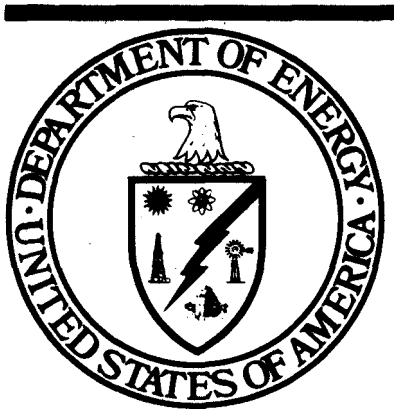
A. 6040

SOLAR/1050-79/50

Solar Project Description

BOND CONSTRUCTION COMPANY's SINGLE FAMILY RESIDENCE Gladstone, Missouri December 3, 1979



U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

Solar/1050-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
BOND CONSTRUCTION COMPANY'S
SINGLE FAMILY RESIDENCE - GLADSTONE, MISSOURI

Prepared for the
Department of Housing and Urban Development

Under Contract Number
H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

The Boeing Company
David Beers, Program Manager

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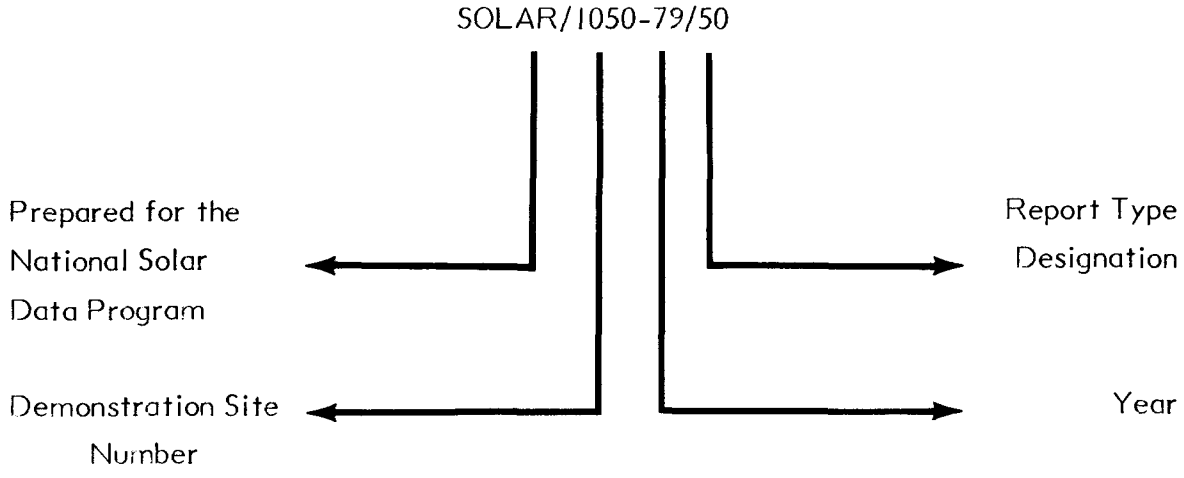
LIST OF FIGURES

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 Bond construction Company's single family residence project site, is designated as SOLAR/1050-79/50. 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 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 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 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 descriptions:

- o Collector Type - Liquid
- o Freeze Protection - Anti-freeze/Water
- o Application - Heating, domestic hot water
- o Storage - Water, 800 gallon tank
- o New or Retrofit - New
- o Performance Evaluation Instrumentation - Yes
- o Site-Specific Features - Gas fired boiler auxiliary heating

The Bond Construction's Company solar energy system (Grant H-8151) is installed in an approximately 1930 square-foot, three bedroom single family dwelling located in Gladston, Missouri. The system is designed to provide solar energy for space heating and domestic hot water heating.

Solar energy is collected by two banks of liquid flat plate collectors with a gross area of 465 square feet. The two collector banks are mounted on the roof of the house and face due south at an angle of 37 degrees to the horizontal to optimize solar energy collection.

Solar energy is transferred from the collector array to an 800 gallon storage tank in the basement. Water is used as the heat collection, transfer and storage medium. Freeze protection is provided by means of circulation anti-freeze through the collectors.

Overheating protection is provided by venting vapor from storage using collectors as radiators at night, and allowing collectors to boil.

Space heating demands are met by circulating water from storage through a liquid to air heat exchanger through the distribution system of the house. Auxiliary space heating is provided by a natural gas fired furnace.

Solar energy for heating domestic hot water is provided by transferring water from a storage tank to a conventional 82- gallon domestic hot water heater through a heat exchanger jacket located around the hotwater tank. Auxiliary energy for domestic hot water is provided by an electrical immersion heater in the domestic hot water tank.

The dwelling has been fully instrumented for performance evaluation since December 1978 and the data is integrated into the National Solar Data Network.

Original cost estimates for provisioning and installation of the solar system are given in section VI of this report. However, the final solar system cost and the cost of its instrumentation are not included in this report.

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

The following are the general characteristics for the Bond Construction site.

- Building type - Single family detached
- Latitude - 39°
- Longitude - 95°
- Altitude - 895 ft

HEATING DESIGN TEMPERATURES

- Outdoor - -10.0° F DB
- Indoor - 72° F DB

BUILDING

- Building faces - North
- Average stories above ground - 2.0
- Average stories below ground - 1.0
- Height above grade - 29 ft
- Conditioned floor area - 1932 sq ft
- Roof type - Sloped with 37° pitch angle

DESIGN HEAT LOSS/LOAD

- Heat Loss - 48,492 Btu/hr
- Heat gain -
- Shading
    - Heating season -
    - Cooling season -

No illustration abailable at this time

Figure III-1. Site Plan

- Appliance, lighting and equipment load -
- Domestic hot water daily requirement - 80 gal/day
- Average horizontal insolation
  - January - 708 Btu/ft^2/day
  - July - 1959 Btu/ft^2/day
- Annual degree days
  - Heating - 4711 Btu/ft^2/day
  - Data location - Kansas City, Missouri
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

MECHANICAL SYSTEM

- Heating
  - Solar - Liquid active collectors
  - Auxiliary - Gas-fired furnace/fireplace
  - Distribution - Blowers to ducting

DOMESTIC HOT WATER

- Daily water demand - 80 gal per day
- Solar - Collectors to storage
- Auxiliary - Electric immersion heater

GENERAL DATA

- Manufacturer - Ionic solar
- Model name/number -
- Type of system - Liquid active collectors to DHW and heating

SYSTEM AND COMPONENT SUMMARY

- Collector types - 1
- Circulation loops - 5
- Thermal storage units - 1
- Operational modes - 3
- Pumps - 4
- Valves - 7
- Blowers - 1
- Dampers - 0
- Sensors - 5
- Flow regulators - 2
- Pressure regulators - 0
- Fail safe controls - 5

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (Bond Construction Company H-8151) located at Gladston, Missouri is a liquid active system utilized for heating, and domestic hot water. Auxiliary units are provided for heating, and domestic water.

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

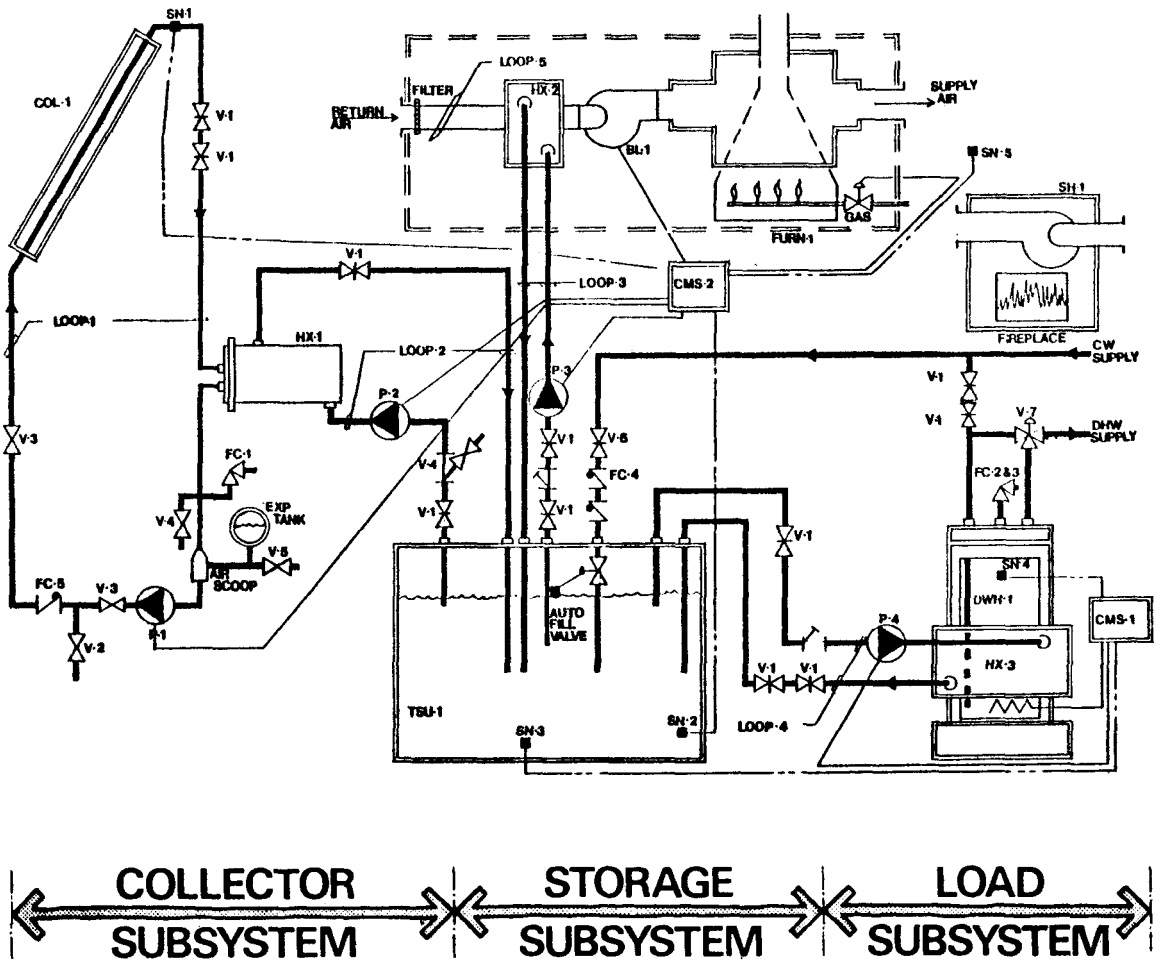


Figure IV-A-1. General Overview

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

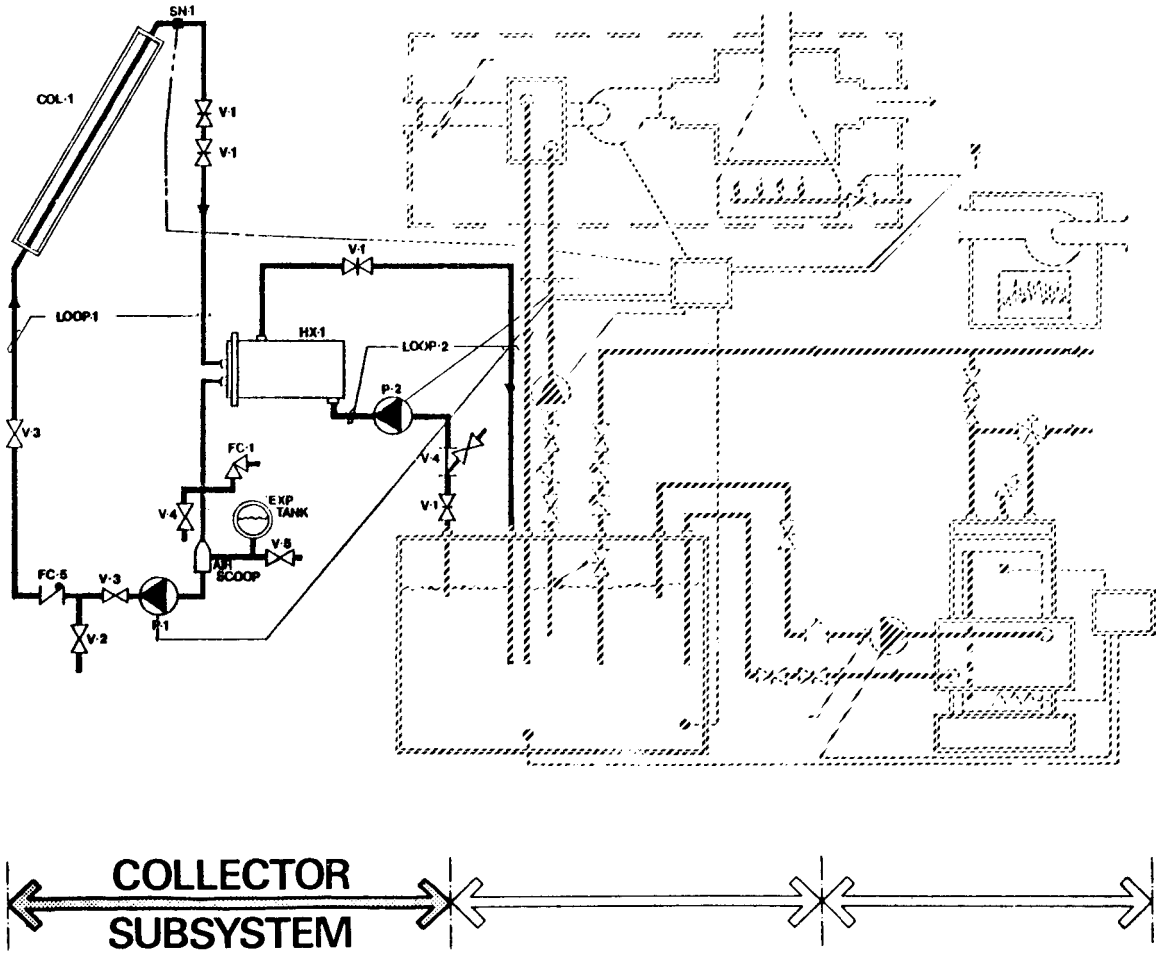


Figure IV-B-1. Collector Subsystem

Collector array subsystem consists of 20 liquid flat plate collector panels. Freeze protection is provided by anti-frreze/water flowing from storage through the collectors. Included in the collector subsystem are an air scoop and a 60 gallon expansion tank.

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

- Manufacturer - American Heliothermal
- Model name/number - Micromit 200
- Type - Liquid Flat Plate, Tube and Plate
- Location - Roof
- Orientation - South
- Tilt angle - 37° from horizontal
- Collector characteristics
- Number of collector panels - 20
- Array configuration - Parallel, two rows of seven and two rows of three.
    - Total gross area of array - 465 square feet
    - Net aperture area - 416 square feet
    - Net absorber area - 465 sq ft
    - Weight per panel, empty - 195 lb
    - Weight per panel, full - 204 lb
    - Weight of filled array and support structure - 4,080 lbs
    - Panel length - 79.5 inches
    - Panel width - 42.1 inches
    - Frame depth - 3.4 inches
    - Standoff height - 0
    - Built in Collector - Collector built into and forms weatherproof surface of roof
- Cover plates
    - Number of cover plates - One
    - Location - Outer layer of multiple layers or single cover

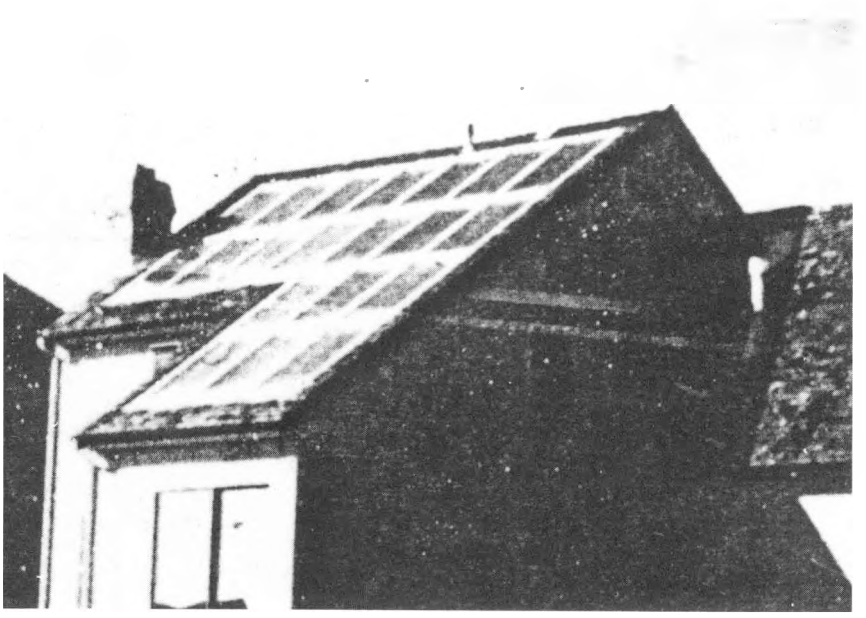


Figure IV-B-2. Solar collector

- Cover plate No. 1 -
  - Manufacturer - ASG
  - Product name/number - Sunadex A
  - Material - Glass tempered, water white
  - Thickness - 0.156 inch
  - Optical properties (solar region) (infrared region)
    - Transmittance 91% 5%
    - Reflectance 8%
    - Emittance - 1%
- Edge or surface treatment, other than coating - Mechanical, ground
- Coating on cover plate material - None
- Absorber
  - Manufacturer - American Heliothermal
  - Model name/number - Micromit 200
  - Material - Galvanized steel
  - Substrate material dimension
    - Thickness - 0.040 inch
    - Length - 77.5 inches
    - Width - 40.1 inches
- Coating
  - Manufacturer - Dr Harry Tabor
  - Model name/number - Selective Black
  - Application method - Electroplated
  - Material - Tabor Selective Black

- o (solar region) (infrared region)
  - o Absorptance - 92% Unknown
  - o Reflectance - 8% Unknown
  - o Emittance - 29% hemispherical emittance
- o Heat transfer fluid passages
  - o Location - Beneath absorber
  - o Pattern - Parallel
  - o Materials - Galvanzied steel
  - o Wall thickness - 0.094 inch
  - o Internal diameter - 0.5 inch
  - o Maximum operating conditions
    - Temperature - 97o F
    - Pressure - 100 psi
  - o Fluid passage bond to substrate - Mechanical connection
  - o Protective coating inside fluid passage - Galvanized
- o Insulation
  - o Layer one -sides
    - Manufacturer - Celotex
    - Product name/number - Celotex boards
    - Material - Celotex board
    - Thermal resistance - R5
  - o Layer two-sides
    - Manufacturer - American Heliothermal
    - Product name/number - Micromit 200 Wool
    - Material - Mineral Wool
    - Thermal resistance - R4

- Layer one - back
  - Manufacturer - American Heliothermal
  - Product name/number - Micromit 200
  - Material - Mineral Wool
  - Thermal resistance - R4
- Gaskets and sealants
  - Inner cover - Silicone (GE-1200)
  - Frame joint - Welded
  - Backing plate - Mechanical crimp
- Frame
  - Manufacturer - American Heliothermal
  - Product name/number - Micromit 200
  - Material Galvanized steel
  - Protective coating - Galvanized
  - Number of structure attach points per module to building - 4
  - Desiccant - Yes - Dowfrost
  - Freeze protection - Anti-freeze
  - Overheating protection - Venting vapor from storage using collectors as radiators at night, and allowing collectors to boil.
- Collector performance
  - Method of evaluation - NBS
  - y intercept - 0.74
  - Slope - 0.92
  - Point Number 1 2 3 4
  - n = Collector thermal efficiency(%) - 66.5 57.5 48.0 38.5
  - t_i=collector inlet temperature(^{o}F) - Not
  - t_a=ambient air temperature(^{o}F) - Available
  - I_t= insolation intensity Btu/hr ft^2 -

o	ASHRAE $(t_i - t_a)/I_t$ -	0.10	0.20	0.30	0.40

- o η = collector thermal efficiency
- o U_L = collector heat loss factor
- o F_R = collector heat removal factor
- o t_a = ambient air temperature, ^{o}F
- o $(\tau\alpha)$ = Transmissivity-absorptivity product at normal incidence
- o t_i = collector inlet temperature, ^{o}F
- o t_f = average fluid temperature
- o I_t = radiation (insolation) intensity on collector, $Btu/hr.ft^2$

LIQUID CIRCULATION LOOP NO. 1 (COL-1 TO HX-1)

- o Maximum design operating temperature - 233° F
- o Pressure - 50 psi
- o Heating
  - Design liquid flow - 10.0 GPM
  - Design pump speed - 1,750 rpm
- o Cooling
- o Heat transfer medium -
  - o Volume of liquid in loop - 45 gallons
  - o Anticipated liquid temperatures
    - Maximum - 220° F
    - Minimum - 110° F
  - o Provisions for expansion
    - Expansion tank volume - 60 gallons
  - o Medium - 50% water and 50% ethylene glycol
  - o Specific heat - 0.82 Btu/lb/° F
  - o Density - 67 lb/ft^3
  - o Boiling point - 228° F

- Freezing point - Minus 34° F
- Maximum recommended use temperature - 300° F
- Minimum recommended use temperature - Minus 40° F
- Toxicity - Non - Potable
- pH factor - 9.3
- Chemical feeder to maintain pH factor - No
- Inhibitor - Yes

- Components within circulation loop
  - Pump(s) - P-1
  - Heat exchanger(s) - HX-1
  - Collector(s) - COL -1
  - Valves(s) - V-1, V-2, V-3, V-4 and V-5
- Piping
  - Rigid - Copper
  - Piping insulation - Fiberglass
  - Location - Above grade
  - Getters - Di-Electric Film
  - Thermal resistence - R3
- Circulator pump (P-1)
  - Manufacturer - Bell & Gossett
  - Model name/number - 1,522 - 1 S
  - Type - Centrifugal
  - Maximum operating conditions
  - - Static pressure - 125 psi
    - Temperature - 230° F
  - Material exposed to heat transfer fluid - Brass (Impeller)/Cast iron
  - Motor size - 0.25 HP; 115 V; 1 phase; 60 Hz

- Maximum motor speed - 1,750 rpm
- Drive - Direct
- Speed - Single
- Pump speed - 1,750 rpm
- Circulating volume - High head mode - 10.0 gpm
- Operating head (dynamic) - High head mode - 12.4 psi
- Motor operation - 0.25 bhp

- Heat Exchanger (HX-1)
  - Manufacturer - Young Radiator
  - Model name/number - F-504-EY-IP
  - Type of exchanger - Liquid to liquid
  - Type of flow - Counter
  - Heat exchanger design - Shell & tube
  - Number of separations - Single

	Side One	Side Two
o Convection	Forced	Forced
o Part of Circulation Loop (s)	Loop 1	Loop 2
o Maximum Manufacturers Rated		
- Temperature -	350° F	350° F
- Pressure -	150 psi	150 psi
o Heat Transfer Area -	36 ft^2	36 ft^2

- Description

	Side 1	Side 2
o Length of tubing without fins -	3½ ft	3 ft
o Diameter of tubing -	¼ inch	¼ inch

- Heating design capacity - 60,000 Btu/hr
- Effectiveness - 0.77%
- Design flow rate

	Side One	Side Two
	10 gpm	40 gpm
Related pump -	P-1	
Liquid Temperatures -	Entering	Leaving
- Side 1	118° F	104° F
- Side 2	100° F	103° F

- Distribution Valve (V-1) - BMI
  - Function - On - Off
  - Operation - Manual
  - Type - Gate
- Distribution Valve (V-2)
  - Function - Drain
  - Operation - Manual
  - Type - Gate
- Distribution Valve (V-3)
  - Manufacturer - GB
  - Model name/number - 1¼ Circuit setter
  - Function - Flow adjusting
  - Operation - Manual
  - Type - Gate
- Distribution Valve (V-4)
  - Function - Drain
  - Operation - Manual
  - Type - Gate

- Distribution Valve (V-5)
  - Function - Drain
  - Operation - Manual
  - Type - Gate
- Liquid Circulation Loop No. 2 (Collector side of TSU-1)
  - Design operating temperature - 200° F
  - Pressure - 0 psi
  - Heating
    - Design liquid flow - 40 gpm
    - Design pump speed - 1,750 rpm
  - Cooling
  - Heat transfer medium:
  - Anticipated Liquid temperatures
    - Maximum - 200° F
    - Minimum - 90° F
  - Provisions for expansion - Expansion space in TSU-1
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 67 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 200° F
  - Toxicity - Potable
  - pH factor -
  - Chemical feeder - No
  - Inhibitor - No

- Components within circulation loop
  - Pump(s) - P-2
  - Heat exchanger(s) - HX-1
  - Thermal storage unit(s) - TSU-1
  - Valve(s) - V-1, V-4
  - Other(s) - Strainer
  - Piping
    - Rigid - Steel
    - Interior Coating - Galvanized
    - Insulation - Fiberglass
    - Location - Above grade
- Circulator pump (P-2), TSU-1-to-HX-1
  - Manufacturer - Bell & Gossett
  - Model name/number - Series 2 inch
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 125 psi
    - Temperature - 200° F
- Material exposed to heat transfer fluid - Cast iron stainless
- Motor size - 0.167 HP; 115 V; 1 phase; 60 Hz
- Maximum motor speed - 1,750 rpm
- Drive - Direct
- Speed - Single
- Pump speed - 1,750 rpm
- Circulating volume - High head mode - 40.0 gpm
- Operating head (dynamic) - High head mode - 3.5 psi
- Motor operation - 0.166 bhp

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

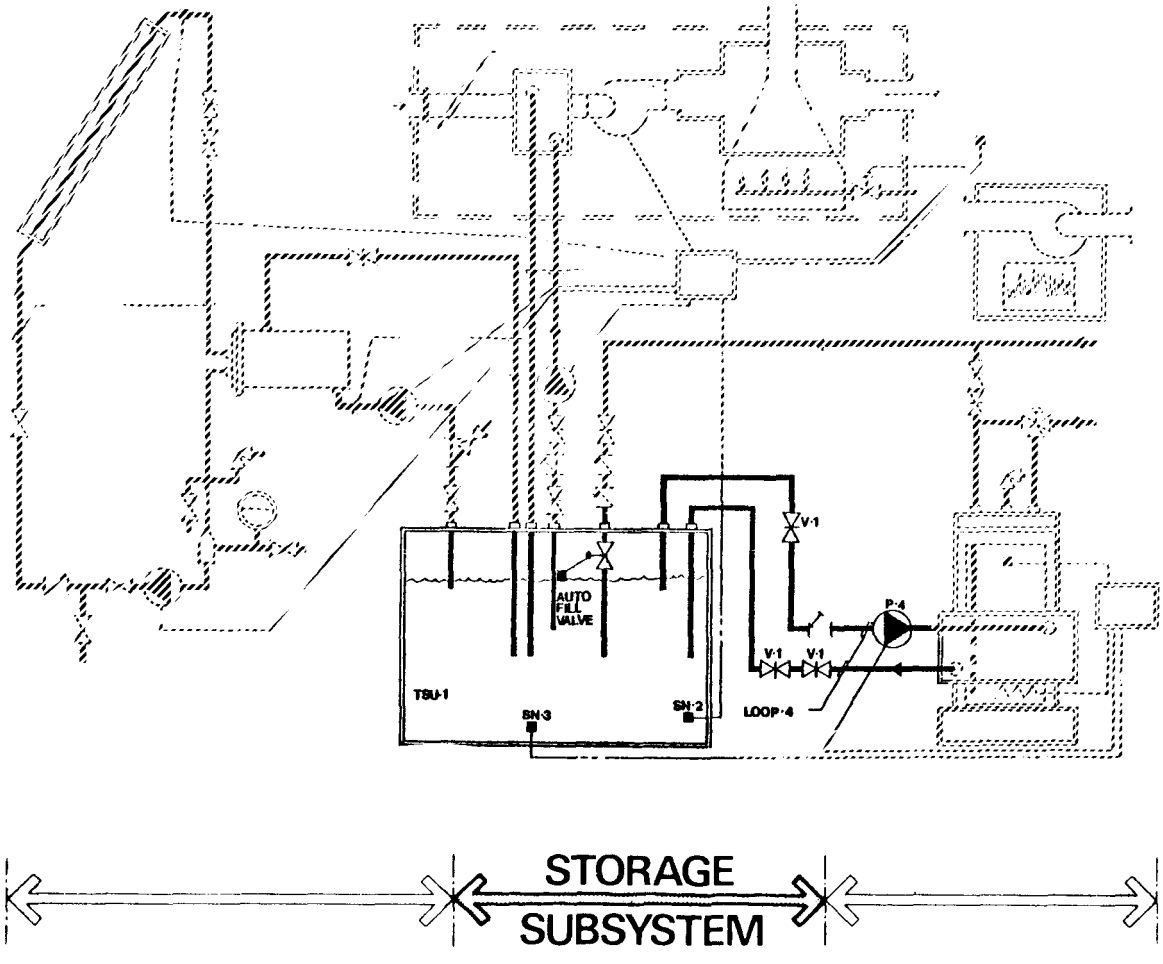


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by an 800 gallon storage tank in the basement. This tank is made of steel with an epoxy interior liner. It measures 5.5 feet in length, 5.5 feet in width, 4.0 feet in height with 4 inches of polyurethene in the bottom and 8 inches of fiberglass on the top and sides for insulation. Preheated city water is stored in an 82-gallon DHW tank.

THERMAL STORAGE UNIT (TSU-1)

- Manufacturer - Ionic Solar
- Model name/number - Custom built for this project
- Container
  - Total storage volume - 121 ft^3
    - Length - 5.5 ft
    - Width - 5.5 ft
    - Height - 4.0 ft
- Storage medium
  - Design operating temperature- Maximum 180° F, Minimum 90° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Recommended medium temperature - 180° F
  - Toxicity - Potable
  - pH Factor - 7.0
  - Inhibitor - No
- Heat transport to and from medium
  - Collector side - No heat exchanger in container
    - Medium flows through loop - 2
  - Demand side - No heat exchanger in container
    - Medium flows through loop - 3
  - Domestic hot water system - No heat exchanger in container
    - Medium flows through loop - 4

- Container construction
  - Type - Metal - (0.25 inch thick)
  - Location - In basement
  - Auxiliary heaters - No
  - Insulation - Glass fiber
  - Exterior finish - Masonite (¼ inch)/Painted
  - Filters - No
  - Interior lining - Epoxy

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

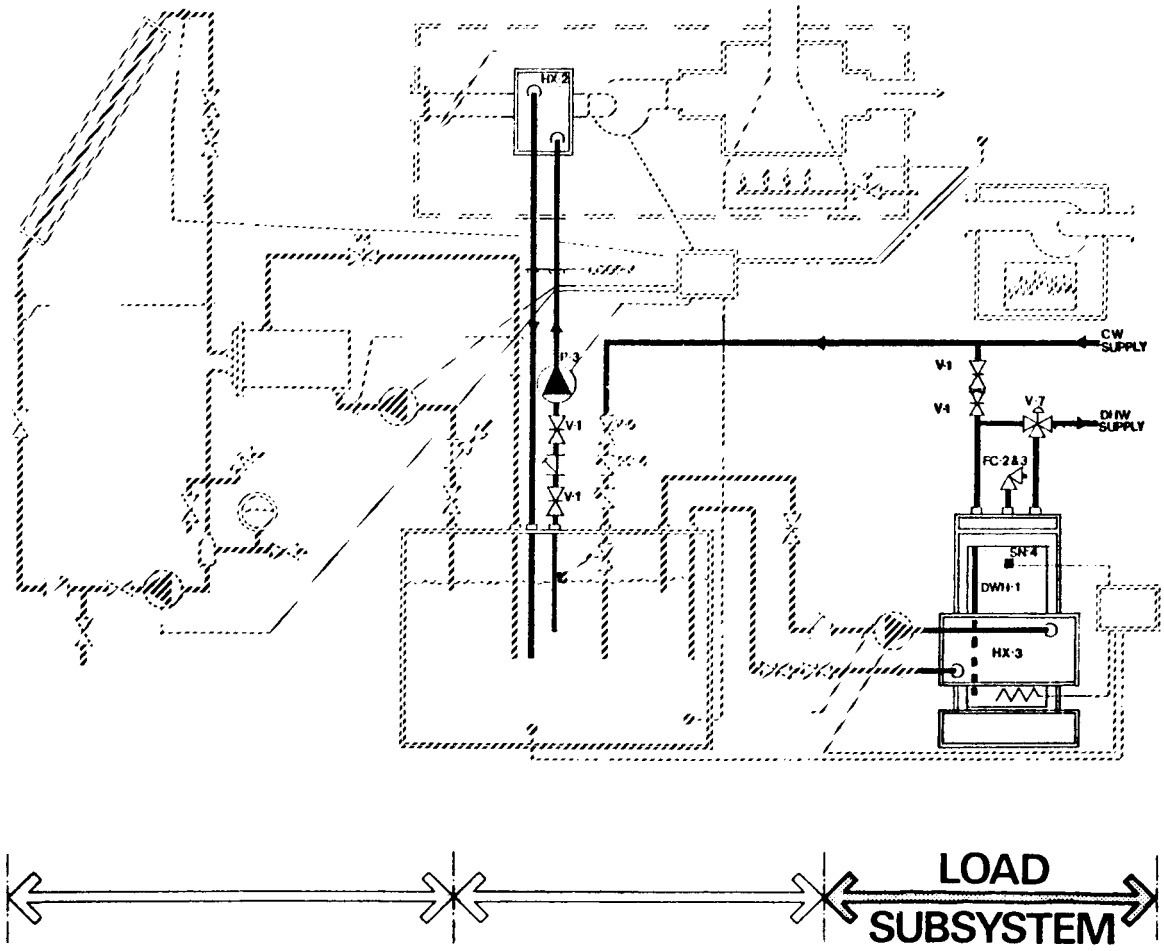


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy is stored in an 800 gallon storage steel tank in the basement. Solar energy is transferred from the storage tank, by P-3, to the hot-air heating system by a liquid-to-air heat exchanger (HX-2) contained in the furnace duct work. Similarly, solar energy is transferred from the storage tank, by P-4, to the DHW tank by an annular heat exchanger (HX-3) jacket around DWH-1. Auxiliary energy is available for heat and hot water should solar energy be insufficient.

LIQUID CIRCULATION LOOP NO. 3 (DEMAND SIDE OF TSU-1)

- Design maximum operation temperature - 180° F
- Pressure - 0 psi
- Heating
  - Design liquid flow - 10.0 gpm
  - Design pump speed - 2,600 rpm at maximum; 2,000 at minimum
- Heat transfer medium
  - Volume of liquid in loop - 800 gallons
  - Anticipated liquid temperature
    - Maximum - 180° F
    - Minimum - 80° F
  - Provision for expansion - Expansion space in TSU-1
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 180° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Components within circulation loop
  - Pump(s) - P-3
  - Heat exchanger - HX-2
  - Thermal storage unit(s) - TSU-1
  - Valve(s) - V-1

- Other(s) - Strainer

- Circulator pump (P-3)
  - Manufacturer - Grundfos
  - Model name/number - UPS-20-42F
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 125 psi
    - Temperature - 230^0 F
  - Material exposed to heat transfer fluid - Stainless/Cast iron body
  - Motor size - 0.05 HP; 115 V; 1 phase; 60 Hz
  - Maximum motor speed - 2,620 rpm
  - Drive - Direct
  - Speed - Single
  - Pump speed - 1,900 rpm
  - Circulating volume - High head mode - 10.0 gpm
  - Operating head (dynamic) - High head mode - 3.03 psi
  - Motor operation - 0.05 bhp
- Heat Exchanger (HX-3)
  - Manufacturer - Brod and McClung
  - Model name/number - Pace 123
  - Type of flow - Cross
  - Heat of exchanger design - Duct coil
  - Type of exchanger - Air to liquid

	Air Side	Liquid Side
o Convection	Forced	Forced

	Air Side	Liquid Side
o Part of circulation loop -	Loop 5	
- Material -		Copper

- o Overall heat transfer coefficient - 547 btu/hr
- o Heating
  - Design heating cpacity - 24,000 Btu/hr
  - Effectiveness - 74%

	Air Side	Liquid Side
o Design flow quantity	1,200 cfm	10 gpm
o Related circulator number	BL-1	P-3
o Circulator speed - High		
o Temperatures		
- Entering -	70° F	100° F
- Leaving -	92° F	96° F

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

- o Design maximum operating temperature - 180° F
- o Pressure - 0 psi
- o Heating
  - o Design liquid flow - 10.0 gpm
  - o Design pump speed - 2,600 rpm
- o Heat transfer medium
  - o Volume of liquid in loop - 800 gallon
  - o Anticipated liquid temperature
    - Maximum - 180° F
    - Minimum - 90° F
  - o Provisions for expansion - Expansion Space in TSU-1

- Medium - Water (100%)
- Specific heat - 100 Btu/lb/^{o} F
- Density - 62 lb/ft^{3}
- Heat capacity -
- Boiling point - 212^{o} F
- Freezing point - 32^{o} F
- Medium manufacturers recommend use of temperature
  - Maximum - 140^{o} F
  - Minimum - 90^{o} F
- Toxicity - Potable
- pH factor - 7.0
- Inhibitor - None

- Components within circulation loop
  - Pump(s) - P-4
  - Domestic water heater(s) - DWH-1
  - Heat exchanger(s) - HX-3
  - Thermal storage unit(s) - TSU-1
  - Valve(s) - V-1
  - Other - Strainer
- Circulator pump (P-4), TSU-1 to DWH-1
  - Manufacturer - Grundfuss
  - Model name/number - UPS-20-42 F
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 125 psi
    - Temperature - 230^{o} F

- Material exposed to heat transfer fluid - Stanless/Cast iron body
- Motor size - 0.05 HP; 115 V; 1 phase; 60 Hz
- Maximum motor speed - 2,620 rpm
- Drive - Direct
- Speed - Single

- Design Conditions
  - Pump speed - 1,900 rpm
  - Circulating volume - High head mode - 10.0 gpm
  - Operating head (dynamic) - High head mode - 3.03 psi
  - Motor operation - 0.05 bhp
- Heat Exchanger (HX-3)
  - Manufacturer - American Appliance
  - Model name/number - 82-SEJ-A
  - Type of flow - Annular jacket
  - Heat exchanger design - Annular jacket
  - Type of exchanger - Liquid to liquid
  - External exposed area - 17 ft^2
  - Thermal insulation - R-17

	Side One	Side Two
o Convection -	Forced	Forced
o Part of circulation loop -	4	
- Material -	Steel	Coper
o Design flow rate	10 gpm	10 gpm
o Related pump -	P-4	

- Piping
  - Rigid - Steel
  - Location - Above grade
  - Insulation - fiberglass
  - Thermal resistence - R-3
  - Filter(s) - Between storage and P-4
    - Manufacturer - Fairview
    - Product name/number - PA 16055
    - Type - 3/4 in full flow 250

AIR CIRCULATION LOOP NO. 5 (HX-2 TO SPACE HEATING)

- Flow Rate
  - Heating -
    - Maximum - 1,200 cfm
    - Blower speed - 1,075
- Components
  - Blowers - BI-1
  - Furnaces - Furn-1
  - Heat Exchanger - HX-2
  - Filter - Disposable fiberglass
- Ducting
  - Location - Above grade
  - Type - Steel/Galvanized
  - Joint - Clamped

CONTROL MODE SELECTOR (CMS-2)

- Modes controlled
  - Manufacturer - Independent Energy Inc.
  - Product Model/Number - C 120
  - Type - Thermistor/Temperature (SN-1 and SN-2)
    Thermostat (SN-5)
  - Collector to storage - ON-(SN-1) $<$ (SN-2) + 10
    - OFF-(SN-1) $>$ (SN-2) + 2
  - Storage to space - ON-(SN-5) Setting (SN-2) 90
    - OFF-(SN-5) Setting
  - Storage to hot water - ON-(SN-3)
    - OFF-(SN-3)

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

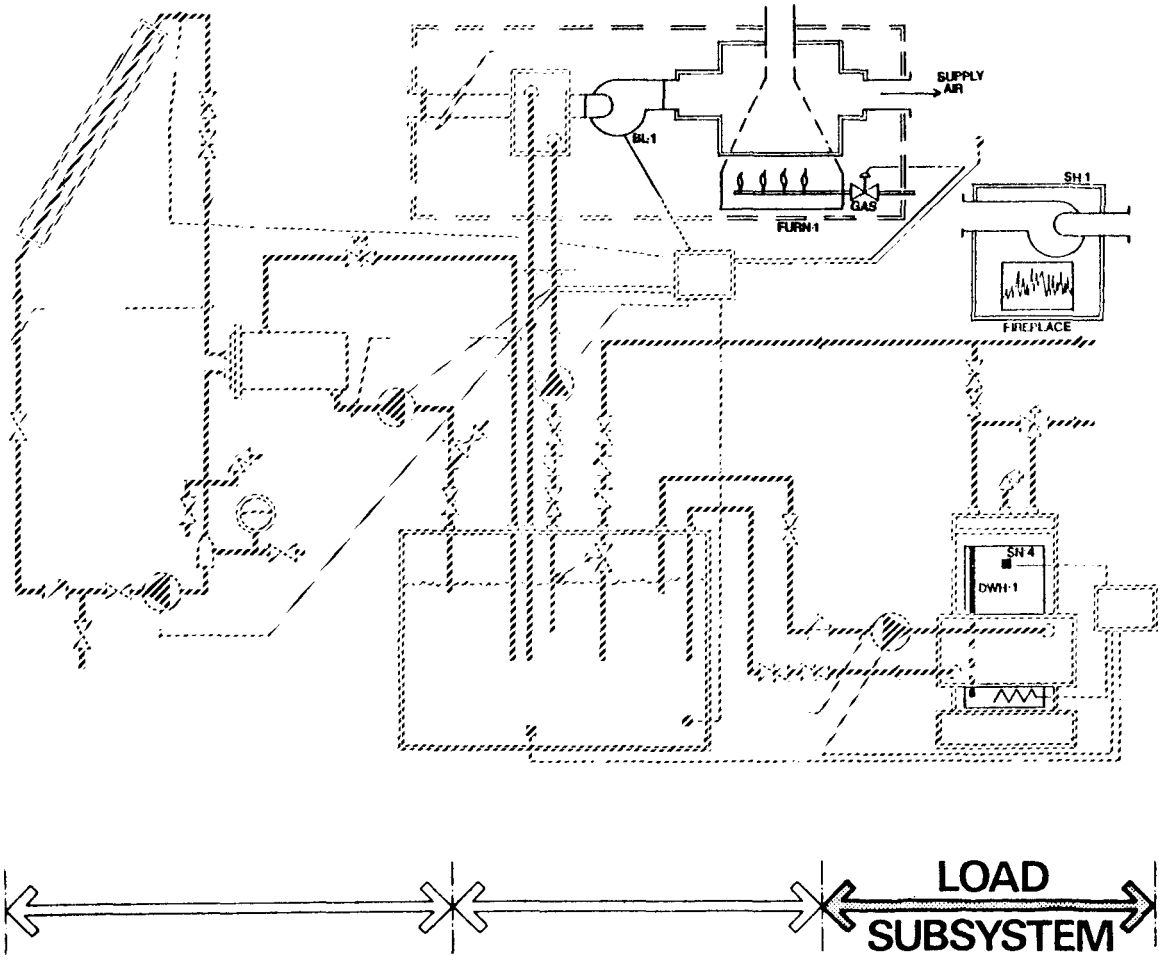


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystems, domestic hot water tank, furnace and fireplace 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, BOIL-1, AND SH-1)

- Domestic Water Heater (DWH-1)
  - Manufacturer - American Appliance
  - Model - 82 SEJ-A
  - Energy source - Electric; 236 V; 1 phase; 60 Hz
  - Tank size - 82 gallon
  - Water Volume - 82 gallon
  - Energy input - 15,364 Btu/hr (4500W)
  - Energy output - 15,364 Btu/hr (4500W)
  - Maximum temperature rating - 180°
  - Heating stages - Single
  - Maximum recovery rate - 17 gal/hr
  - Yearly average inlet temperature - 50° F
  - Design output temperature - 120° F
  - Thermal resistance - R11
  - Corrosioin protection anodes - No
  - Burner ignition method - Electronic
  - Flue vent - No
- Boiler (FURN-1)
  - Manufacturer - General Electric
  - Model name/number - BLU080E936AO
  - Energy source - Natural gas
  - Energy input - 80,000 Btu/hr
  - Energy output - 64,000 Btu/hr
  - Maximum temperature - 80° F
  - Burner Heating Stages - Single

- Design Energy at highest heat
  - Input - 80,000 Btu/hr
  - Output - 64,000 Btu/hr
- Design air temperature rise
  - Low fan volume - 50° F
  - High fan volume - 80° F
- Burner ignition method - Gas pilot
- Flue vent - No

- Supplemental Heater (SH-1)
  - Model name/number - Fireplace
  - Type - Wood burning fire place
  - Heater description - Wood stone with fan unit pulling cool air from room and heating in duct and discharging hot air back into room.

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

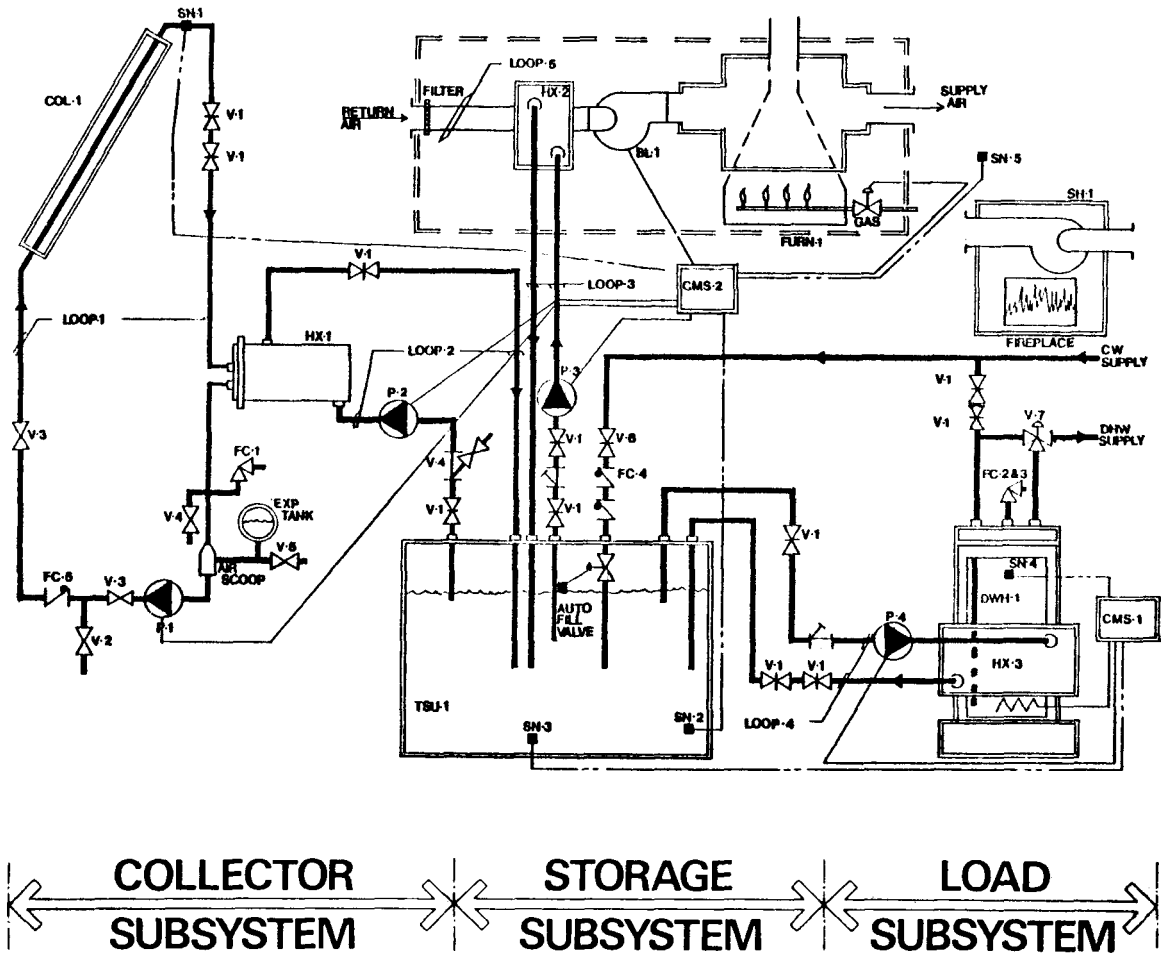


Figure IV-F-1. Controls Diagram

The Bond Construction Company'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 and cooling) d) auxiliary loads subsystems.

The auxiliary load system includes a gas fired furnace, domestic hot water tank and for supplemental heat, a fireplace. Anti-freeze and prevention of overheating are also included in this system.

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 there is a temperature difference of 20° F between a control sensor located at the collector and a control sensor located inside the storage tank (near the bottom). At this time the controller turns on both the collector and storage circuit pumps (P-1 and P-2, respectively). Solar energy is transferred from the collector to the storage tank by an external heat exchanger. Both pumps continue to operate until the temperature difference is less than 5° F. The controller then turns both pumps off.

Mode 2 - Storage-to-Space Heating:

This mode activates when the room temperature drops to the setting on the house thermostat. At this point, this mode is initiated if the storage temperature, measured by a control sensor inside the tank (near the top), is higher than 95° F. If so, the furnace circuit pump (P-3) turns on and hot water circulates from the storage tank through a liquid-to-air heat exchanger in the furnace. At the same time the furnace fan turns on, forcing air past the heat exchanger, thereby transferring the solar energy to the heating load. If the room temperature drops an additional increment (set point), the auxiliary gas burner turns on to provide an additional increment (set point). The auxiliary gas burner turns on to provide auxiliary energy to the heating load. The mode terminates storage temperature to 90° F while in this mode. The fan and gas furnace continue to supply energy until the thermostat demand is satisfied. This mode does not activate the storage temperature is below 95° F when the room thermostat calls for heat. Auxiliary energy is then provided by the gas furnace. The pump, fan and burner (is on) are turned off when the room temperature exceeds the thermostat setting.

Mode 3 - Storage-to-DHW:

This mode activates when there is a temperature difference of 10° F between the control sensor located inside the storage tank (near the top) and the control sensor located in the hot water tank (near the middle). This mode terminates when the

temperature difference drops to 3° F. Pump P-4 circulates hot water, when this mode activates, from the storage tank through an annular jacket surrounding the hot water tank. Energy is thereby transferred to the water in the hot water tank. The electric immersion heater, in the hot water tank, turns on to provide auxiliary energy to the DHW, if the temperature in the hot water tank drops below its thermostat setting.

Mode 4 - Elimination of Excess Heat in Summer:

This mode activates when the storage tank temperature, as determined by an aquastat located in the tank, exceeds 180° F. The collector and storage circuit pumps (P-1 and P-2, respectively) at this time are activated, thereby transferring energy from the storage tank to the collector by way of the external heat exchanger. This energy is then radiated from the collector to the atmosphere. This mode continues until the storage temperature drops below 180° F.

Mode 5 - Snow Removal in Winter:

This mode activates when the collector and storage circuit pumps (P-1 and P-2) are manually switched on in order to melt the snow that has accumulated on the collector.

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. Addtional 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 temperature
- 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.

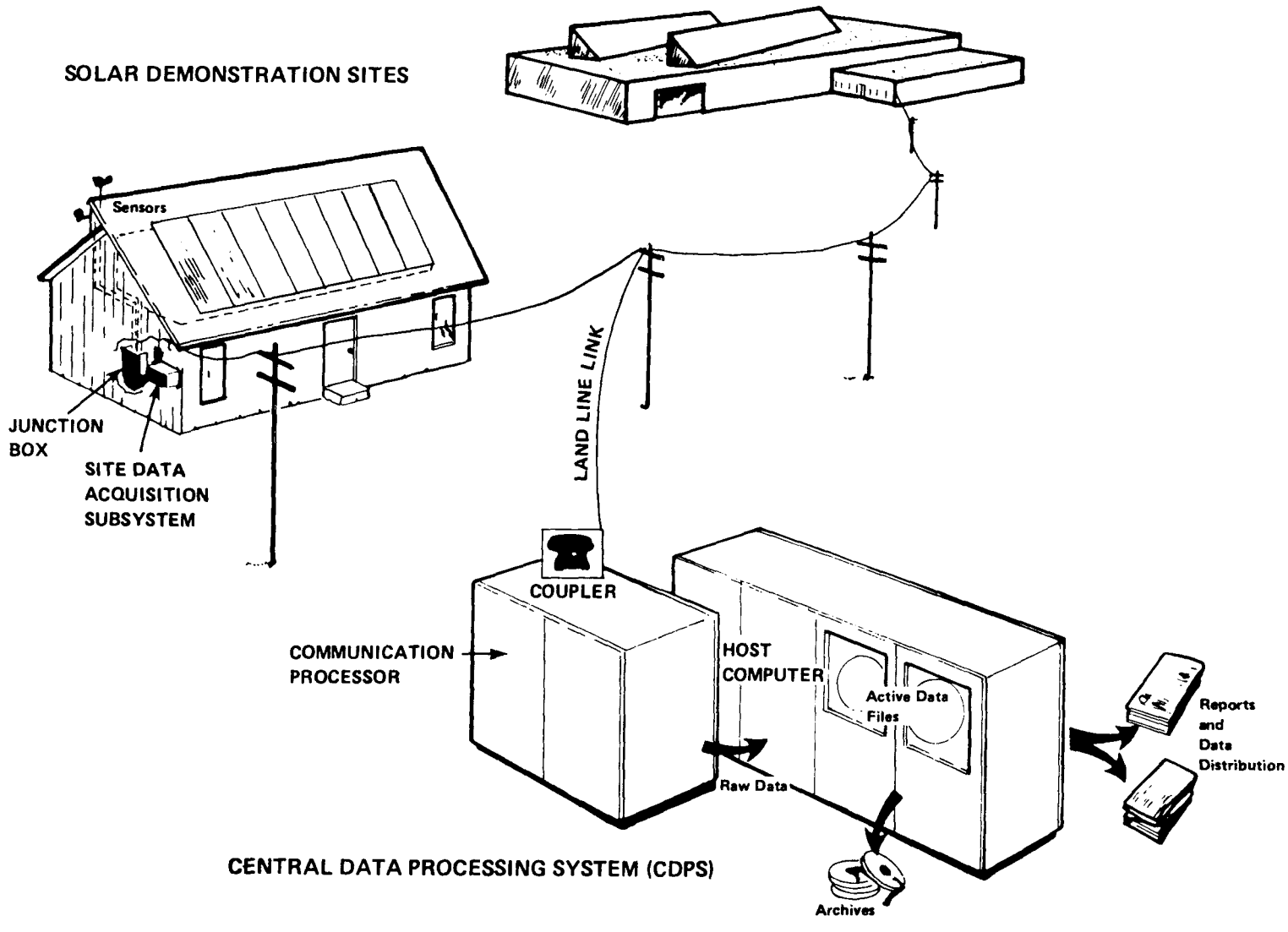


Figure V-A-1. The National Solar Data Network

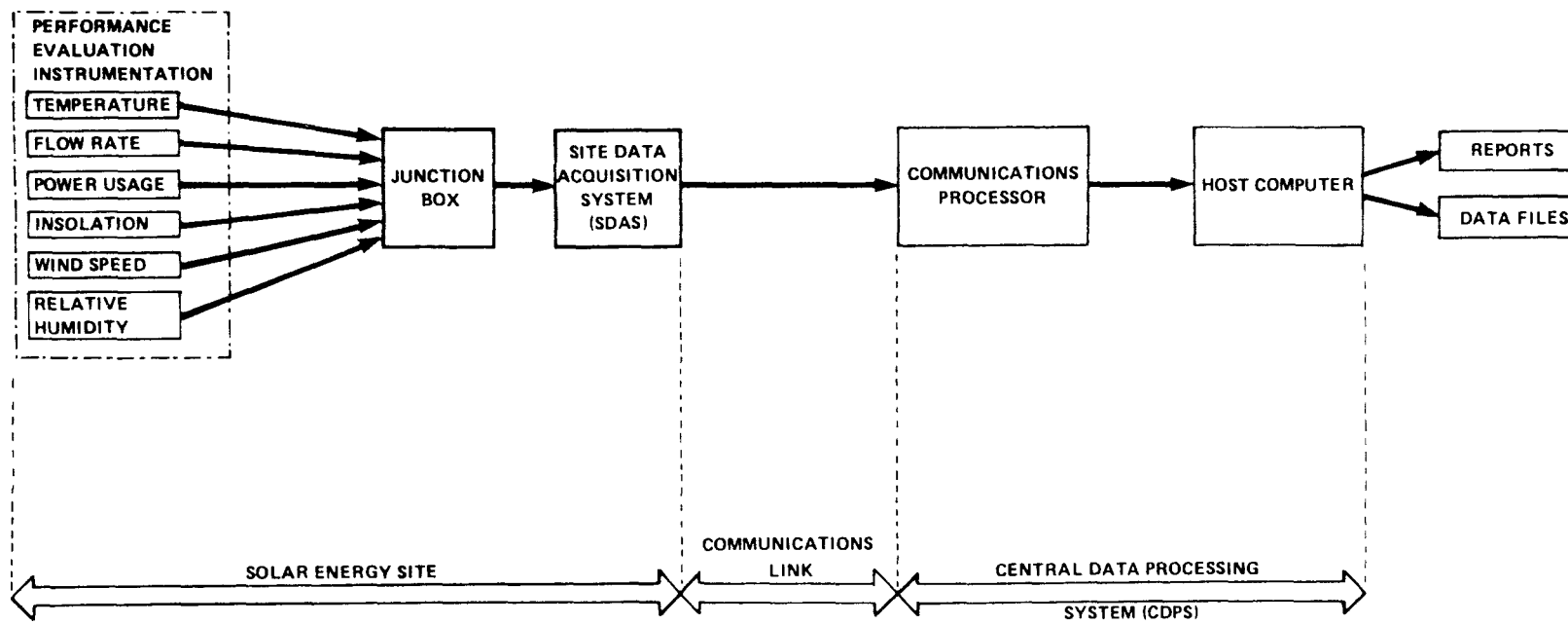


Figure V-A-2. Data Flow Path for the National Solar Data Network

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 performance analyses.

Apprpriate 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.

SENSORS	DESCRIPTION OF MEASUREMENT	Model No
I-001	Total Insolation	Eppley PSP
T-001	Outside ambient temperatures	53P-60/1S4S
T-100	Temperature, collector inlet	S53P-60
T-101	Temperature, collector outlet	S53P-60
W-100	Flow, collector / HX loop	MK V 1¼, 1.5-15
T-102	Temperature, HX (collector) outlet	S53P-60
T-103	Temperature, HX (collector) inlet	S53P-60
EP-100	Power, collector / HX loop pump	PC5-1
T-200	Temperature, HX (storage) inlet	S53P-60
T-201	Temperature, HX (storage) outlet	S53P-60
W-200	Flow, HX / storage loop	MK V 2, 5-50
EP-200	Power, HX / storage loop pump	PC5-1
T-202	Temperature, water storage	S53P-396
T-203	Temperature, water storage	S53P-266
T-204	Temperature, water storage	S53P-150
T-400	Temperature, furnace coil (storage) outlet	S53P-60
T-401	Temperature, furnace coil (storage) inlet	S53P-60
W-400	Flow, furnace coil / storage loop	MK V 1, 1.2-12
EP-400	Power, furnace coil / storage loop pump	PC5-1
T-300	Temperature, DHW HX (storage) outlet	S53P-60
T-301	Temperature, DHW HX (storage) inlet	S53P-60
W-300	Flow, DHW HX / storage loop	MK V 3/4, .7-7
EP-300	Power, DHW HX / storage loop pump	PC5-1
T-302	Temperature, DHW tank liner	S32B
T-303	Temperature, cold water supply	S53P-60
T-304	Temperature, water heater outlet	S53P-60
W-301	Flow, cold water supply to DHW system	HERSEY 430 mod.
EP-301	Power, water heater (4 passes)	PC5-29
T-402	Temperature, house return air	S53P-100
T-403	Temperature, solar heating high	S53P-100
T-404	Temperature, gas heating high	S53P-100
W-401	Flow, house return air	430DC
EP-401	Power, furnace blower	PC5-10

SENSORS	DESCRIPTION OF MEASUREMENT	Model No
F-400	Volumetric Flow, natural gas to furnace	AC-175
T-600	Temperature, house ambient	S53P-28
EP-600	Power, fireplace heat blower	PC5-10
T-305	Temperature, storage tank surface	S32B

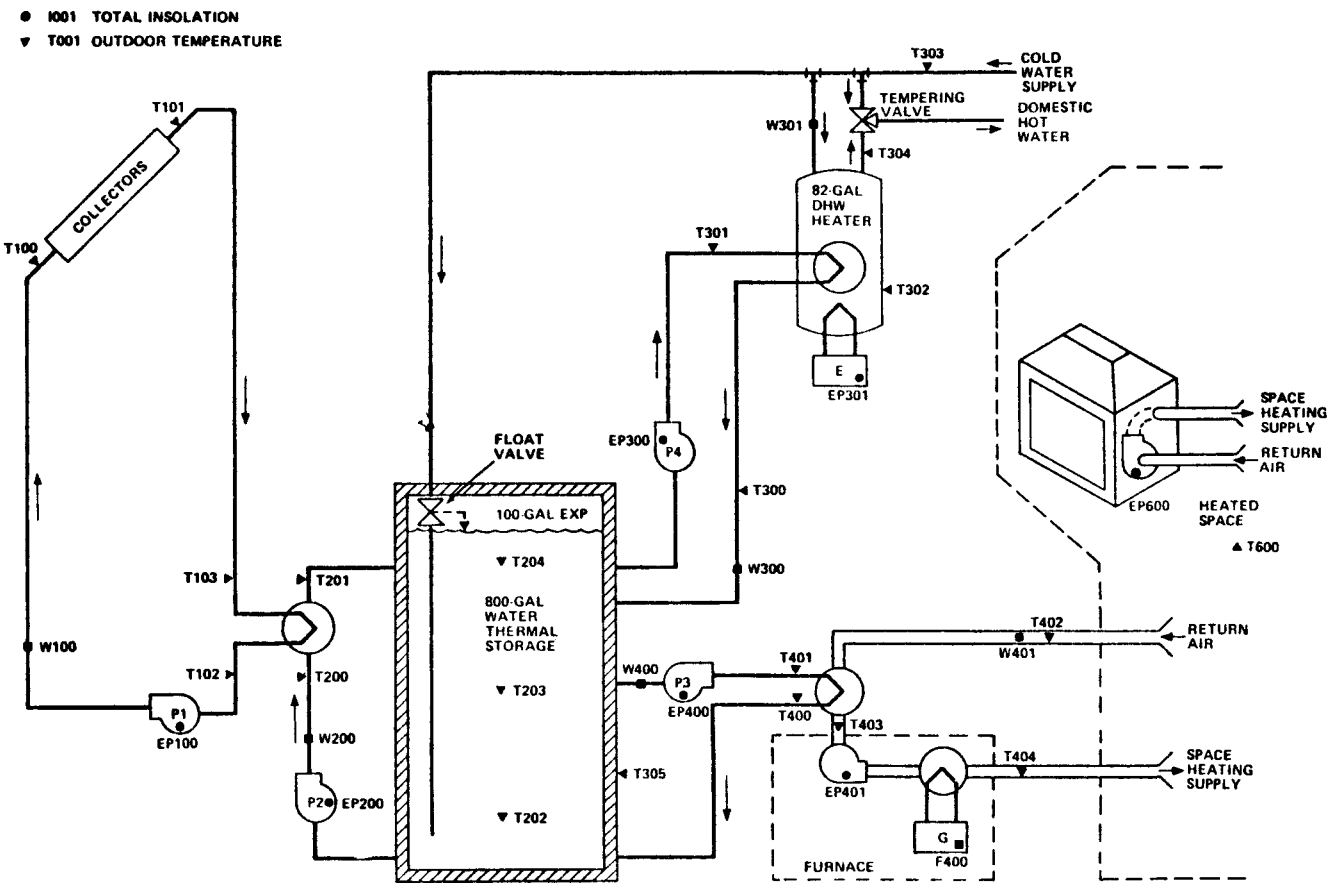


Figure V-B-1. Sensor and Control Diagram

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	7,540.00	
Energy Storage	1,515.00	
Distribution and Controls		
Installation	1,800.00	
Other	3,412.00	
Total	14,267.00	14,267.00

C. Construction Period:

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, 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 suplement 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 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 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 radation 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 wel 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 of 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.

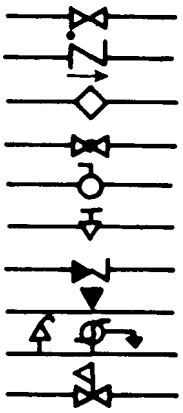
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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.

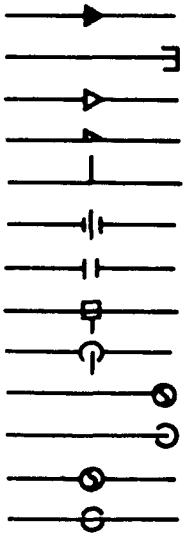
B. Legend For Solar System Schematics

VALVES



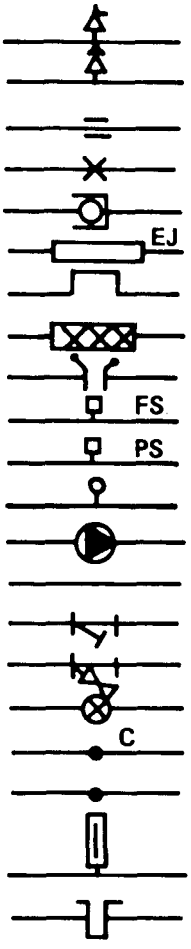
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS

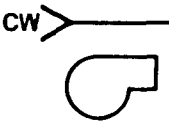


DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

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

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