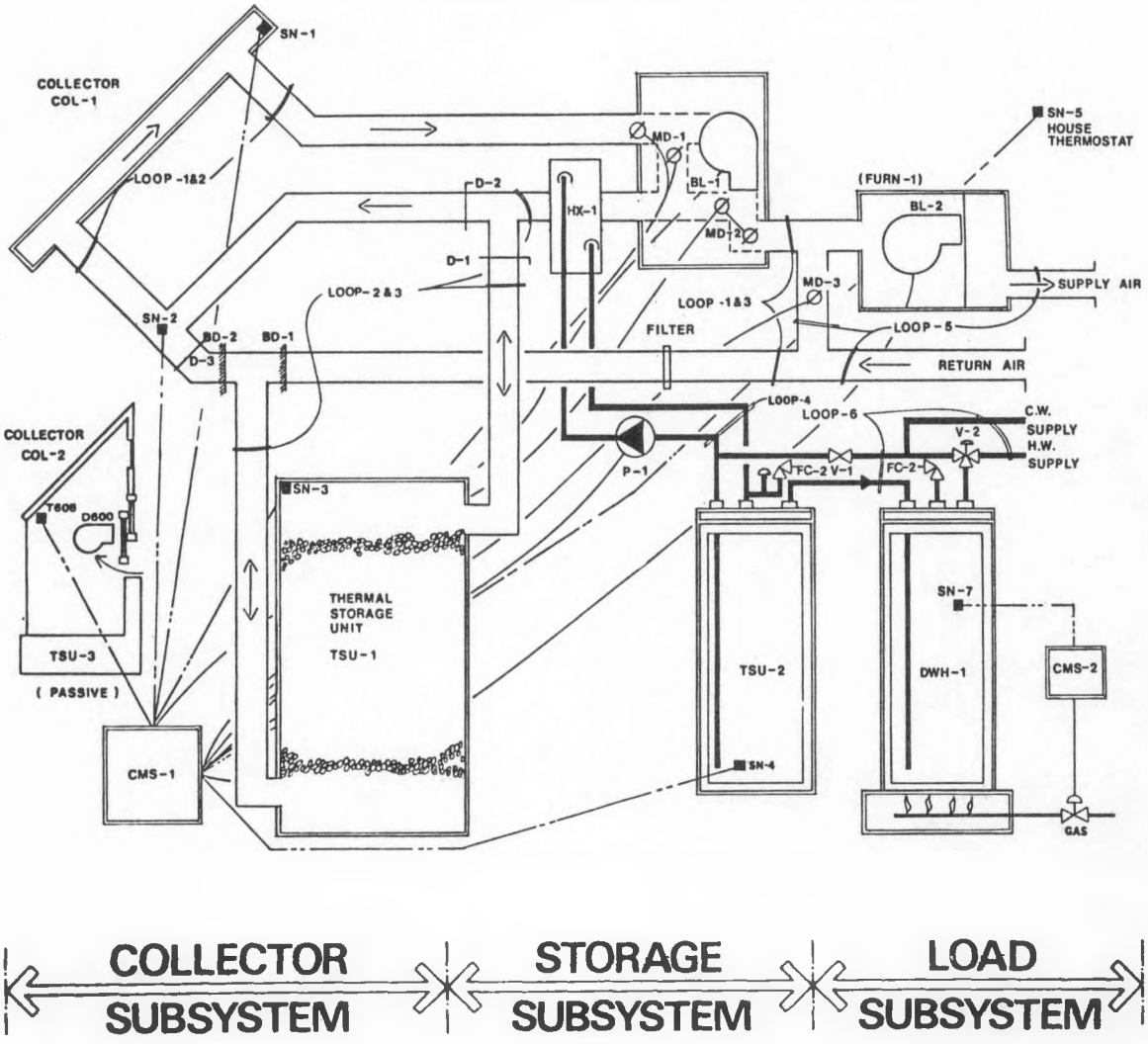


Figure IV-F-1. Controls Diagram

The John Byram, Jr. active solar system is shown on figure IV-F-1. The system consists of the following four subsystems: a) Collector, b) storage, c) load (space heating and DHW) and d) auxiliary load subsystems, and has four modes of operation.

ACTIVE SOLAR SYSTEM

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

Mode 1 - Collector-to-Space Heating:

This mode activates when the collector is operating and a space heating demand exists. Solar collection operations are controlled by temperature sensors located in the inlet and outlet ducts. When the collector outlet temperature exceeds the collector inlet temperature by 40° F, solar energy collection begins and continues until the temperature difference is less than 25° F.

Mode 2 - Collector-to-Storage and DHW Preheating:

This mode activates when the collector is operating and there is no demand for space heating. This mode terminates when solar energy collection stops. Control for solar energy collection is the same as in mode 1. The DHW preheat operation activates when the collector is operating and an aquastat located in the preheat tank indicates that a DHW preheat demand exists.

Mode 3 - Storage-to-Space Heating:

This mode activates when there is a demand for space heating, the collector is not operating, and the temperature of storage is higher than 90° F. This mode terminates when either the space heating demand is met or the collectors start operating under the conditions of mode 1.

Mode 4 - Summer Mode, DHW Preheating:

This mode activates when there is a DHW preheat demand and the collectors are operating.

V. SOLAR SYSTEM DESCRIPTION, PASSIVE

A. General Overview (see figure V-A-1)

PASSIVE SOLAR HEATING SYSTEM

The main entrance to the house is through a small room with a cobblestone floor and large, south-facing glass windows. The floor of this room is 16 inches thick and made of reinforced concrete and granite. The partition between this room and the main living area is a brick wall below double hung windows. This area serves as a greenhouse and functions in the winter as a passive solar space heating system.

Solar heat passing through the exterior windows is collected and stored in the Trombe Wall and the floor. Heat is provided to the main living areas either by opening the interior set of windows and door, or by turning on a low wattage fan which blows hot air through a ceiling duct into the Great Room. Excessive heat loss at night through the windows is prevented by use of heavily insulated drapes enclosed in a box valance. Shade from deciduous trees in the front yard prevents this room from overheating in the summer.

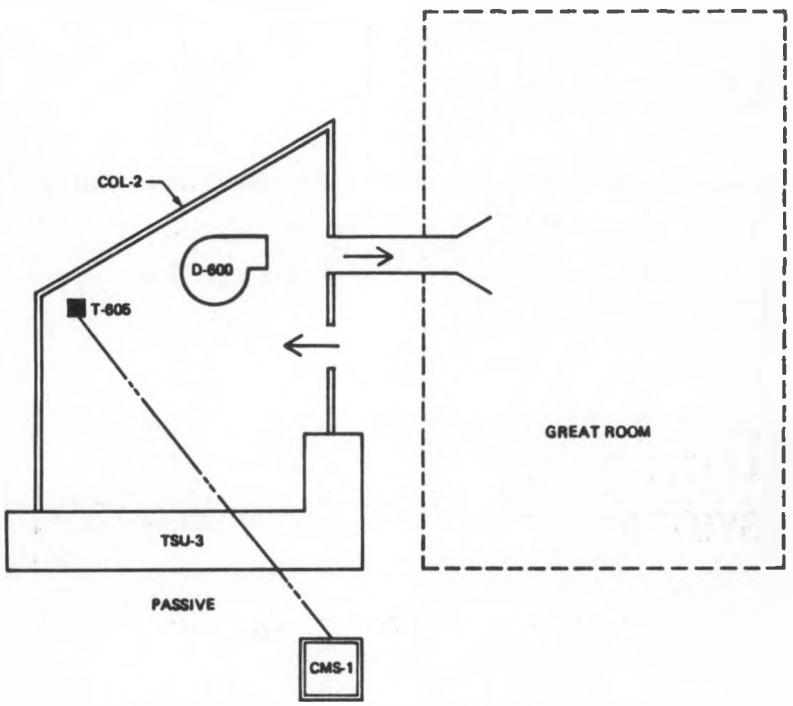


Figure V-A-1. Passive Solar Heating System

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

Collector (COL-2) array consists of a greenhouse with thermopane windows, which act as a passive collector. The thermopane windows are double hung with a storm window.

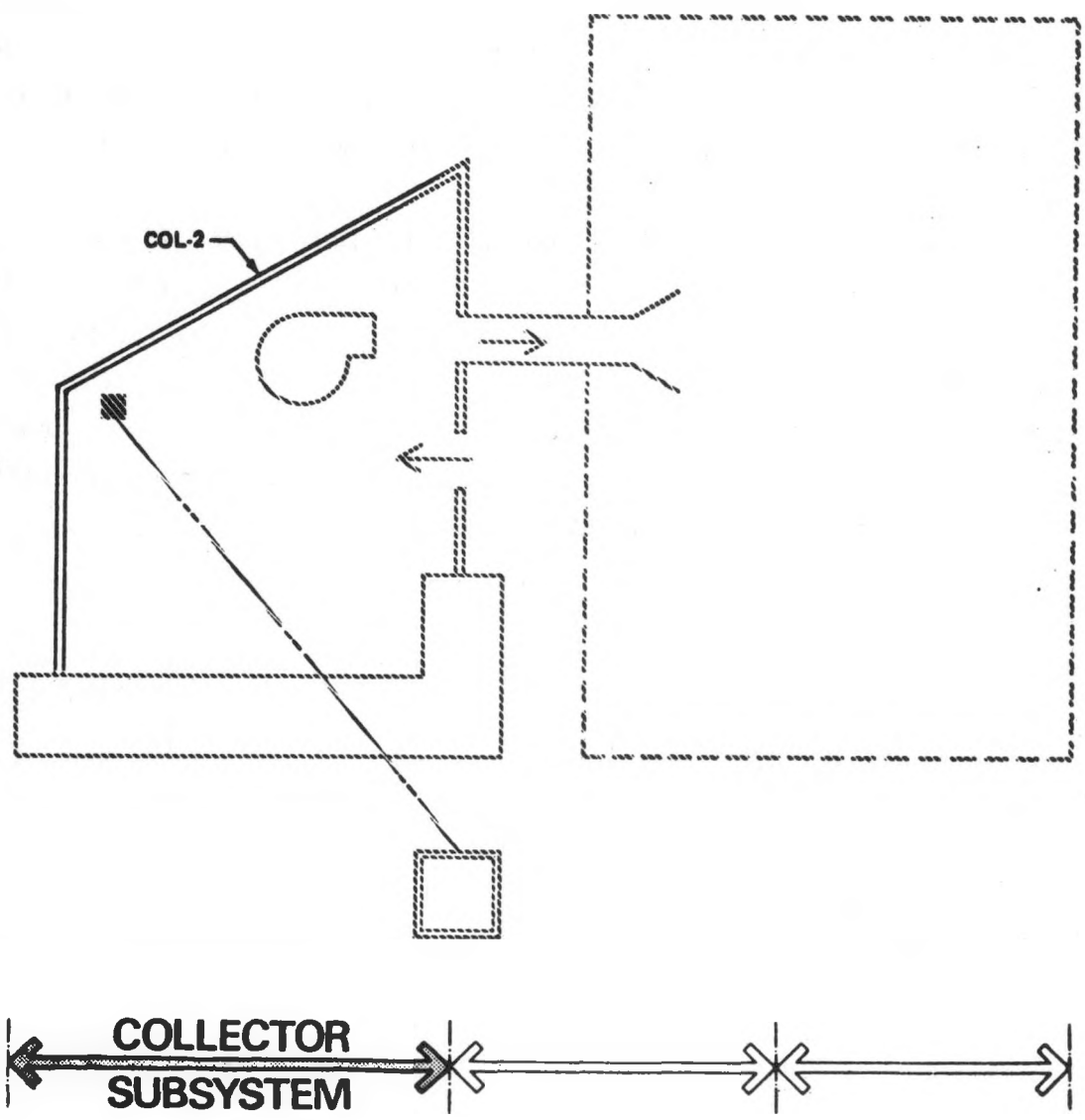


Figure V-B-1. Collector Subsystem

COLLECTOR, TYPE NO. 2

- Manufacturer - Unknown
- Model name/number - Greenhouse
- Type - Passive collector
- Location - South windows of greenhouse and floor
- Tilt - 90^{o} from horizontal (vertical windows and horizontal floor)
- Collector characteristics
  - Number of panels - Windows, Double Hung
  - Total gross area of array - 99 ft^2
  - Net aperture area - 99 ft^2
  - Net absorber area - 99 ft^2
  - Weight per panel, empty - Unknown
  - Weight per panel, full - Unknown
  - Weight of filled array and support structure - Unknown
  - Panel length - Unknown
  - Panel width - Unknown
  - Frame depth - Part of supporting structure
  - Standoff height - None
- Built-in collector - Yes, in exterior wall and floor (TSU-3)
- Collector shading -
  - Area shaded in June - 90%
  - Area shaded in December - 10%
  - Maximum shade during functional season - Winter is functional season in this case, therefore, the shading is 10%
- Cover plates
  - Number of cover plates - 2
- Cover plate No. 1 -
  - Location - Outer layer

- Manufacturer - Site built
- Material - Storm windows
- Optical properties

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

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

- Cover plate No. 2
  - Manufacturer - Site built
  - Product Name/Number - Double hung windows
  - Material - Glass
- Absorber
  - Manufacturer - Site built
  - Material - Pink and Black Cobblestone, and 4" thick concrete slab
  - Substrate material dimension
    - Thickness - 10 in. cobblestone
  - Number of absorbers per collector - 2 (10 inch thick layer of cobblestones and 4 inch thick concrete slab)
- Coating - None
- Heat transfer fluid passages
  - Location - Above absorber
  - Materials - Airspace within room
- Insulation
  - Layer one - sides
    - Manufacturer - Site-built
    - Product Name/Number - Exterior Wall
    - Material - Glass fiber and 2 in by 6 in studwall

- Thermal resistance - R-22

o Layer two-sides

- Manufacturer - Site-built
- Product name/number - Interior Wall
- Material - 2 in by 4 in Stud wall
- Thermal resistance - R-3

o Layer one - back

- Manufacturer - Site-built
- Product name/number - Site-built
- Material - Short Trombe Wall and door
- Thermal resistance - R-2

o Frame

- Manufacturer - Site-built
- Product Name/Number - House walls
- Material - Wood
- Protective coating - None
- Standoffs used - No
- Number of structure attach points per module to building - Continuous
- Built-in collector - Part of load supporting structure

o Reflectors - None

- Desiccant - No
- Freeze protection - No
- Overheating protection - Heat blown to storage

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

Solar energy is stored by 180 ft^3 mass floor and trombe wall. It measures 21.5 ft x 6.0 ft x 3 ft and is constructed with wood, concrete, and cobblestones.

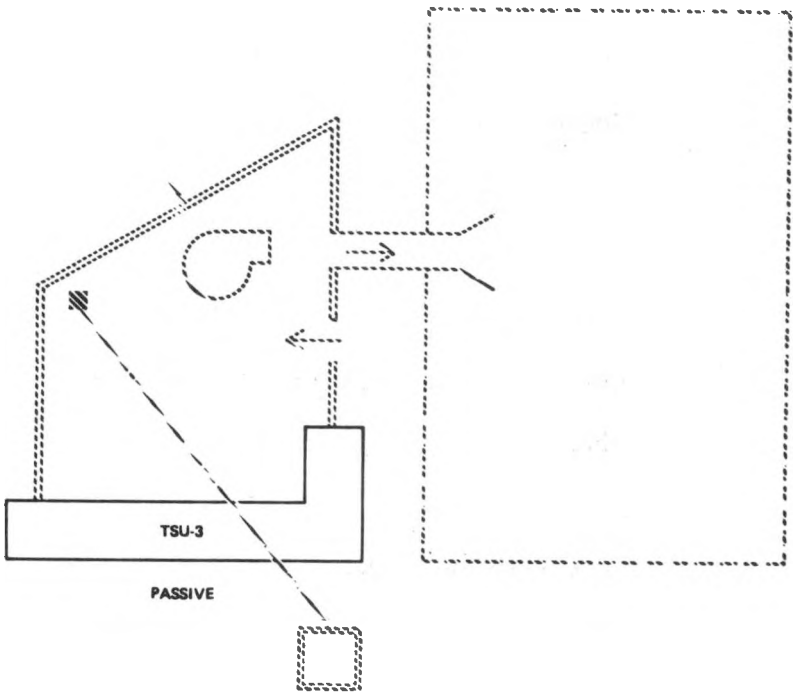


Figure V-C-1. Storage Subsystem, Passive

Thermal Storage Unit (TSU-3, Greenhouse Passive System)

- Manufacturer - Site built
- Model name/number - (Mass Floor)
- Total storage container volume - 180 ft^3
- Volume of storage medium - 180 ft^3
  - Length - 21.5 ft
  - Width - 6.0 ft
  - Thick - 14 inches

  (Mass floor)
- Maximum rated operating conditions
  - Temperature - 90° F
- Storage medium

- Design operating temperatures

  Heating - 90^{o} F
- Medium - Cobblestone/Concrete
- Specific heat - 0.17 Btu/lb/^{o} F
- Density - 133 lb/ft^{3}
- Heat capacity - 23 Btu/ft^{3}/^{o} F

- Medium manufacturers recommended use of temperature
  - Maximum - 90^{o} F
  - Minimum - As set by user
- Wall construction (Between greenhouse and great room)
  - Type - Concrete/Wood/Cobblestone
  - Interior lining - None
  - Location - Above grade
  - Auxiliary heaters - No
  - Insulation - Glass fiber, 5½ in. Batt
  - Exterior finish - None
  - Filters - No

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

Solar heat which is collected and stored in the floor provides heat to the main living areas by opening the interior set of windows and door or by turning on fan D600 which blows the warm greenhouse air thorugh a ceiling duct into the Great Room.

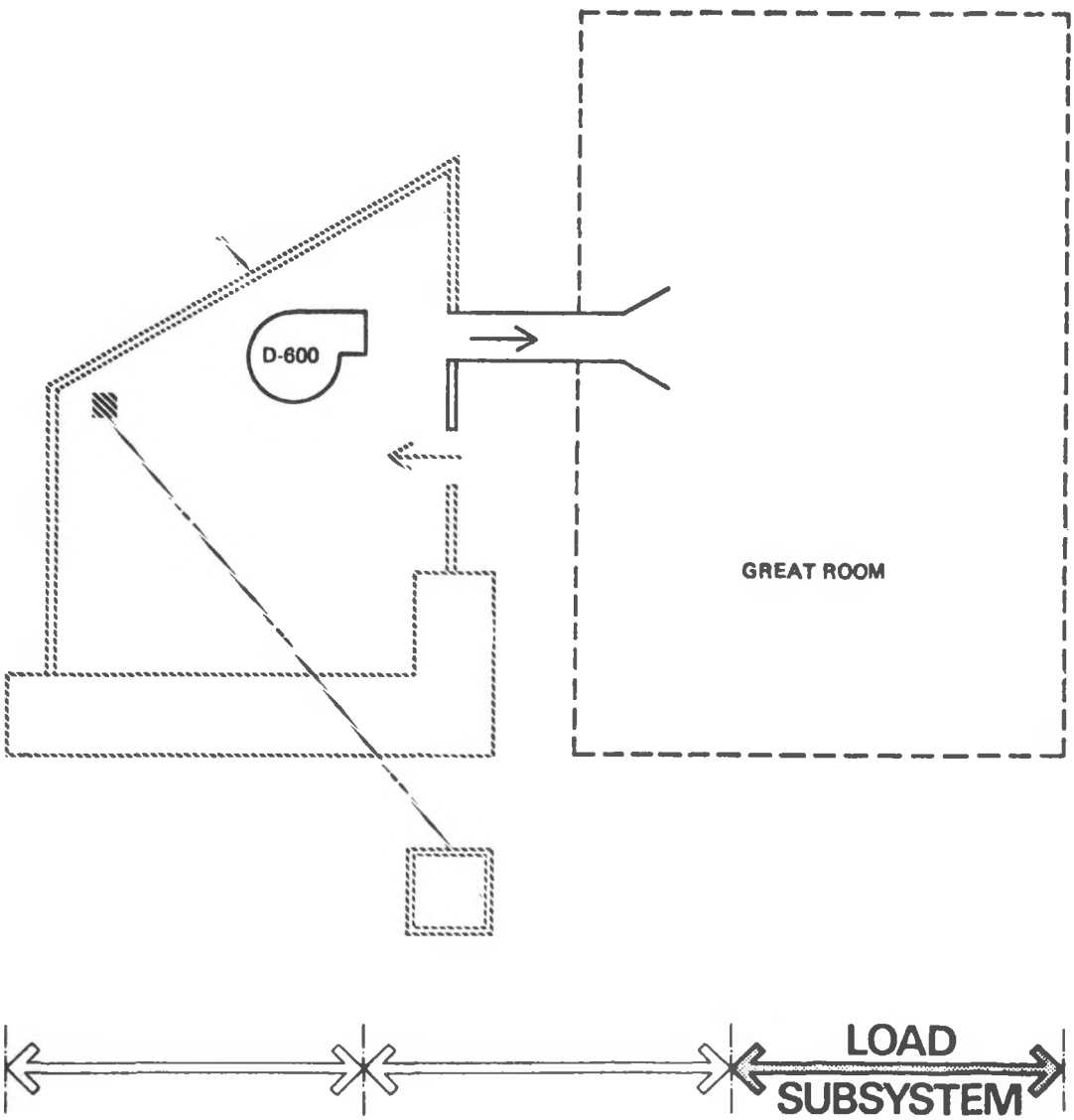


Figure V-D-1. Energy-to-Load Subsystem

AIR CIRCULATION LOOP NO. 7 (COL-2 TO SPACE)

- Heating
  - Maximum design temperature - 90° F
- Components within circulation loop
  - Fan - D 600
  - Thermal Storage Unit - TSU-3
  - Damper - Window between the greenhouse and the great room are utilized as dampers
- Fan (D 600)
  - Manufacturer - Unknown
  - Model name/number - Unknown
  - Motor size - Unknown
  - Design conditions
    - Circulating volume - 800 cfm
- Control Mode Selector (CMS-1)
  - Manufacturer - Solaron
  - Modes controlled
    - Passive Greenhouse to Space Heat

      - ON - (SN-6)>90° F
  - Sensor (SN-6)
  - Type - Thermostat

E. Modes of Operation (see figure V-E-1)

The John Byram Jr. passive system is shown on figure V-E-1. The system consists of a) Collector, b) storage and c) spaceheating and has two modes of operation.

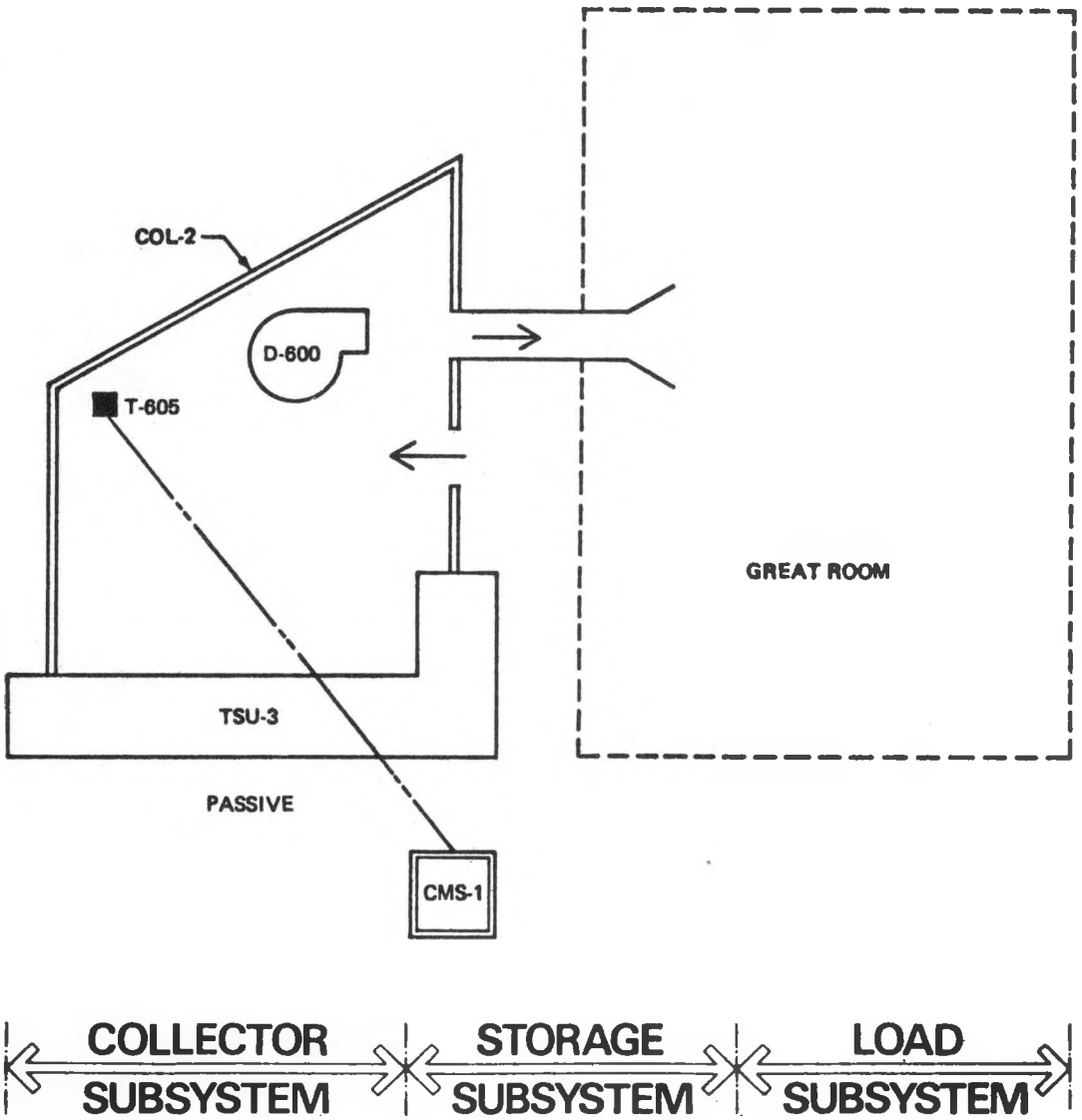


Figure V-E-1. Controls Diagram

PASSIVE SOLAR SYSTEM

Operation of the passive solar system involves the following modes of operation.

Mode 1 - Winter Mode, Space Heating

Heat is provided to the main living area either by opening the interior set of windows and door or by turning on a low wattage fan which blows warm air through a ceiling duct.

Mode 2 - Excessive Heat Loss Prevention

Excessive heat loss at night is prevented by use of heavily insulated drapes enclosed in a box valance.

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.

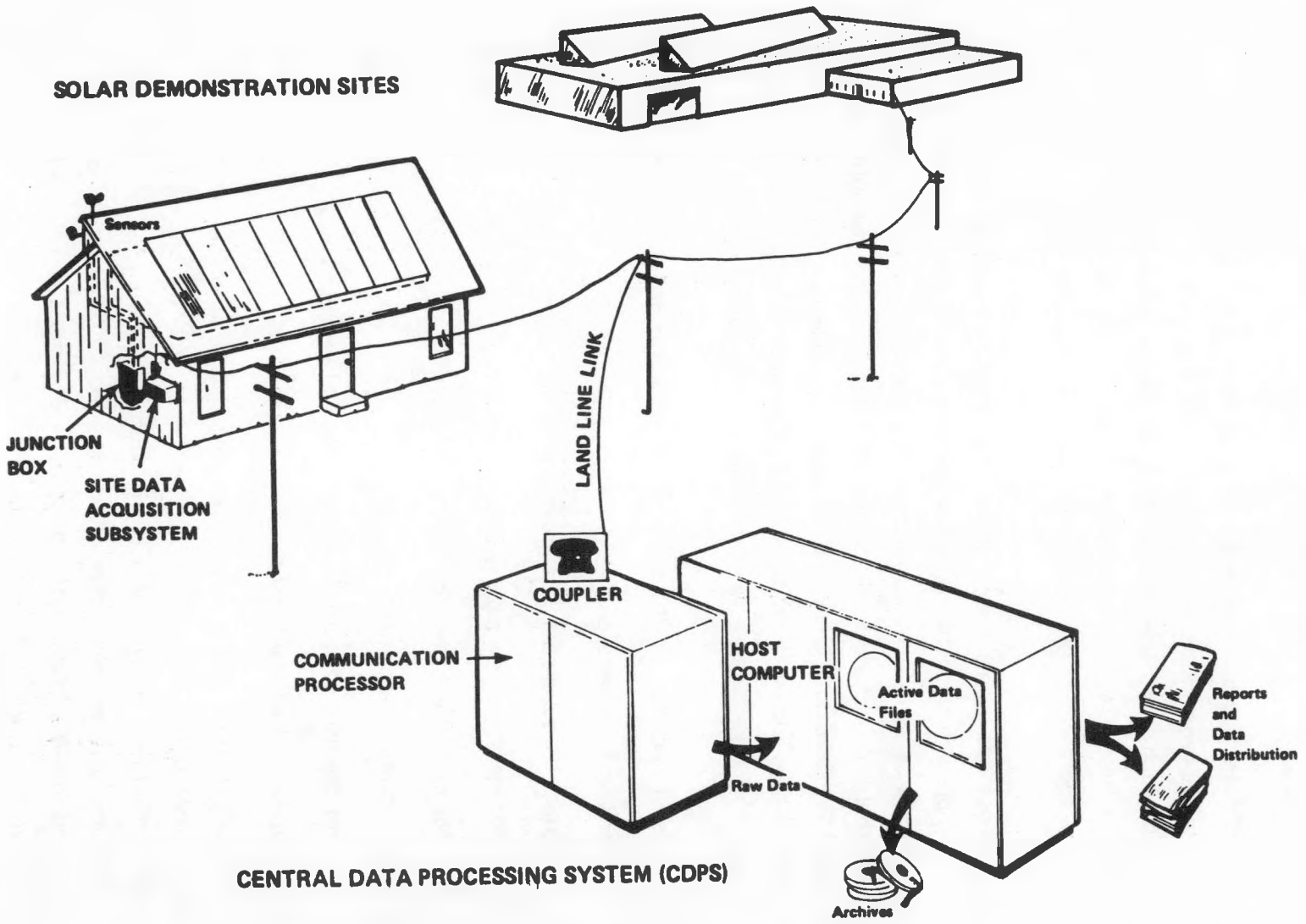


Figure VI-A-1. The National Solar Data Network

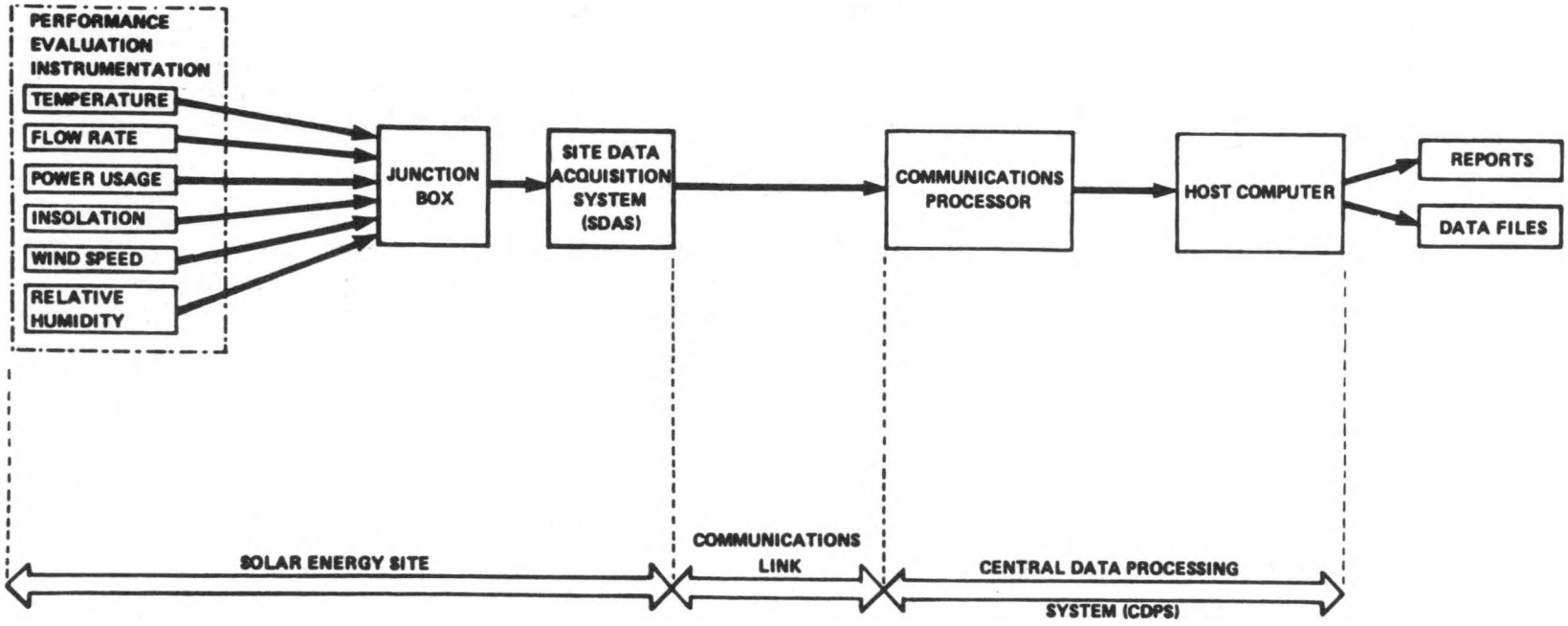


Figure VI-A-2. Data Flow Path for the National Solar Data Network

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

B. On-Site Instrumentation

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

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Solar Insolation	Eppley PSP
T001	Temperature, outside ambient	S53P-60
T100	Temperature, collector inlet	S57P-100
T150	Temperature, collector outlet	S53P-100
W100	Flow, Collector loop	430 DC (Kurz)
W400	Flow, heated space return air	430 DC (Kurz)
T101	Temperature, rock storage top duct	S57P-100
T151	Temperature, rock storage bottom duct	S53P-100
T102	Temperature, air HX input	S57P-100
T152	Temperature, air HX output	S53P-100
EP100	Power, Air handler	O-S PC5-10
T200	Temperature, rock storage top	S53P-60
T201	Temperature, rock storage, mid	S53P-60
T202	Temperature, rock storage, bottom	S53P-60
T300	Temperature, cold water make-up	S53P-60
T350	Temperature, preheat tank outlet	S53P-60
T351	Temperature, DHW tank outlet	S53P-60
W300	Flow, cold water make-up	Hersey PN 430
EP300	Power, hot water circulation pump	PC5-103
W301	Flow, hot water circulation loop	FLOSCAN 300-3
T302	Temperature, DHW HX coil inlet	S53P-60
T352	Temperature, DHW HX coil outlet	S53P-60
W302	Gas consumption of DHW heater	AC-175
T400	Temperature, furnace inlet air	S57P-100
T450	Temperature, furnace outlet air	S53P-100
W401	Gas consumption, furnace	AC-175
EP400	Power, furnace blower	O-S PC5-10
T401	Temperature, heated space return air	S53P-100
T203	Temperature, rock storage exterior	S32B
EP500	Power, air conditioning unit	O-S PC5-29
T303	Temperature, outside surface of preheat tank	S32B
T600	Temperature, Great Room area	S53P-28
RH600	Relative Humidity, Great Room area	W-M HM-111-P

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
T604	Temperature, bedroom/bath area	S53P-28
D200	Contact Closure, position of damper D-3	49-495
D300	Contact Closure, position of damper D-4	49-495
T605	Temp. Greenhouse (west wall)	S53-28
D600	Contact Closure (Greenhouse fan)	W88ACPX-4
D400	Position switch of damper D-5	W88ACPX-4
W200	Air flow, rock bed	430 DC (Kurz)

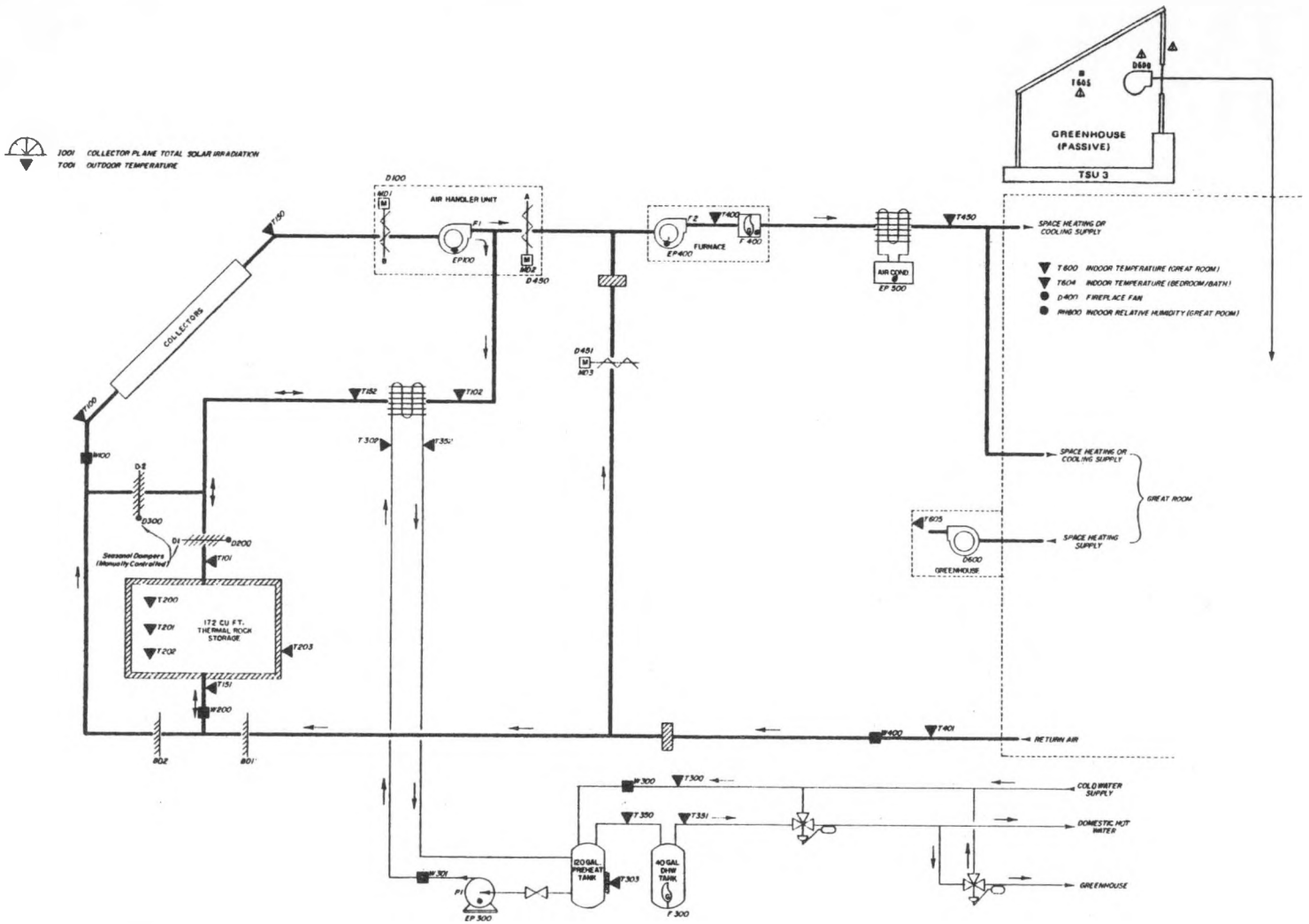


Figure VI-B-1. Sensor and Control Diagram

VII. COST DATA

A. General

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

B. Construction Grant Funds

Solar Subsystem	Applicants Request	Construction Grant
Collectors	$7104	$
Energy Storage	500	
Distribution and Controls	3064	
Installation	3000	
Other (Greenhouse)	3000	
Total	$16,664	$16,664

C. Construction Period: March 1977 through July 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.

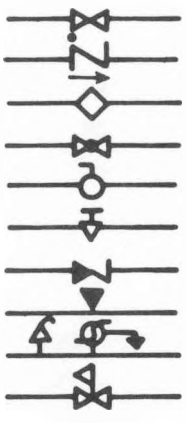
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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.

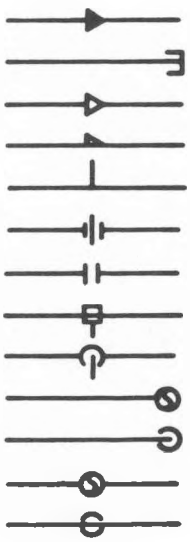
B. Legend For Solar System Schematics

VALVES



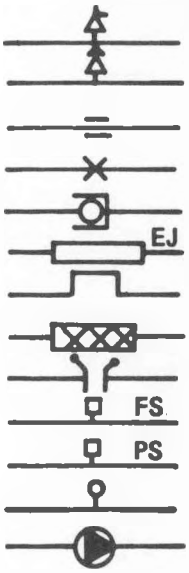
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

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
C
CONTROL SENSOR
INSTRUMENTATION SENSOR
THERMOMETER
THERMOMETER WELL ONLY

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

*U.S. GOVERNMENT PRINTING OFFICE: 1981-740-145/2256