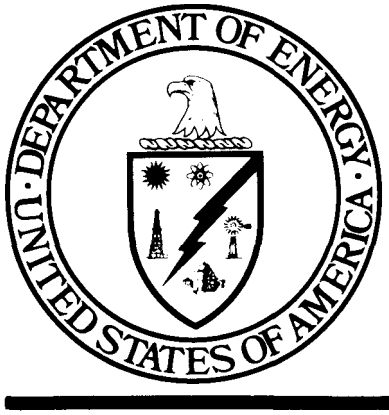
SOLAR/1018-79/50

Solar Project Description

STEWART-TEELE-MITCHELL SINGLE FAMILY RESIDENCE
Malta, NY
December 5, 1979



U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

Solar/1018-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
STEWART-TEELE-MITCHELL
SINGLE FAMILY RESIDENCE - MALTA, NY

Prepared for the
Department of Housing and Urban Development

Under Contract Number
H-2372

David Moore
Solar Heating and Cooling Demonstratin Program Manager

By

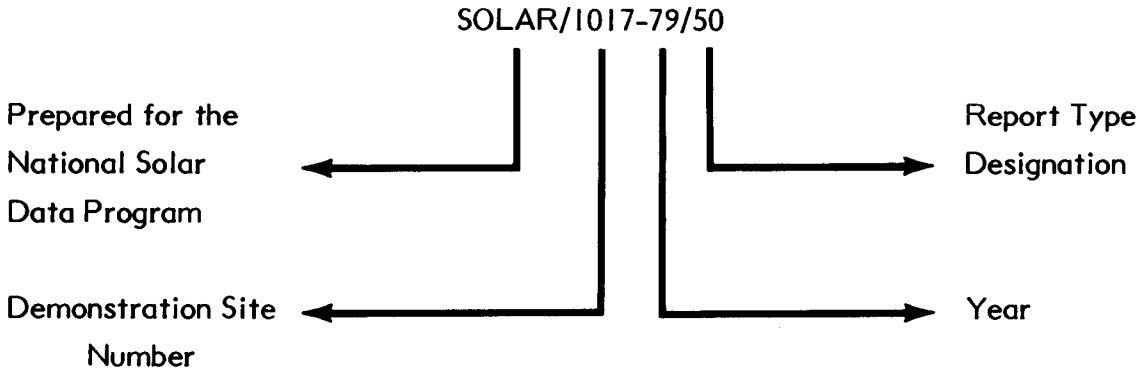
The Boeing Company
David Beers, Program Manager

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 Facilities Development Corporation. Condominiums project site is designated as SOLAR/1017-79/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type - Liquid
- o Freeze Protection - Glycol - Water
- o Application - Heating, domestic hot water
- o Storage - Water, 1000 gallon tank
- o New or Retrofit - New
- o Performance Evaluation Instrumentation - Yes
- o Site-Specific Features - Gas fired boiler auxiliary heating

The Stewart-Teele-Mitchell solar energy system (H-2716) is installed in a 1,900 square-foot, single family dwelling located in Malta, New York. The system is designed to provide solar energy for space heating, and domestic hot water heating.

Solar energy is collected by two banks of flat plate collectors with a gross area of 432 square feet. The two collector banks are mounted on the roof of the house and face due south at an angle of 45^{o} to the horizontal to optimize solar energy collection.

Solar energy is transferred from the collector array to a 1,000 gallon insulated storage tank in the basement. Water is used as the heat collection, transfer and storage medium. Freeze protection is provided by means of a Glycol-Water solution through the collectors.

Space heating demands are met by circulating water from storage through heating coils in the air distribution system of the house. Auxiliary space heating is provided by an oil fired boiler.

Solar energy for heating domestic hot water is stored in a 75-gallon preheat tank and circulates to a conventional 40-gallon domestic hot water heater through a heat exchanger located between the collectors and the solar storage tank. Auxiliary energy for domestic hot water is provided by a natural gas fired DHW tank.

The dwelling has been fully instrumented for performance evaluation since 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 VI of this report. However, the final solar system cost and the cost of its instrumentation are not included in this report.

III. SITE AND BUILDING DESCRIPTION

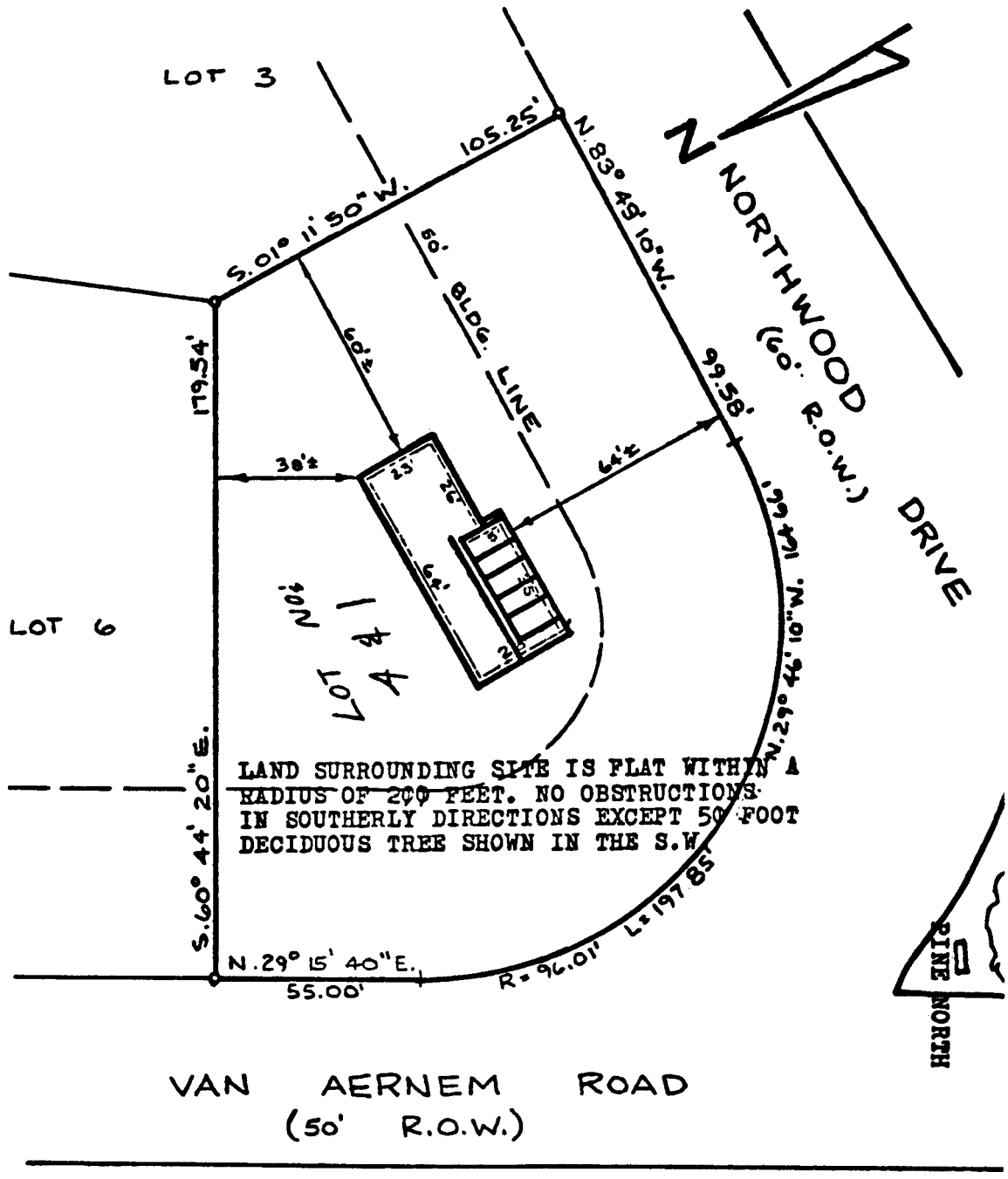


Figure III-1. Site Plan

Building Description (See Figure III-1)

- Type - Single family detached
- Total area - Approximately 1900 sq. ft.
- Solar conditioned area - 1900 sq. ft.
- Roof slope at collector - 45^{o}

Site Description (See Figure III-1)

- Topography - flat
- Latitude - 43^{o}
- Longitude - 74^{o}
- Elevation - 277 ft.
- Design heat loss - 32,600 Btu/hr
- Annual degree days
  - Heating - 6650 $Btu/ft^2/day$
  - Data location - Cambridge, MA
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration
- Average horizontal insolation
  - January - 488 Btu/ft^2
  - July - 1662 Btu/ft^2
- Shading
  - Heating season - 0
  - Cooling season - 0

Mechanical System

- Heating
  - Solar - Liquid active flat plate
  - Auxiliary - Oil fired furnace
  - Distribution - Furnace Duct

Domestic Hot Water

- Daily water demand - 40 gal/day
- Solar - Liquid active flat plate
- Auxiliary - Natural gas

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

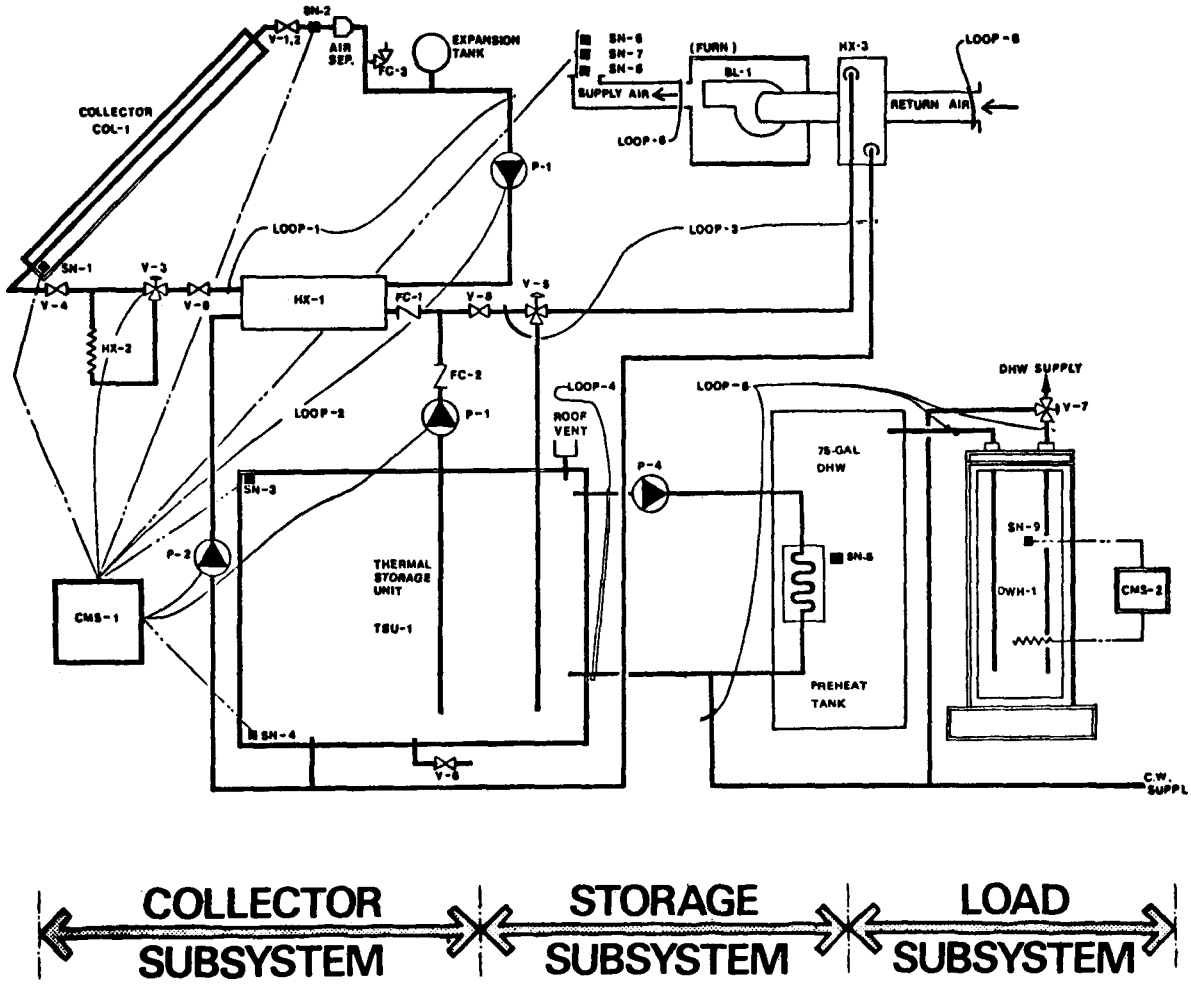


Figure IV-A-1. General Overview

The Stewart-Teele-Mitchell (Grant H-2716) site is a single-family residence in Malta, New York. The home has approximately 1900 square feet of conditioned space. Solar energy is used for space heating the home and preheating domestic hot water (DHW). The solar energy system has an array of flat-plate collectors with a gross area of 432 square feet. The array faces south at an angle of 45 degrees to the horizontal. A glycol/water solution is the transfer medium that delivers solar energy from the collector array to a heat exchanger. Water is then

used as the transfer medium that delivers solar energy from the heat exchanger to storage, to the space heating and DHW loads. Solar energy is stored in the basement in a 1000-gallon insulated tank. Preheated city water is stored in a 75-gallon preheat tank and supplied, on demand, to a conventinal 40-gallon DHW tank. When solar energy is insufficient to satisfy the space heating load, an oil-fired furnace provides auxiliary energy for space heating. Similarly, the DHW tank provides auxiliary energy for water heating by natural gas.

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

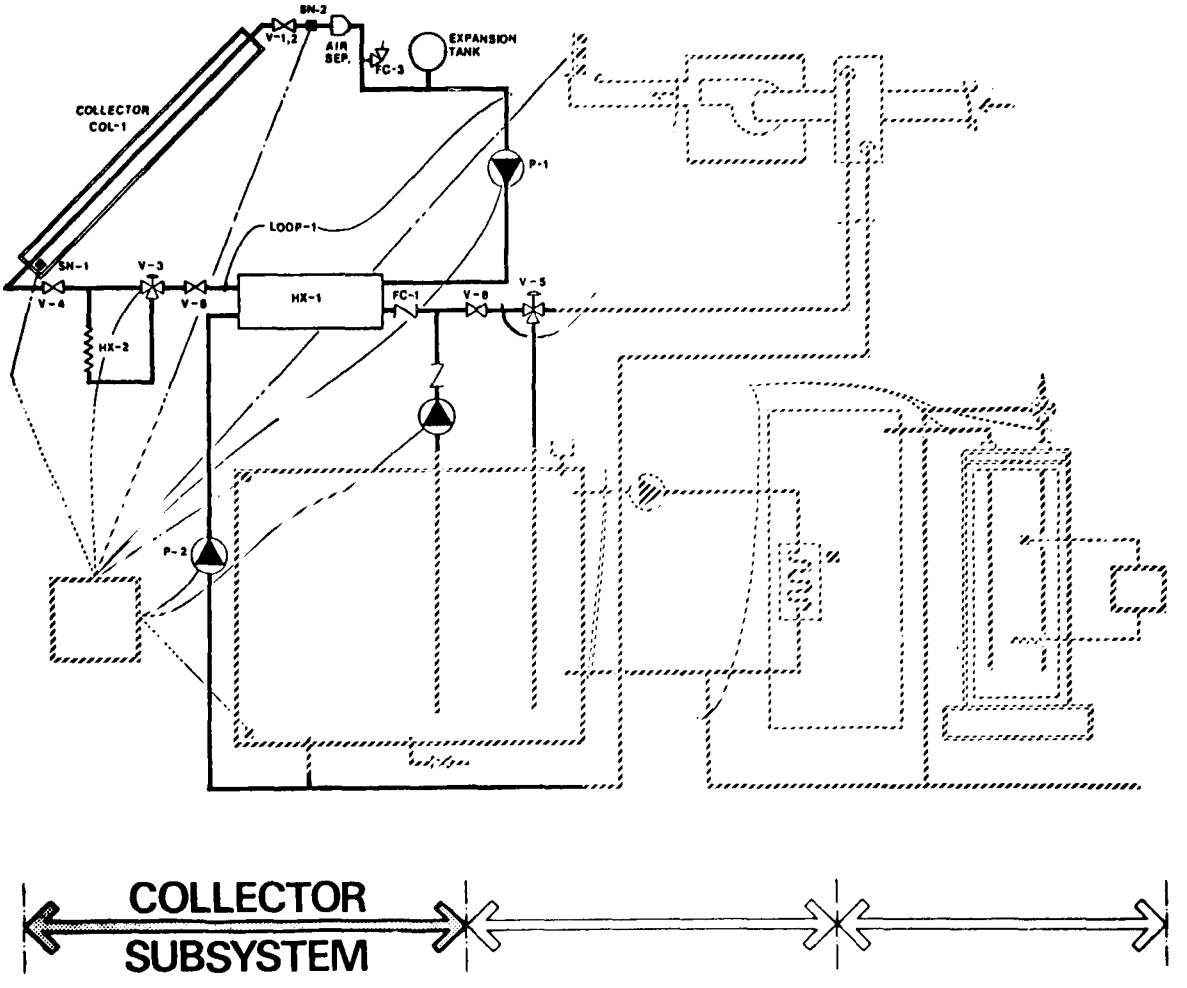


Figure IV-B-1. Collector Subsystem

Collector array system consists of 24 low iron glass, liquid flat plate collector panels with a gross area of 432 square feet. Freeze protection is provided by the addition of glycol in the water flowing to storage from the collectors.

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

- o Manufacturer - Lennox
- o Model Name/Number - LSC 18-IS
- o Type - Liquid flat plate, tube and plate
- o Location - Roof
- o Orientation - Due South
- o Tilt angle - Fixed 45^{o} from horizontal
- o Number of collector panels - 24
- o Array configuration - Two rows of 12 panels in parallel

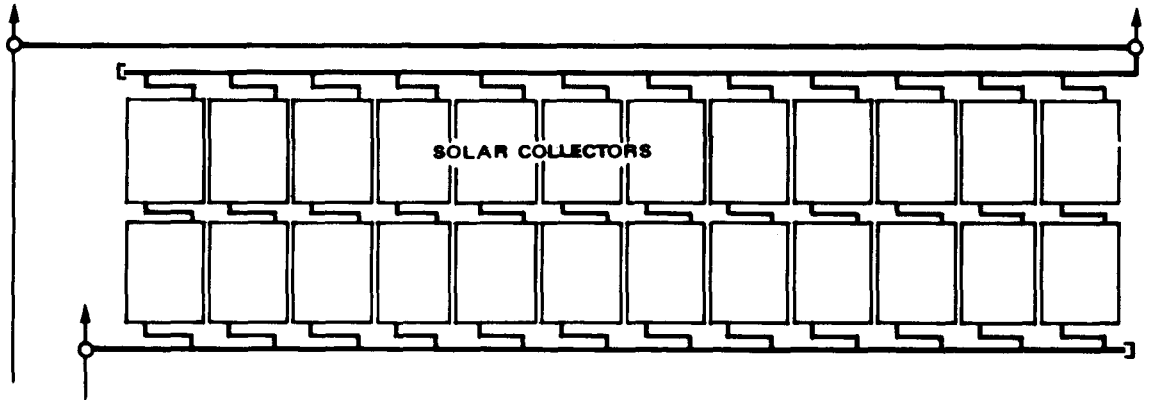


Figure IV-B-2. Solar Collector

- Collector
  - Total gross area of array - 432 sq. ft.
  - Net aperture area - 359 sq. feet
  - Total net absorber area - 370 sq. ft.
  - Weight per panel, empty - 123 lb.
  - Weight per panel, full - 126 lb.
  - Weight of filled array and support structure - 3325 lb.
  - Panel length - 72.1 in.
  - Panel width - 3.4 in.
  - Frame depth - 6.3 in.
  - Standoff height - 3 in.
- Glazing (cover plate)
  - Number of cover plates - One
  - Location - Outer layer of multiple layers
- Cover plate No. 1 -
  - Manufacturer - ASG Ind.
  - Material - Low iron glass
  - Thickness - 0.125 in.
  - Optical properties

	(solar region)	(infrared region)
- Transmittance	95%	00
- Reflectance	4%	4%
- Emittance -	92%	

  - Edge or surface treatment, other than coating - Chemical etch
  - Coating on cover plate material - None
  - Coating function - Anti-reflective
  - Method - Dipped

- Absorber
  - Manufacturer - Lennox
  - Model Name/Number - LSC 18-1S
  - Material - Steel (ASTM A374, A375)
  - Substrate material dimension
    - Thickness - 0.033 uniform
    - Length - 64.75 in.
    - Width - 31.8 in.
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - Norrel Corp.
  - Material - Black chrome over bright nickel
  - Application method - Electro plated

	Solar	Infrared
o Absorptance,	95%	10%
o Reflectance,	5%	90%
o Emittance -	10%	

- Heat transfer fluid passages
  - Location - In absorber
  - Pattern - Parallel
  - Materials - Copper tube 194 HSM
  - Wall thickness - 0.028 in.
  - Internal diameter - 0.194 actual
  - Maximum operating conditions
    - Temperature - 450° F
    - Pressure - 150 psi

- Fluid passage bond to substrate - Mechanical 95-5 Silver Solder brazing
- Protective coating inside fluid passage - None

- Insulation
  - Layer one - sides
    - Manufacturer - Certainteed Co.
    - Product Name/Number - CGS - 850
    - Material - Glass fiber
    - Thermal resistance - R-4
    - Binder - Phenolic
  - Layer one - back
    - Manufacturer - Certaineed Co.
    - Product Name/Number - GGS - 850
    - Material - Glass fiber
    - Thermal resistance - R-13

- Gaskets and sealants
  - Inner cover - Not specified
  - Outer cover - Not specified
  - Frame joint - Acrylic solvent release type Acryl-R-5514
- Frame
  - Manufacturer - Kawner
  - Product Name/Number - A603T5
  - Material - Aluminum Glass Frame
    - Other - Galvalume Collector
  - Protective coating - Anodized
  - Number of structure attach points per module to building - 4

- Desiccant - No
- Freeze protection - Anti-freeze/water
- Overheating protection - Energy dumping heat exchanger
- Reflector - None

- Collector performance
  - Method of evaluation - NBS
  - y intercept - $F_R (\tau\alpha)_n$ - 0.81
  - Slope - $F_R U_L$ - 0.96

Point Number	1	2	3	4
η = Collector thermal efficiency (η%) -	47.4	56.5	66.8	14.5
t_i = collector inlet temperature (^{o} F) -	183	153	113	82
t_a = ambient air temperature (^{o} F) -	67	66	64	64
I_t = insolation intensity Btu/hr ft^2 -	341	348	353	355
ASHRAE $(t_i-t_a)/I_t$ -	0.34	0.25	0.14	0.05

  - Test flow rate - 235.0 lb/hr.
  - Test collector area
    - Gross - 18 ft^2
    - Net - 15.4 ft^2
  - Fluid specific heat - 1.00 Btu/lb. ^{o} F
  - Test fluid medium - 100% Water

Liquid Circulation Loop No. 1 (Solar Energy Collector)

- Maximum design operating temperature - 205^o F
- Pressure - 7.5 ft. head
- Heating design liquid flow - 8 GPM
- Design pump speed - 1750 rpm

- Heat transfer medium -
  - Anticipated liquid temperature - 220° F
  - Expansion tank - Yes
  - Water - 50%
  - Ethylene glycol - 50%
  - Specific heat - 0.85 Btu/lb/° F
  - Density - 67 lb/ft^3
  - Heat capacity - 56.95 Btu/ft^3/° F
  - Boiling point - 232° F
  - Freezing point - Minus 40° F
  - Medium manufacturers recommend use temperature - 205° F
  - Toxicity - Non-potable
  - pH factor -7
  - Chemical feeder to maintain pH factor - Yes
  - Inhibitor - Yes
- Circulator pump (P-1)
  - Manufacturer - Bell and Gossett
  - Model Name/Number - Iron and bronze booster pump
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 125 psi
    - Temperature - 220° F
  - Material exposed to heat transfer fluid - Cast iron
  - Motor size - 0.167 HP, 115V, 1 phase, 60 Hz
  - Maximum motor speed - 1750 rpm
  - Drive - Direct

- Pump speed - Single, 1750 rpm
- Circulating volume - Low head mode - 10 GPM
- Operating head (dynamic) - Low head mode - 7.5 psi
- Motor operation - 0.28 bhp

- Heat Exchanger (HX-1)
  - Manufacturer - Bell and Gossett
  - Model Name/Number - WU 65-43
  - Type - Counter
  - Heat Exchanger design
    - Shell & tube
    - Number of tube passes - 4
    - Shell passes - 1
    - Number of separations - Single

	Side One	Side Two
o convection -	Forced	Forced
o Location -	TSU (1)	
	DHW (1)	
o Part of Circulation Loop No. -	Loop 1	Loop 2
o Temperature -	375° F	375° F
o Pressure -	150 psi	300 psi
o Heat transfer/surface area - 22.1 ft^2		
o Description		
	Side 1	Side 2
o Length of tubing -	4 ft	
o Diameter of tubing -	3/4 in	3 in
o Design flow rate -	10 gpm	7.5 gpm
o Material - Copper	Steel	

- Piping
  - Rigid - Copper Type M
  - Piping insulation - Glass fiber
  - Location - Above grade
  - Filters - None
  - Exterior finish
    - Glass cloth
    - Two coats plastic
    - Tape and mastic
- Distribution Valve (V-1)
  - Function - Bleed
  - Operation - Automatic
  - Type - Gate
- Distribution Valve (V-2)
  - Function - Bleed
  - Operation - Automatic
  - Type - Gate
- Distribution Valve (V-3)
  - Manufacturer - Honeywell
  - Model Name/Number - Y8044A - 1044
  - Function - 3 way diverting/Purge valve
  - Operation - Automatic
  - Type - Globe
- Distribution Valve (V-4)
  - Function - Bleed

Liquid Circulation Loop No. 2 (Col to TSU-1)

- Design operating temperature - 205° F
- Pressure - 5.4 ft head
- Heating design liquid flow - 7.5 GPM
- Design pump speed - 1750 rpm
- Heat transfer medium
  - Anticipated liquid temperatures - 205° F
  - Provision for expansion - Roof vent to TSU-1
  - Medium - 100% Water
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 63 lb/ft^3
  - Heat capacity - 63 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 205° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - No
  - Inhibitor - No
  - Piping
    - Rigid - Copper Type M
    - Insulation - Glass fiber
    - Location - Above grade
- Circulator pump (P-2) Loop 2 & 3 circulation
  - Manufacturer - Bell and Gossett
  - Model Name/Number - Iron and Bronze Booster Pump
  - Type - Centrifugal

- Maximum operating conditions
  - Dynamic pressure - 125 psi
  - Temperature - 220° F
- Material exposed to heat transfer fluid - Iron
- Motor size - 0.167 HP, 115V, 1 phase, 60 Hz
- Maximum motor speed - 1750 rpm
- Drive - Direct
- Speed-Single
- Pump speed - 1750 rpm
- Circulating volume - Low head mode - 7.5 GPM
- Operating head (dynamic) - Low head mode - 5.4 psi
- Motor operation - 0.28 bhp

- Distribution Valve (V-5)
  - Manufacturer - Honeywell
  - Model Name/Number -
  - Function - Flow directional
  - Operation - Automatic
  - Type - Load control

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

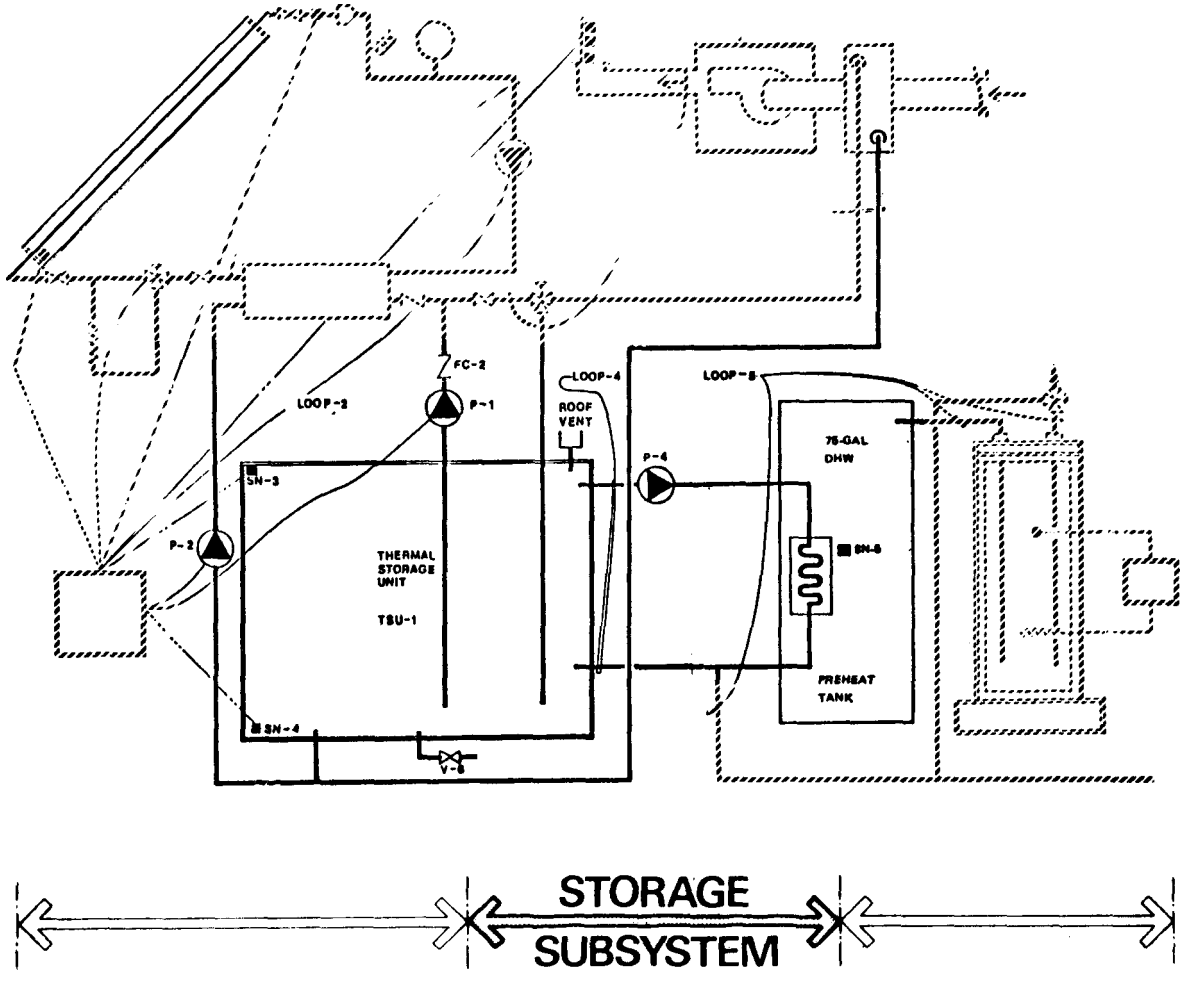


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by a 1,000 gallon storage tank in the basement. This tank is made of metal with an epoxy interior lining. It measures 4 feet in diameter, 10 feet in length, and 5 feet in height. The container is insulated with glass fiber.

- Container construction
  - Type - Metal
  - Interior lining - epoxy
  - Location - In basement
  - Auxiliary heaters - No
  - Insulation - Glass fiber
  - Exterior finish - Unspecified except by exterior insulation
  - Filters - None

Thermal Storage Unit (TSU-1)

- Container
  - Total storage volume - 200 ft^3
    - Length - 10 ft
    - Diameter - 4 ft
    - Height - 5 ft
- Storage medium
  - Heating design temperature
    - Maximum - 205° F
    - Minimum - 100° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Toxicity - Potable
  - pH Factor - 7.0
  - Inhibitor - No

- Heat Transport to and from medium
  - Collector side - No heat exchanger in container
  - Medium flow - Through Loop 2
  - Demand side - No heat exchanger in container
  - Medium flow - Through Loop 3

Liquid Circulation Loop No. 3 (Collector or Storage)

- Design maximum operation temperature - 205° F
- Pressure - 5.4 ft head
- Heating design liquid flow - 7.5 GPM
- Design pump speed - 1750 rpm
- Heat transfer medium
  - 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 - 205° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Piping
  - Rigid - Copper Type M
  - Location - Above grade
  - Filters - None

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

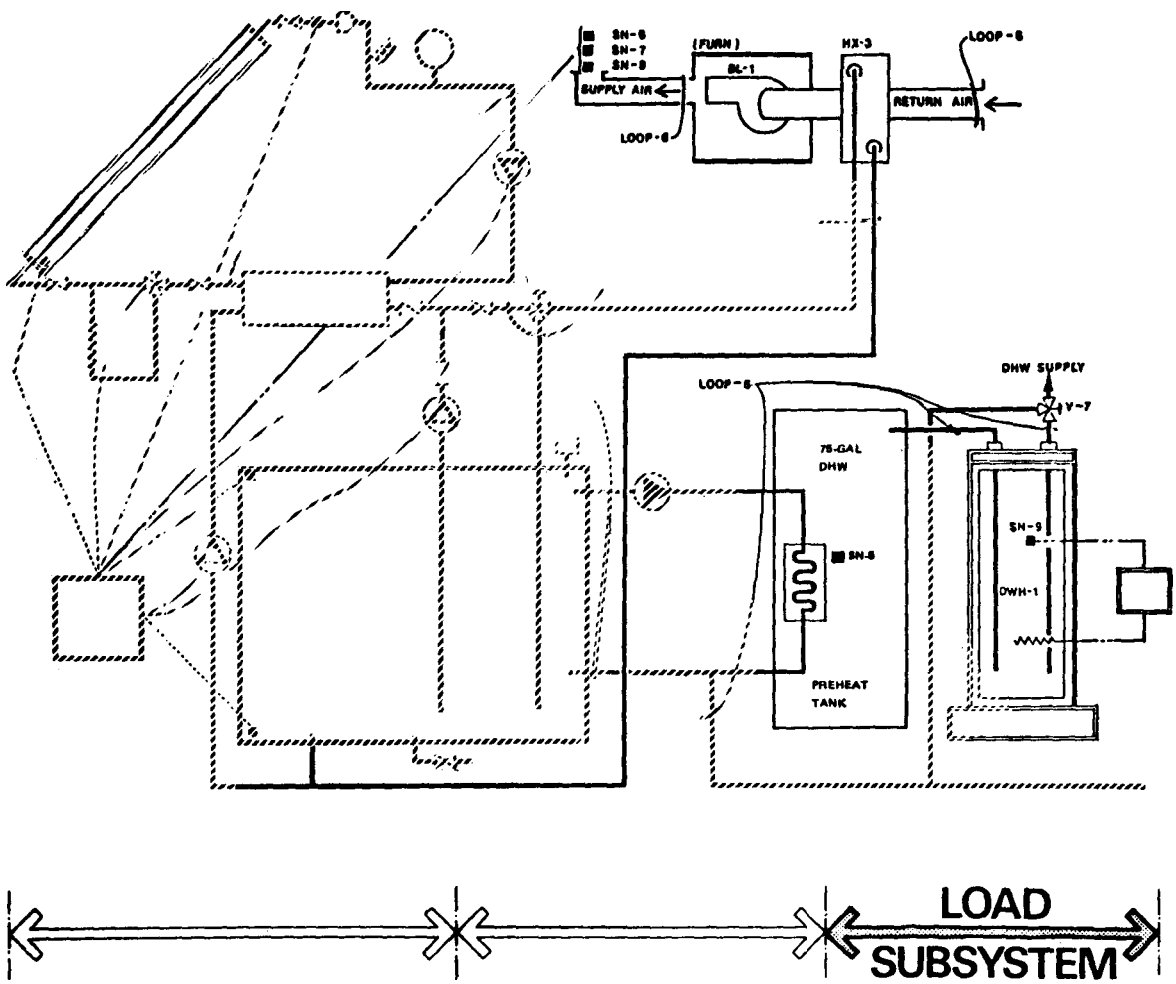


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy is stored in the basement in a 1000-gallon insulated tank. Preheated city water is stored in a 75-gallon preheat tank and supplied, on demand to a natural gas fired conventional 40-gallon DHW tank.

Solar energy is also used for space heating. The stored energy is circulated through a heat exchanger (HX-3) to the oil furnace and through the air ducts by BL-1.

Liquid Circulation Loop No. 4 (TSU-1 to DHW-1)

- Design maximum operating temperature - 205° F
- Heating design liquid flow - 9 GPM
- Heat transfer medium
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 205° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - No
  - Inhibitor - No
- Circulator pump (P-4), TSU-1-to-DHW-1
  - Manufacturer - Taco
  - Model Name/Number - Circulator 007
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 30 psi
    - Temperature - 205° F
  - Material exposed to heat transfer fluid - Stainless - Bronze
  - Motor size - 0.04 HP, 115V, 1 phase, 60 Hz
  - Maximum motor speed - 3450 rpm
  - Drive - Direct
  - Speed - Single

- Pump speed - 3450 rpm
- Circulating volume - Low head mode - 24 GPM
- Operating head (dynamic) - Low head mode - 5.5 psi
- Motor operation - 0.09 bhp

- Heat Exchanger (HX-1)
  - Manufacturer - Ford Products
  - Model Name/Number - AQUA - Coil
  - Type of exchanger - Liquid to liquid
  - Type of flow - Coil in tank, like cross flow
  - Heat exchanger design - Fin coil
  - Number of separations - No information available

	Side one	Side two
Convection -	Forced	Forced
Design flow rate -	9 gpm	HW demand 1.5 gpm
Related pump -	P-3	
Liquid Temperature		
- Entering -	40° F	
- Leaving -		140° F

- Piping
  - Rigid - Copper Type M
  - Insulation - Glass fiber
  - Location - Above grade

Liquid Circulation loop 5

- Maximum operating conditions - 150° F
- Flow rate - House demand

- Heat transfer medium - Water (100%)
- Distribution Valve (V-6)
  - Function - Drain
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid -
- Distribution Valve (V-7)
  - Manufacturer - Watts Regulator Co.
  - Model Name/Number - 70 - A-T Water Tempering
  - Function - 3-way - mixing - Tempering
  - Operation - Automatic
  - Type - Globe
  - Material exposed to heat transfer fluid -
- Heat Exchanger (HX-2)
  - Type of flow - Cross
  - Type of exchanger - Overheat Purge Coil

	Air Side	Liquid Side
o Convection	Natural	Forced
- Effectiveness -	Unknown	Unknown
- Material -	Aluminum	Copper
o Design flow Quantity -	Unknown	10 gpm

Air Circulation Loop No. 5 (HX-3 to Space Heating)

- Flow rate - 1200 cfm
- Components
  - Blower - BL-1
  - Furnace - Gas fired Furn 1

- Heat Exchanger (HX-3)
  - Manufacturer - McQuay Coil
  - Model Name/Number - 5 WH0803
  - Type - Air to Liquid
  - Type of flow - Cross
  - Heat exchanger Design - fin coil

	Air Side	Liquid Side
o Convection -	forced	forced
o Material -	Aluminum	Copper
o Design flow quantity -		10 gpm

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

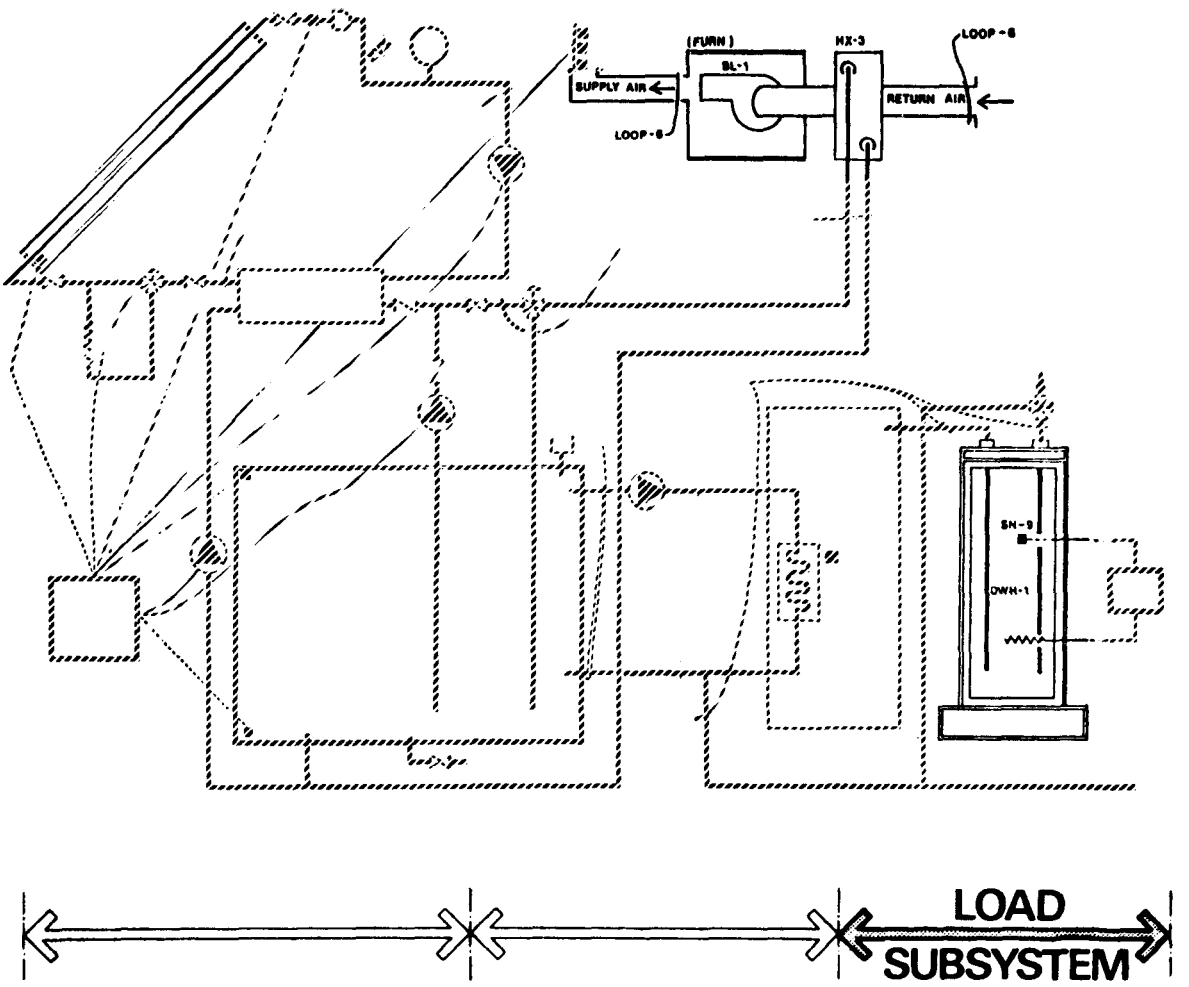


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystems, domestic hot water tank, and furnace 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 (DHW)

- Domestic Water Heater (DWH-1)
  - Manufacturer - Rheem
  - Model - Apollo 100
  - Energy source - Natural gas
  - Tank size - 40 gal
  - Energy input - 30,717 Btu/hr
  - Energy output - 32,500 Btu/hr
  - Maximum pressure rating - 300 psi
  - Maximum temperature rating - 160° F
  - Design operating pressure - 150 psi
  - Heating stages - Single
  - Maximum recovery rate - 40 gal/hr
  - Yearly average inlet temperature - 50° F
  - Design output temperature - 150° F
  - Thermal resistance - R-3
  - Corrosion protection anodes - Magnesium
  - Burner ignition method - Pilot
  - Flue vent - No
- Boiler (FURN-1)
  - Manufacturer - Lennox
  - Model Name/Number - 01103 - 105 UP FLO
  - Energy source - Oil, No 2
  - Energy input - 105,000 Btu/hr
  - Energy output - 84,000 Btu/hr
  - Burner ignition method - Electric

- Blower - BL-1
- Flue vent - Automatic

Control Mode Selector (CMS-1)

- Modes controlled
  - Collector to storage - ON - (SN-1) Less than 100° F
  - Collector to space - ON - (SN-1) Less than 100° F
  - Storage to hot water - ON - (SN-3) less than (SN-5) 1 10
  - Storage to space - ON - (SN-1) Less than 100° F
  - Energy Dumping - ON - (SN-1) Less than 100° F
  - Auxiliary to Space - ON - (SN-1) more than 100%
- Sensor (SN-1)
  - Type - Aquastat
- Sensor (SN-2)
  - Type - Aquastat
- Sensor (SN-3)
  - Type - Aquastat
- Sensor (SN-4)
  - Type - Aquastat
- Sensor (SN-5)
  - Type - Aquastat
- Sensor (SN-6, 7, and 8)
  - Type - thermostat
- Control Mode Selector (CMS-2)
  - Modes controlled - Auxiliary Heat to hot water
  - Sensor - SN9 - Aquastat

- Subsystem Fail Safe Controls
  - Manufacturer - Bell & Gossett
  - Types
    - FC-01 - Check Valve
    - FC-02 - Check Valve
    - FC-03 - Pressure relief Valve (30 psi set point)

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

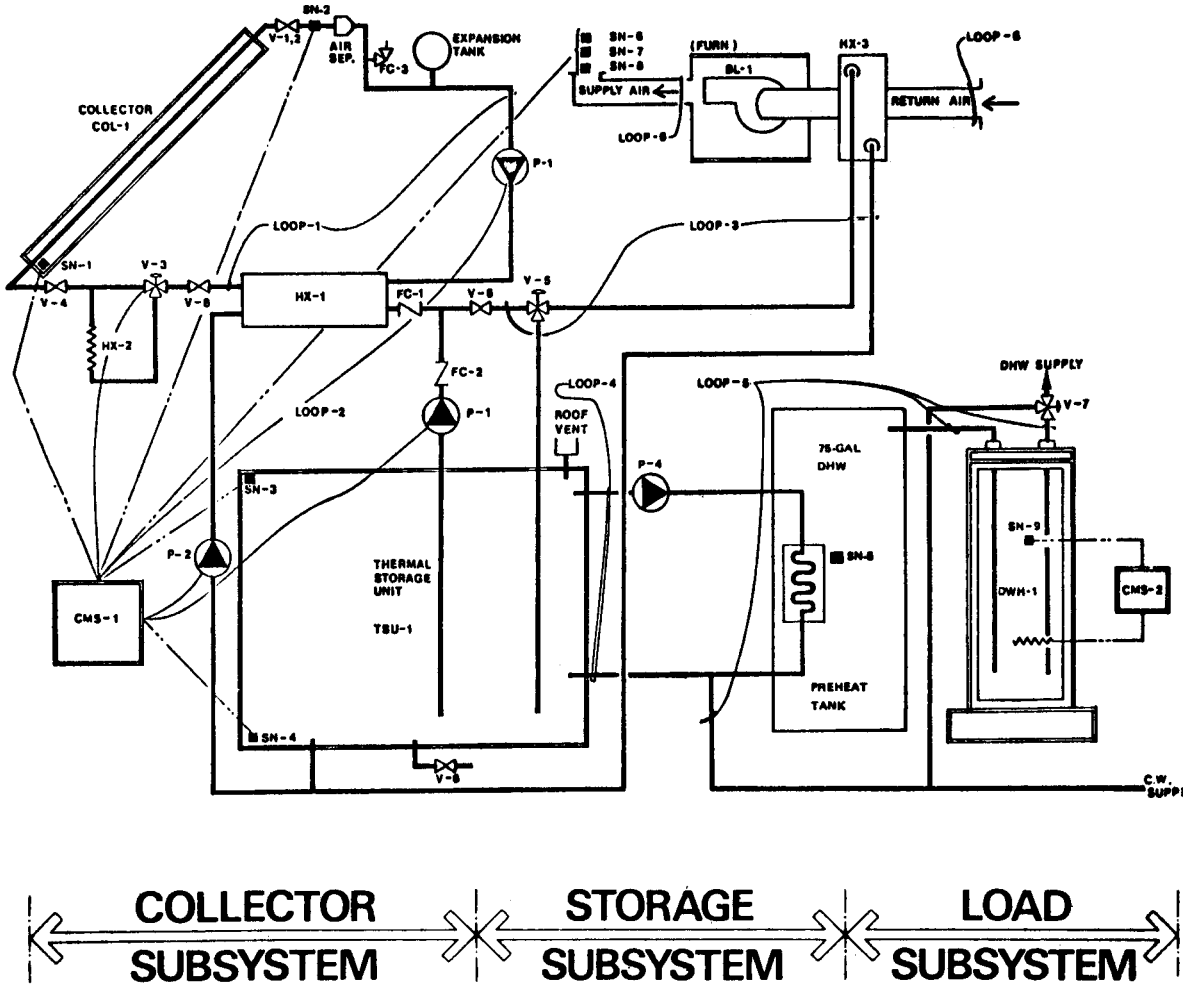


Figure IV-F-1. Controls Diagram

The Stewart-Teele-Mitchell's 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, Preheat DHW) and d) auxiliary loads subsystems. Among the auxiliary subsystems are the natural gas fired DHW and oil fired Furnace.

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

Mode 1 - Collector-to-Storage:

This mode activates when the collector temperature exceeds the storage temperature by 20° F and terminates when a temperature difference of 3° F is reached. Solar energy is transferred through the heat exchanger that transmits energy from the solar collection loop to the storage loop. Collector loop pump P1 and storage loop pump P2 are operating.

Mode 2 - Collector-to-Space Heating:

This mode activates when mode 1 conditions are satisfied and there is a demand for space heating. The collected solar energy bypasses storage and flows directly to the solar heating coil in the air-handling system. Mode diversion valve V2 is open.

Mode 3 - Storage-to-Space Heating:

This mode activates when there is a demand for space heating, the temperature at the top of the storage tank exceeds 100° F, and solar energy from the collector is not available. Pump P3 is operating.

Mode 4 - Storage-to-DHW Tank:

This mode activates when the temperature at the top of the storage tank exceeds the preheat tank water temperature by 10° F. Pump P4 is operating.

Mode 5 - Summer Mode, Collector-to-Vent:

This mode activates when the collector array output fluid temperature exceeds 220° F. The collected solar energy is rejected through a fintube heat exchanger located outside the dwelling. Valve V1 directs the collector loop flow through a purge unit.

V. PERFORMANCE EVALUATION INSTRUMENTATION

A. The National Solar Data Network

The National Solar Data Network (see figure V-A-1) has been developed for the Department of Energy to process data collected from specific residential demonstration sites which were selected for thermal performance evaluation. The data flow in the Network includes monthly and seasonal system performance reports describing the thermal performance of the solar energy system and subsystems.

The performance evaluation instrumentation at each selected demonstration site is part of a comprehensive data collection system that allows for valid analyses of the solar system performance. Collected data are both applicable and practical in calculating thermal performance factors that describe the behavior of the solar system (see NBSIR 76-1137), National Bureau of Standards. Additional instrumentation may also be included as a result of site-specific requirements. Typically, the instrumentation includes sensors that monitor the following:

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

Site data are recorded automatically at prescribed intervals by the Site Data Acquisition System (SDAS). The recorded data are transmitted daily to the Communications Processor in the Central Data Processing System (CDPS). The communications link between every SDAS and the CDPS consists of voice-grade telephone lines and telephone data couplers. A reading is transmitted from the SDAS internal timer with every data sample to ensure that the data are time-tagged correctly.

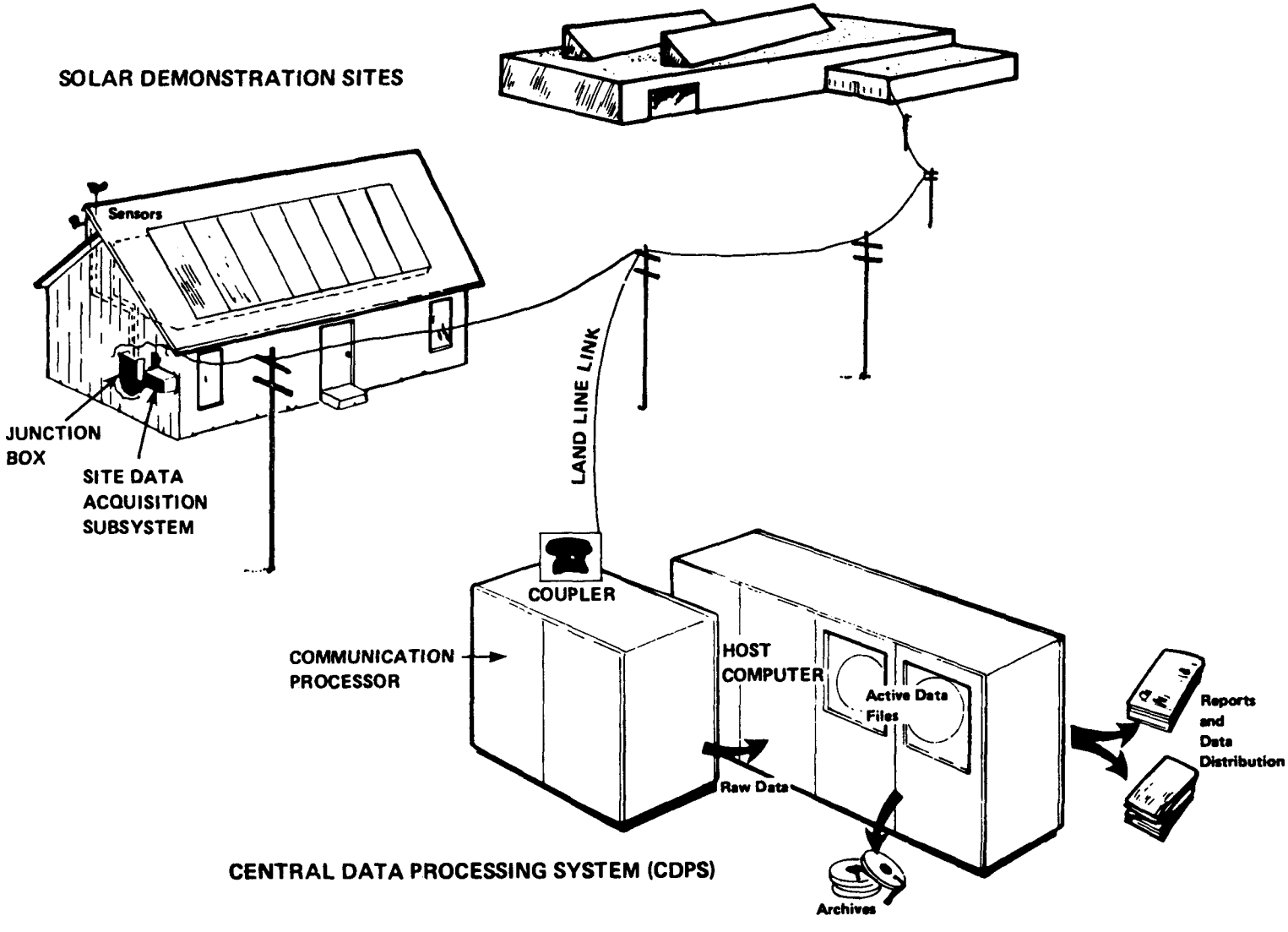


Figure V-A-1. The National Solar Data Network

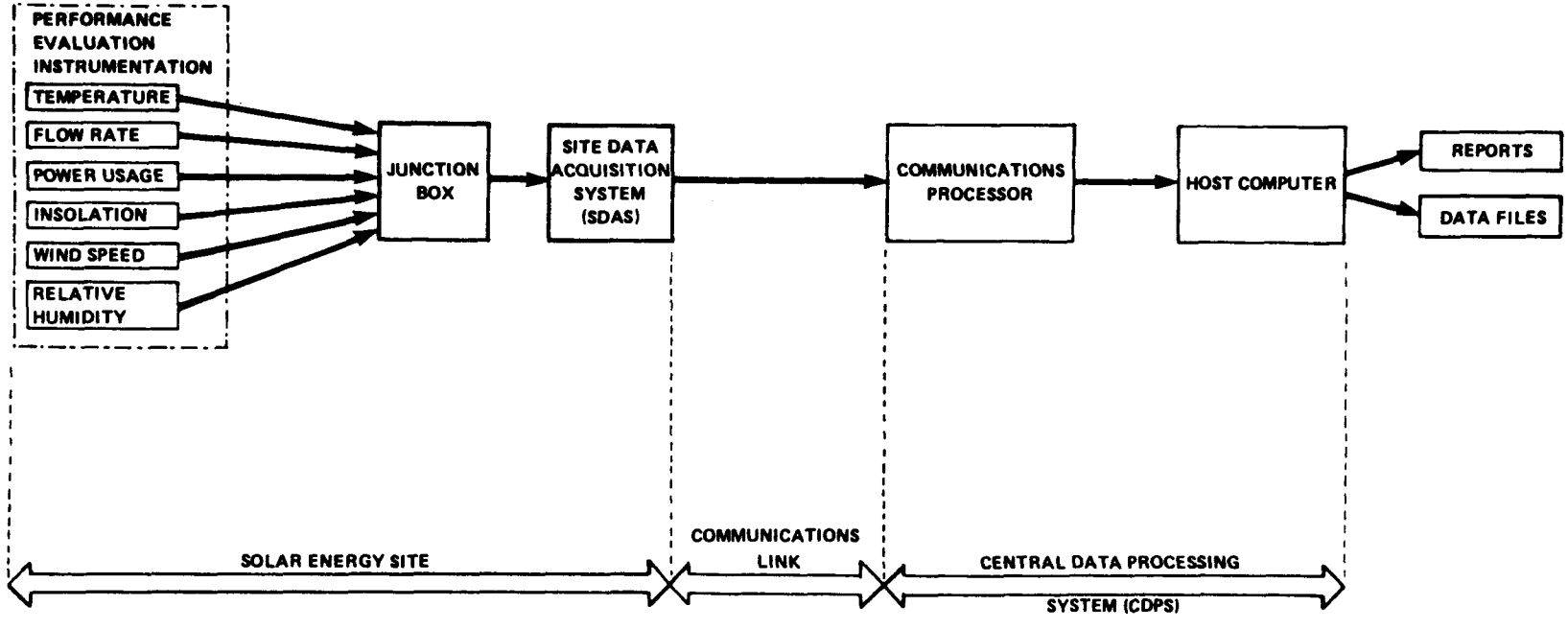


Figure V-A-2. Data Flow Path for the National Solar Data Network

The Communications Processor scans the receiving data to identify any apparent transmission errors and verifies correct site contact by checking the address code transmitted by the SDAS. Data is stored temporarily in the Communications Processor and processed by the Host Computer. The processing includes measurement checking to ensure that the data are reasonable; that is, that they are not beyond the known instrument limits and that they are not erratic. Data which appear questionable are discarded and are not used in the solar system preformance analyses.

Appropriate equations were formulated and programmed to define desired performance factors for the solar energy systems at each selected demonstration site. A performance factor is a number that describes either the efficiency or the quantity of energy lost, gained, or converted by a solar energy system or by a component. All valid data are processed using these performance factor equations to generate hourly performance factors. Hourly performance factors are integrated into daily and monthly performance factors. These hourly, daily, and monthly performance factors are stored in data files in the CDPS. These data files also include measurement data, expressed in engineering units; numerical and textual site identification; and specific site data used in generating the performance factors.

B. On-Site Instrumentation

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

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Total insolation	Eppley, PSP
T001	Outside ambient Temperature	S53P-60
T100	Temperature, Collector return	S57P-60
TD100L	Temperature, Collector, Low	
TD100H	Temperature, Collector, High	S53P-60
W100	Flow, Collector	MK V-1¼, 1.5-15GPM
EP100	Power, Collector Pump	O-S, PC5-1
T101	Temperature, return from Heat Exch.	S57P-60
TD101-L	Temperature, Heat Exchanger, Low	
TD101-H	Temperature, Heat Exchanger, High	S53P-60
T200	Temperature, Heat Exch. Load,	S57P-60
TD200-L	Temperature, Heat Exch. Load, Low	
TD200-H	Temperature, Heat Exch. Load, High	S53P-60
T201	Temperature, Storage Tank Exit, Bottom	S57P-60
TD201-L	Temperature, Storage Tank, Low	
TD201-H	Temperature, Storage Tank, High	S53P-60
W200	Flow, Storage Tank and Heat Exchanger	MK V-1¼, 1.5-15GPM
EP200	Power, Pump 2	O-S, PC5-1
T202	Temperature, Storage Tank, top	S53P-202
T203	Temperature, Storage Tank, center	S53P-316
T204	Temperature, Storage Tank, bottom	S53P-443
W201	Power, Pump 3	O-S, PC5-1
T400	Temperature, Solar Heat coil	S57P-60
TD400-H	Temperature, Solar Heat Coil, High	
TD400-L	Temperature, Solar Heat Coil, Low	S53P-60
T-401	Temperature, Furnace return duct	S57P-100
TD401-L	Temperature, Solar Heat Coil, Low	
TD401-H	Temperature, Solar Heat Coil, High	S57P-100
TD402-L	Temperature, Furnace Low	
TD402-H	Temperature, Furnace, High	
T402	Temperature, Furnace Hot air supply	S57P-100 Magnecraft
F400	Fuel Flow, domestic Oil Furnace	W88ACPX-4

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
EP400	Power, Domestic Furnace	O-S, PC5-10
T300	Temperature, DHW Pre-heat Tank return	S57P-60
TD300-H	Temperature, Pre-heat Tank, High	
TD300-L	Temperature, Pre-heat Tank, Low	S53P-60
W300	Flow, DHW Pre-heat Tank	MK V-3/4, .7-7GPM
EP300	Power, DHW Pre-heat Pump	O-S, PC5-1
W301	Flow, Cold Water Suply	MK V-3/4, .7-7GPM
T301	Temperature, Cold Water Supply	S57P-60GPM
TD301-L	Temperature, Pre-heat Tank, Low	
TD301-H	Temperature, Pre-heat Tank, High	S57P-60
TD302-L	Temperature, DHW Heater, Low	
TD302-H	Temperature, DHW Heater, High	S53P-60
F300	Fuel Flow, DHW Heater	1
T600	Temperature, Building (at thermostat)	S53P-60
EP301	Power, Domestic Water Heater	O-S, PC5- 1
W600	Flow, Heating system (Air)	TSI, 1610-12"

ACCESSORY LIST:

S = SHELTER IS2 or IS4
F = FLUID SEAL F-132
W = THERMO WELL F-203U34 (or other)
H = WEATHERHEAD F-102-3
O = OCTAL SOCKET
1 Description pending info on instrumented part.

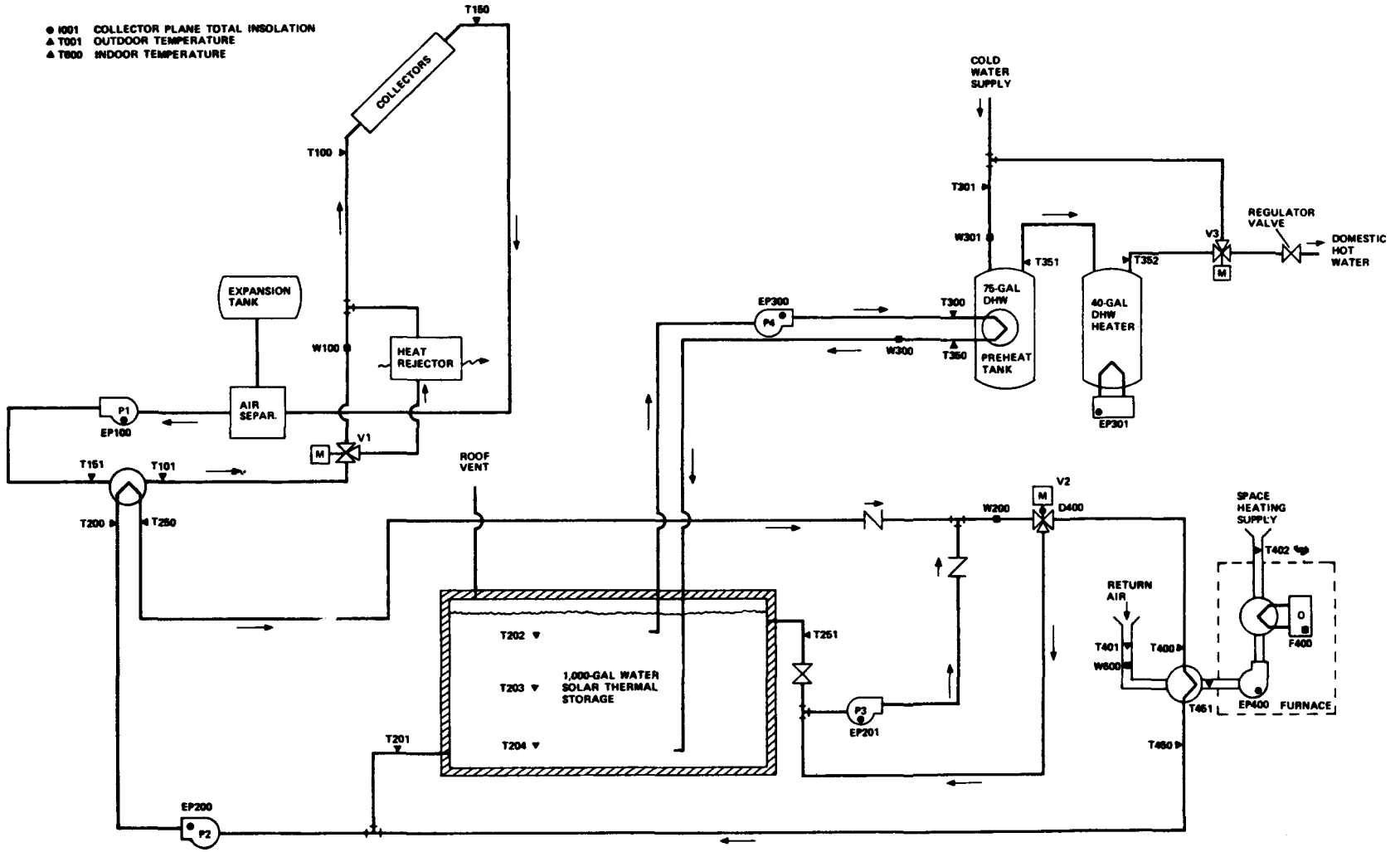


Figure V-B-1. Sensor and Control Diagram

VI. COST DATA

A. General

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

B. Construction Grant Funds

Solar Subsystem	Applicants Request	Construction Grant
Collectors	$ 5,700.	
Energy Storage	1,000.	
Distribution and Controls	6,300.	
Installation	4,000.	
Other	800.	
Total	$17,800.	$17,800.

C. Construction Period: February, 1977 through February, 1978

VII. APPENDIX

A. Glossary

ABSORBER PLATE - The surface in a flat plate collector that absorbs incident solar radiation and transfers the absorbed energy to a heat transfer fluid.
ABSORPTANCE - The ratio of absorbed radiation by a surface to the total incident radiation on that surface.
ABSORPTION SUBSYSTEM - The mechanical equipment that conditions indoor air by an absorption process.
ACTIVE SOLAR SYSTEM - An integrated solar energy system, consisting of collector, storage, solar energy-to-load subsystems, that can condition indoor air or preheat domestic hot water in a controlled manner.
AIR-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which air is the heat transfer fluid.
AIR CONDITIONING - The process of treating indoor air by controlling the temperature, humidity, and distribution to specified comfort settings as set by the occupants in the conditioned space.
AMBIENT AIR - A term for outdoor air, and may be brought into a building to be conditioned or circulated.
ANTI-FREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses additives or solutions to the heat transfer medium, which depresses its freezing point sufficiently to prevent possible water freeze in the solar collectors and the exterior piping.
AUXILIARY ENERGY SUBSYSTEM - The equipment, utilizing conventional energy sources, used to supplement the output provided by a solar energy system and used to provide a full backup system when the solar system is inoperable.
BACKFLOW - The reversal of flow in a distribution system.
BACKFLOW PREVENTOR - A device or means to stop backflow.
BEAM RADIATION - Solar radiation which is not scattered and may be concentrated.
BRITISH THERMAL UNIT (Btu) - A unit of energy that is required to heat one pound of water from 59^{o} F to 60^{o} F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

CLIMATE - The prevailing or average weather conditions of a specific geographic region as described by temperature and other meteorological data.

COLLECTOR MANIFOLD - The piping that connects the absorber tubes in a collector plate.

COLLECTOR PLATE - A term used for an absorber plate.

COLLECTOR SUBSYSTEM - The assembly that absorbes solar radiation and transfers the absorbed thermal energy to a heat transfer fluid.

COMBINED COLLECTORS - An assembly that both collects solar radiation and stores the thermal energy in the same unit.

CONCENTRATING SOLAR COLLECTOR - A solar collector which focuses beam radiation onto an absorber in order to obtain higher energy fluxes than can normally be achieved by flat plate solar collectors.

CONCENTRATOR - A reflective surface or refracting lens used in directing insolation onto an absorber.

CONDITIONED SPACE - The space in a building where the air is conditioned by heating or cooling.

CONTROL SUBSYSTEM - The assembly of electric, pneumatic, and hydraulic actuated sensing devices used in regulating the solar energy system and the auxiliary energy subsystems.

COOLING TOWER - A heat exchanger that transfers waste heat from an absorption cooling system to ambient air.

DIFFUSE RADIATION - Solar radiation which is scattered by air molecules, dust, or other substances suspended in the air.

DRAIN-DOWN FREEZE PROTECTION SYSTEM - A freeze protection system that prevents potential water freeze-up within the collector and exterior piping by automatically draining and replacing the water with a non-freezing medium such as air, nitrogen, etc.

DUCT HEATING COIL - A liquid-to-air heat exchanger in the duct distribution system used to heat air by passing a hot fluid through a coil in the air system.

EQUIVALENT FULL LOAD COOLING HOURS - The seasonal cooling load for a building described as the total number of hours that the air conditioning system will operate under full load conditions to meet the required cooling load.

EMITTANCE - The ratio of energy radiated by a body to the energy radiated by a black body at the same temperature.

EXPANSION TANK - A tank which will permit water to expand whenever it is heated to prevent excessive pressures on the other system components.

FIXED COLLECTOR - A solar collector that is permanently oriented towards the sun and cannot track the sun nor be adjusted for seasonal variations.

FLAT PLATE COLLECTOR - A basic heat collection device used in solar heating systems, which consists of an absorber plate, with insulated bottom and sides, and covered by one or more transparent covers. There are no concentrators or focusing aids in a flat plate collector.

FOCUSING COLLECTOR - A solar collector using a parabolic mirror, fresnel lens, or other type of focusing device to concentrate solar radiation onto an absorber.

FRESNEL COLLECTOR - A concentrating solar collector which uses a fresnel lens to focus beam radiation onto an absorber.

GLAZING - The transparent cover(s) on a solar collector used to reduce the energy losses from the top of the collector.

HEAT TRANSFER FLUID - The fluid that transfers solar energy from the solar collector to the storage subsystem or to the load.

INCIDENCE ANGLE - The angle in which the insolation strikes a surface and the normal for that surface.

INSOLATION - The total amount of solar radiation on a surface in a given unit of time.

LAMINATED GLASS - A glazing consisting of multiple glass sheets bonded together by intervening layer or layers of plastic.

LANGLEY - The standard unit of insolation defined as 1 langley = 1 cal/cm^2, (1 Langley = 3.69 Btu/ft^2).

LIQUID-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which either water or an antifreeze solution is the heat transfer fluid.

LOAD - The total space conditioning or domestic water heating requirements that are supplied by both the solar energy system and the auxiliary energy subsystem.

NOCTURNAL RADIATION - The loss of thermal energy by the solar collectors to the sky at night.

NO-FLOW CONDITION - The condition obtained when the heat transfer fluid is not flowing through the collector array due to a shutdown or a malfunction.

OPAQUE - A surface that is not transparent, thus solar radiation is either reflected or absorbed.

OUTGASSING - The emission of gases by materials and components, usually during exposure to elevated temperature, or reduced pressure.

PACKAGE AIR-CONDITIONING UNIT - A factory-made assembly consisting of an indoor coil, a compressor, an outdoor coil, and other components needed for space cooling operations. This unit may also include additional components to heat the condition space.

PARABOLIC FOCUSING COLLECTOR - A concentrating collector which focuses beam radiation by a parabolic reflector.

PASSIVE SOLAR SYSTEM - An integrated solar energy system that can provide for space heating needs without the use of any other energy source other than the sun.

REFLECTANCE - The ratio of radiation reflected by a surface to the total incident radiation on the surface.

REFLECTED RADIATION - Insolation which is reflected from a surface, such as the ground, and is incident on the solar collector.

ROCK BED - A storage tank using uniform-sized rocks to store solar energy in air-based solar collector systems.

SELECTIVE SURFACE - A surface which has a high absorptance for solar radiation and a low emittance for thermal radiation.

SOLAR CONDITIONED SPACE - The area in a building that depends on solar energy to provide for a fraction of the heating and cooling needs.

SOLAR HEATING SYSTEM - An integrated assembly of collector, storage, solar energy-to-load, and control subsystems required to convert solar energy into thermal energy for space heating requirements, as well as the addition of an auxiliary backup system.

SOLAR RETROFIT - The addition of a solar energy system to an existing structure.

STORAGE SUBSYSTEM - The components used to store solar energy so that the stored energy can be used for heating, cooling, or heating water during periods of low insolation.

STRATIFICATION - The horizontal layering in a medium due to temperature differentials, commonly noticed in storage tanks filled with water.

THERMOSTAT - A temperature sensing device which controls the heating and cooling systems for space conditioning or the hot water heater.

TILT ANGLE FROM HORIZONTAL - Angle between the horizontal plane and the plane of collector.

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

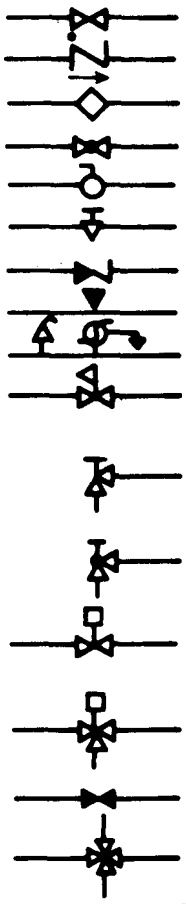
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

VAPOR BARRIER - A material which is used to reduce the transmission of water vapor.

ZONE - A portion of a conditioned space which use a common control because of their similar heating and cooling requirements.

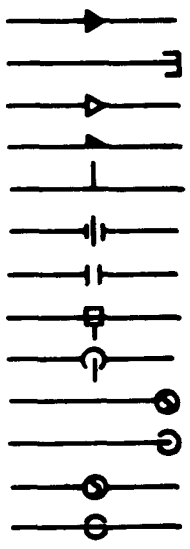
B. Legend For Solar System Schematics

VALVES



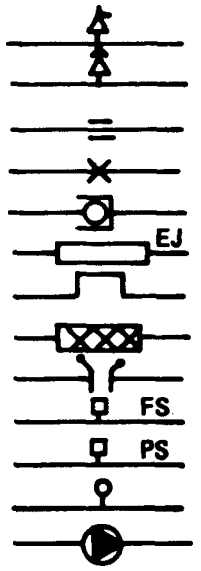
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS

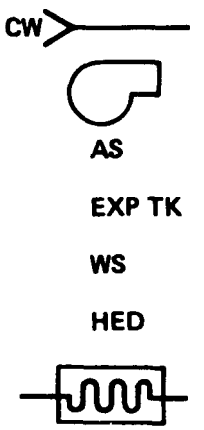


DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

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

U.S. GOVERNMENT PRINTING OFFICE: 1980—640-258/1799