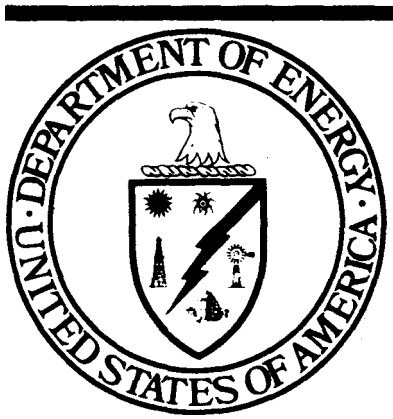
Lh. 60174

MASTER

SOLAR/1005-79/50

Solar Project Description

FLORIDA GAS COMPANY'S SINGLE FAMILY RESIDENCE
Winter Springs, Florida
June 22, 1979



U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

SOLAR/1005-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
FLORIDA GAS COMPANY'S
SINGLE FAMILY RESIDENCE - WINTER SPRINGS, FLORIDA

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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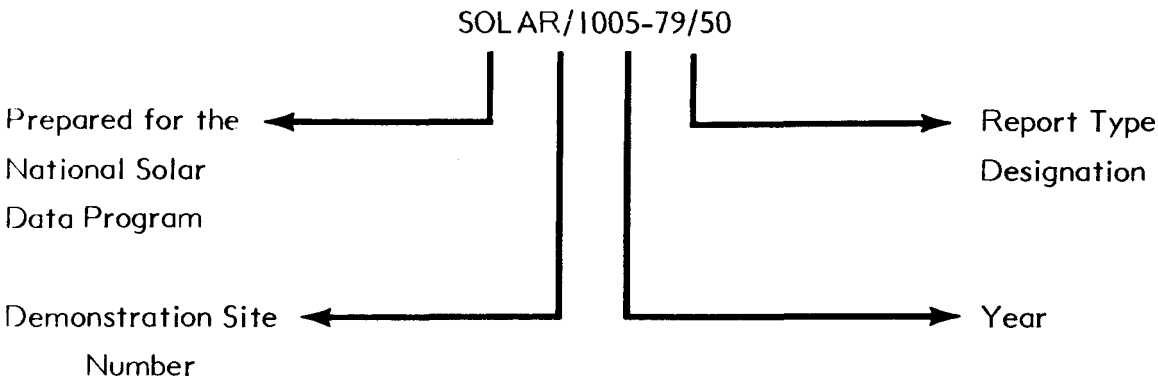
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Florida Gas Company's single family residence project site is designated as SOLAR/1005-79/50. 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 - Yes, recirculation
- o Application - Heating, cooling, domestic hot water
- o Storage - Water, 1350 gallon tank
- o New or Retrofit - New
- o Performance Evaluation Instrumentation - Yes
- o Site-Specific Features - Solar energy powered absorption water chiller, gas fired boiler auxiliary heating

The Florida Gas Company solar energy system is installed in a 1,548 square-foot, three bedroom single family dwelling located in Winter Springs, Florida. The system is designed to provide solar energy for space heating, space cooling, and domestic hot water heating.

Solar energy is collected by two banks of double glazed flat plate collectors with a gross area of 714 square feet. The two collector banks are mounted on the roof of the house and face due south at an angle of 18 degrees to the horizontal to optimize solar energy collection.

Solar energy is transferred from the collector array to a 1,350 gallon underground storage tank. Water is used as the heat collection, transfer and storage medium. Freeze protection is provided by means of circulation of hot water from storage through the collectors. No anti-freeze additive is required.

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 a natural gas fired boiler.

A 3-ton solar energy powered absorption cycle Water Chiller provides chilled water for circulation through the same air distribution system. A gas fired boiler provides supplemental thermal energy to the chiller when sufficient thermal energy is not available from storage.

Solar energy for heating domestic hot water is provided by circulating water from a conventional fifty gallon domestic hot water heater through a heat exchanger located in the solar storage tank. Auxiliary energy for domestic hot water is provided by natural gas whenever the temperature of the domestic hot water tank falls below 130° F.

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

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 cost of its instrumentation are not included in this report.

III. SITE AND BUILDING DESCRIPTION

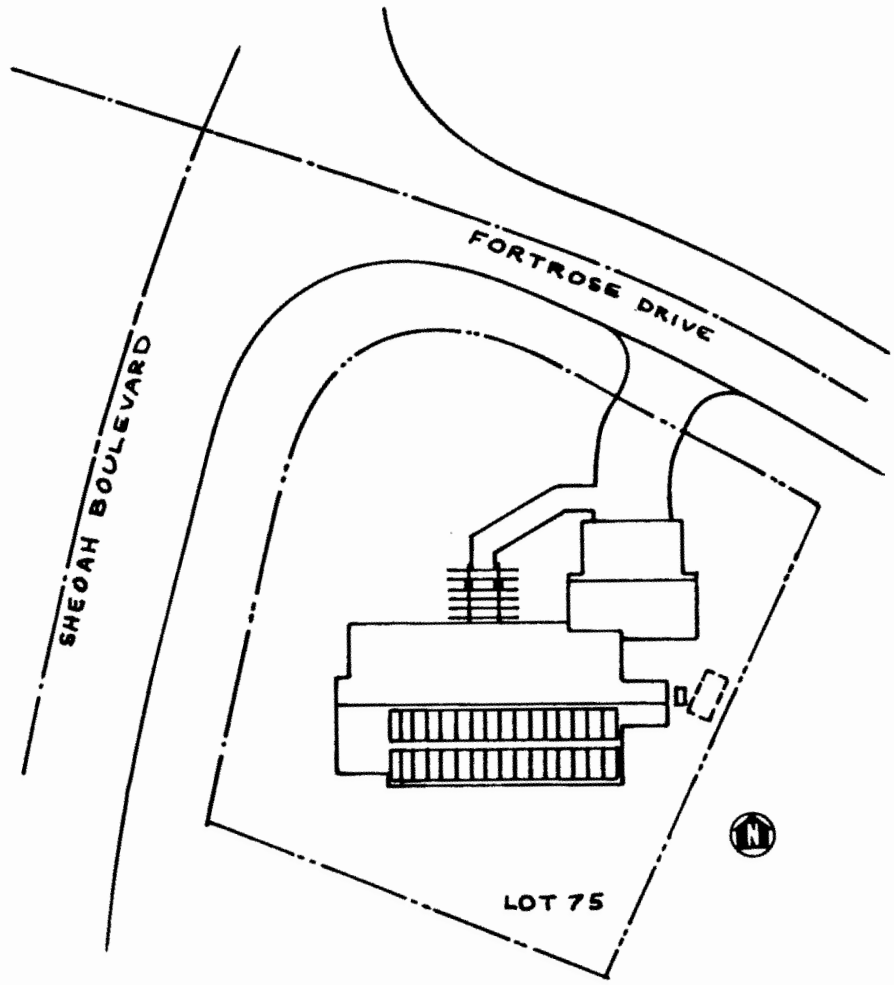


Figure III-1. Site Plan

Site Description (See Figure III-1)

- Topography - Flat
- Latitude - 28°-40'N
- Longitude - 82°
- Elevation - 106 feet
- Annual degree days (65° F base)
  - Heating - 766
  - Data location - Orlando, Florida
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmlospheric Administration
- Average horizontal insolation
  - January - 1100 Btu/ft^2/day
  - July - 1800 Btu/ft^2/day
  - Data location - Orlando, Florida
  - Data reference - "Mean Solar Radiation for Florida Cities" - FL Solar Energy Center, April 77
- Shading
  - Heating season - 30 square feet
  - Cooling season - 0 square feet

Building Description

- Occupancy
  - Single family
  - Family of five
  - Three bedroom living/dining room, kitchen, mech./solar room, 2 bathrooms, attached garage
- Total area - Approximately 2,000 square feet
- Solar conditioned area - 1,548 square feet

- Height - One story
- Roof slope at collector - 4/12 pitch, gable
- Special features - Screened porch

Structure

- Walls (Solar conditioned space)
  - Frame - Concrete foundation, wood frame
  - Exterior finish - Rough sawn 1 x 6 T&G Cedar
  - Insulation - 6" fiberglass batts in 2 x 6 studs
  - Interior finish - Gypsum wallboard
  - Windows - Wood sash
    - Glazing - Single
    - 35% of exterior wall area
  - Doors
    - Front door - Solid wood, weatherstripped
    - Rear door - Opens into garage
    - Garage door - Opens into non-conditioned area
    - Sliding glass door - Opens into screened porch
- Roof
  - Structural frame - Wood truss
  - Exterior finish - Asphalt shingles and tern metal under solar panels
  - Insulation - 9 inch fiberglass batts
  - Interior finish - Gypsum wallboard

Mechanical System

- Heating
  - Solar - Liquid active
  - Auxiliary - Gas fired boiler - Ruud
  - Distribution - Hot air ducting

- Cooling (Non-Solar) Absorption
  - Auxiliary - Arkla, chilled water air conditioner
  - Distribution - Utilizes hot air ducting

Domestic Hot Water

- Daily water demand - 80 gallons per day
- Solar - Double heat exchanger located in solar storage tank
- Auxiliary - 50 gallon gas fired water heater

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (Florida Gas Company Grant H-2728) located at Winter Springs, Florida is a liquid active system utilized for heating, cooling and domestic hot water. Auxiliary units are provided for heating, cooling and domestic water.

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

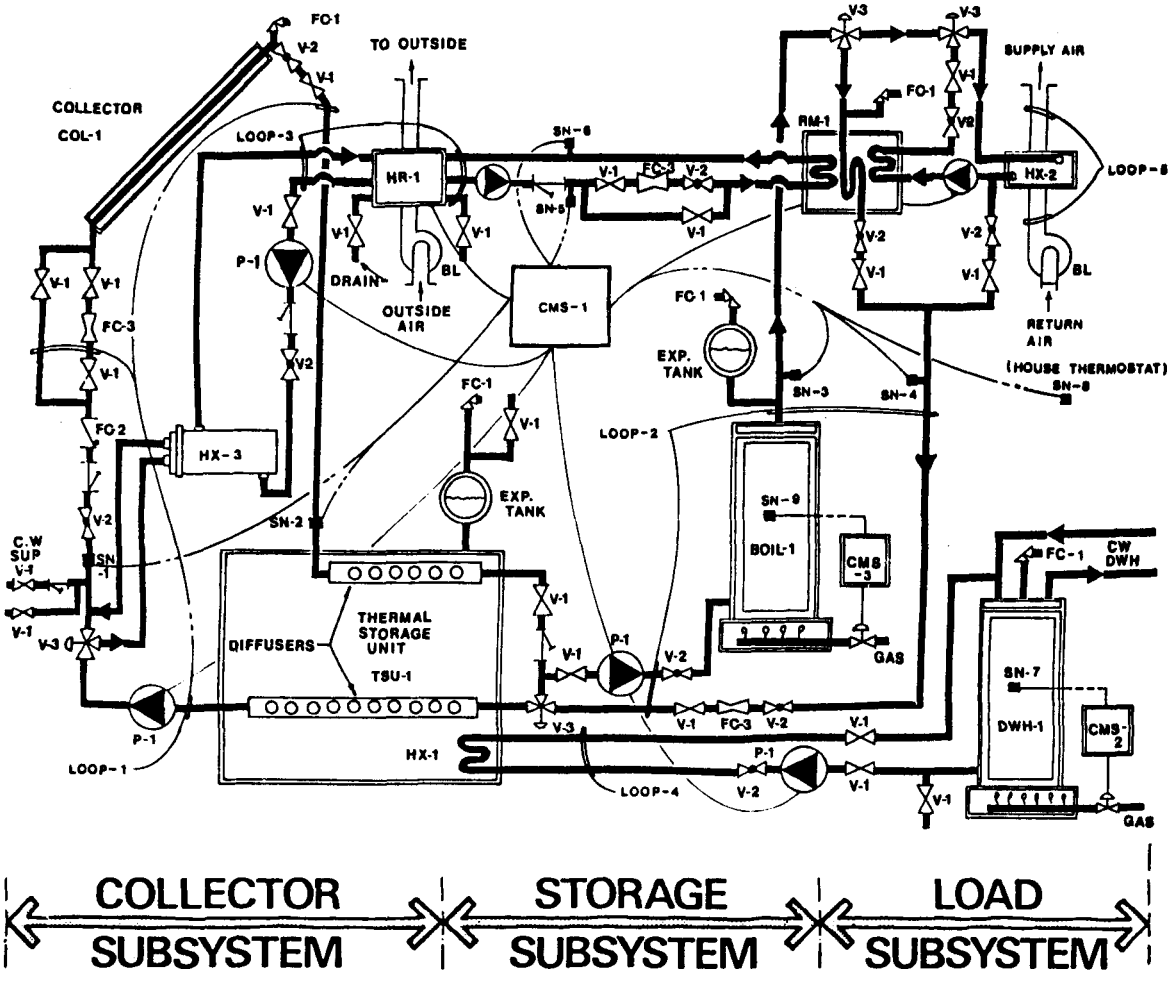


Figure IV-A-1. General Overview

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

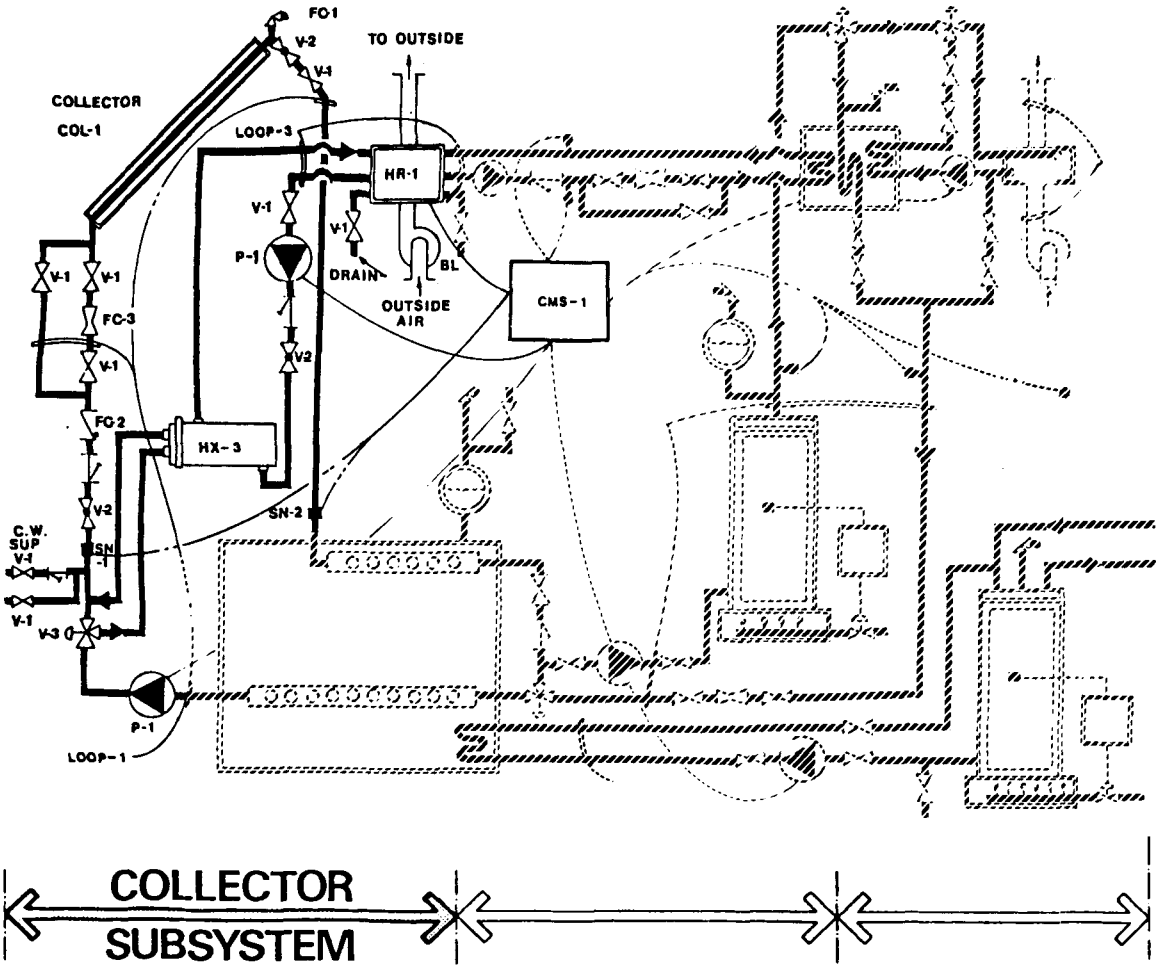


Figure IV-B-1. Collector Subsystem

Collector array system consists of 34 double glazed selective surface, flat plate collector panels. Freeze protection is provided by thermostatically controlled water flow from storage through the collectors.

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

- Manufacturer - Chamberlain
- Model name/number - 711301
- Type - Liquid flat plate, tube and plate
- Location - Roof
- Orientation - Due south
- Tilt angle - 18° from the horizontal
- Number of collector panels - 34 (3 x 7 foot panels)
- Array configuration - Two rows of seventeen panels
- Collector
  - Total gross area of array - 714 square feet
  - Net aperture area - 653 square feet
  - Weight per panel, empty - 190 pounds
  - Weight per panel, full - 195 pounds
  - Weight of filled array and support structure - 7300 pounds
  - Panel length - 84.3 inches
  - Panel width - 36.3 inches
  - Frame depth - 5.1 inches
  - Standoff height - 1 inch
- Glazing (cover plate)
  - Number of cover plates - Two
- Cover plate No. 1 - Outer
  - Manufacturer - ASG Industries
  - Material - Low iron tempered glass
  - Thickness - 0.125 inches
  - Coating - None

Chamberlain Solar Collector Panel Specifications

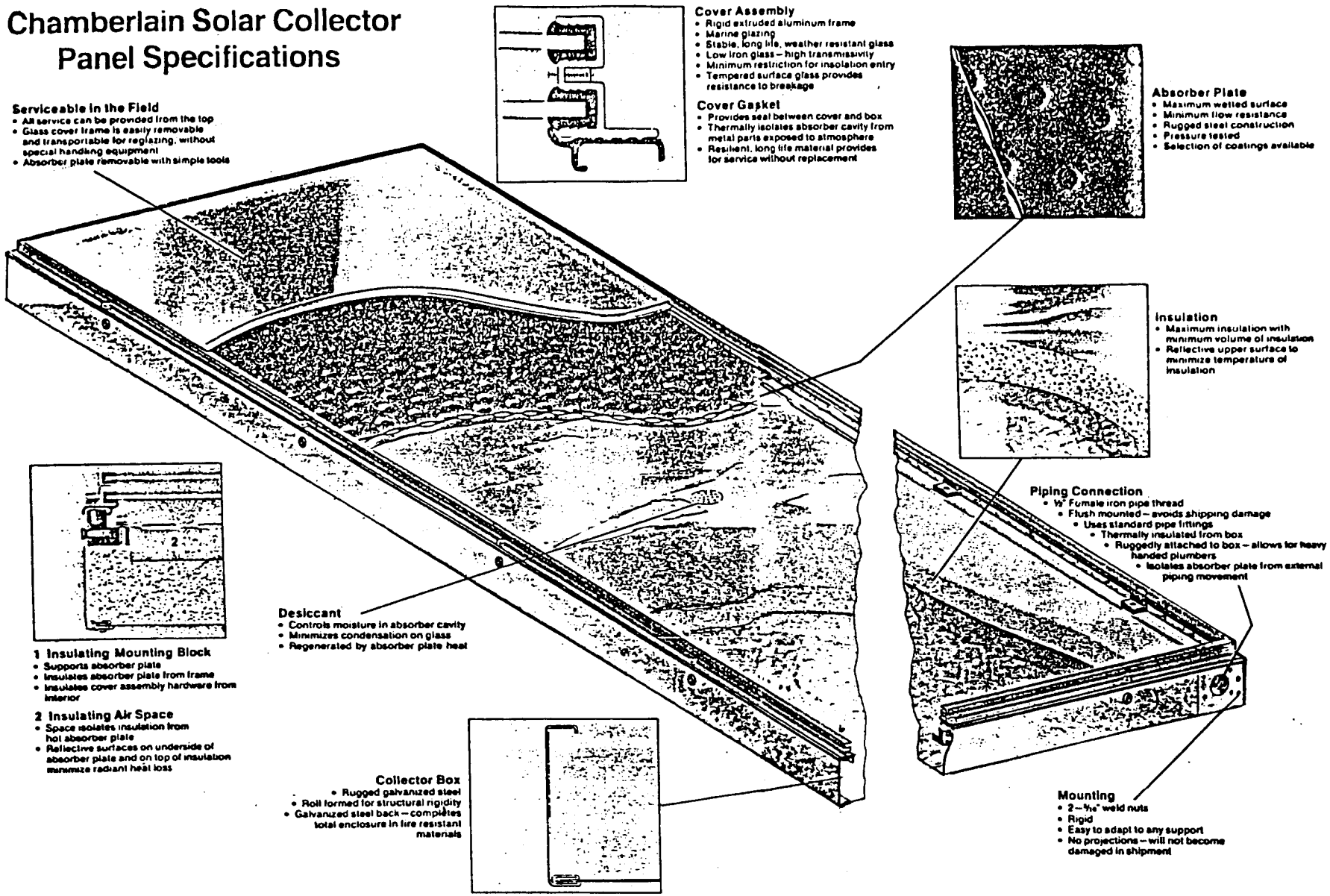


Figure IV-B-2. Solar Collector

- Optical properties (solar region) (infrared region)
  - Transmittance 90% 9%
  - Reflectance 8% 8%
  - Emittance - 93%
- Edge or surface treatment, other than coating - None
- Coating on cover plate material - None

- Cover plate No. 2 - Inner
  - Manufacturer - ASG Industries
  - Product Name/Number - True Temp
  - Material - Double strength tempered glass
  - Thickness - .125 inches
  - Optical properties (solar region) (infrared region)
    - Transmittance 89% --
    - Reflectance 8% 12%
  - Edge treatment - Mechanically ground
  - Coating - None

- Absorber
  - Manufacturer - Trantor
  - Material - Two 20 gage steel plates
  - Substrate material dimension
    - Thickness - .072 inches
    - Length - 82.24 inches
    - Width - 34.25 inches

- Coating
  - Black chrome over dull nickel (Olympic Plating)
  - Application method - Electro-plate

- Absorptance, solar region - 94%; infrared; 12%
- Reflectance, solar region - 06%; infrared: 88%
- Emittance - 94%

- Heat transfer fluid passages
  - Location - In absorber
  - Pattern - Quilted
  - Materials - Steel
  - Wall thickness - .036 inches
  - Internal diameter - 0.045 inches (equivalent)
  - Maximum operating conditions
    - Temperature - 400°F
    - Pressure - 75 psi
  - Fluid passage bond to substrate - Integral
  - Protective coating inside fluid passage - None

- Insulation
  - Layer one - sides
    - Manufacturer - Owens-Corning
    - Product Name/Number - Fiberglass
    - Material - Glass fiber, 1 inch compressed to 0.875 inch
    - Thermal resistance - R-3
  - Layer one - back
    - Product Name/Number - Fiberglass
    - Manufacturer - Owens-Corning
    - Material - Glass fiber, 5 inches compressed to 3 inches
    - Thermal resistance - R-15

- Gaskets and sealants
  - Inner cover - Rubber EPDM
  - Outer cover - Rubber EPDM
  - Backing plate - Rubber EPDM
  - Penetrations - Rubber EPDM
- Frame
  - Manufacturer - Chamberlain
  - Product Name/Number - 71130
  - Material
    - Aluminum - Extruded 6063, for glazing
    - Steel - Roll-formed, for base
  - Protective coating - Painted
  - Number of structure attach points per module to building - 4
  - Desiccant - Silica Gel, self regenerating
  - Freeze protection - Circulation of hot storage fluid
  - Overheating protection - Energy dumping heat exchanger
- Collector performance
  - Method of evaluation - ASHRAE $(t_i-t_a)/I_t$
  - y intercept - .72° F ft^2hr/Btu
  - Slope - 0.58

Point Number	1	2	3	4
n = Collector thermal efficiency (%) -	38	47.5	52.0	55.0
t_i = collector inlet temperature (°F) -	140	140	140	140
t_a = ambient air temperature (°F) -	50	50	50	50
I_t = insolation intensity Btu/hr ft^2 -	150	200	250	300
ASHRAE $(t_i-t_a)/I_t$ -	0.60	0.45	0.36	0.30

- Test flow rate - 277.4 pounds per hour
- Test collector area
  - Gross - 21.0 square feet
  - Net - 19.2 square feet
- Fluid specific heat - 0.91 Btu/lb^{o}F
- Test fluid medium - 50% water, 50% ethylene glycol

Liquid Circulation Loop No. 1 (COL-1 to TSU-1)

- Design maximum operating temperature - 225^{o} F
- Heating design liquid flow - 14 gal.min, minimum
- Cooling design liquid flow - 30 gal/min, maximum
- Heat transfer medium - Water 100% of total volume
  - Specific heat - 1.00 Btu/lb ^{o}F
  - Density - 63 lb/ft^{3}
  - Boiling point - 212^{o} F
  - Freezing point - 32^{o} F
  - Maximum recommended use temperature - 210^{o} F
  - Toxicity - Inhibitors
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - Pot/Batch
  - Inhibitor - Yes
- Piping
  - Rigid - Copper, type L
  - Piping insulation - Glass fiber
  - Location - Above grade
  - Filters - One

- Circulator pump (P-1)
  - Manufacturer - Bell and Gossett
  - Model Name/Number - 60-11
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 8.5 psi
    - Temperature - 225° F
  - Material exposed to heat transfer fluid - Bronze
  - Motor size - 0.25 hp, 115 volts, 1 phase, 60 Hz
  - Maximum motor speed - 1750 rpm
  - Drive - Direct
  - Speed - Single
  - Pump speed - 1750 rpm
  - Circulating volume - Low head mode - 16 gal/min
  - Operating head (dynamic) - Low head mode - 125 psi
  - Motor operation - .17 bhp
- Heat rejection device (HR-1)
  - Manufacturer - Goodfellow
  - Model Name/Number - P8
  - Type - Water cooling tower
  - Number of fans - One
- Distribution Valve (V-1)
  - Function - ON-OFF, drain
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Brass

- Distribution Valve (V-2)
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid - Brass
- Distribution Valve (V-3)
  - Manufacturer - Honeywell
  - Model Name/Number - M734K1014
  - Function - Flow switching and 3 way mixing
  - Operation - Automatic, motorized
  - Type - Ball, 3 way
  - Materials exposed to heat transfer fluid - Brass

Control Mode Selector (CMS-1)

- Modes controlled
  - Collector to storage - ON @ 7° F differential
  - Storage to space
  - Storage to hot water
- Sensors (SN-1) and (SN-2)
  - Manufacturer - Trerice
  - Type - Temperature, Western Thermister
- Sensor (SN-8)
  - Type - Thermostat
- Fail Safe Control (FC-1)
  - Manufacturer - Bell and Gossett
  - Product Name/Number - A-8
  - Type - Pressure relief valve

- Flow Control (FC-2)
  - Manufacturer - Granger
  - Type - Check valve
- Flow Control (FC-3)
  - Product Name/Number - Flow meter
  - Type - Flow sensor

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

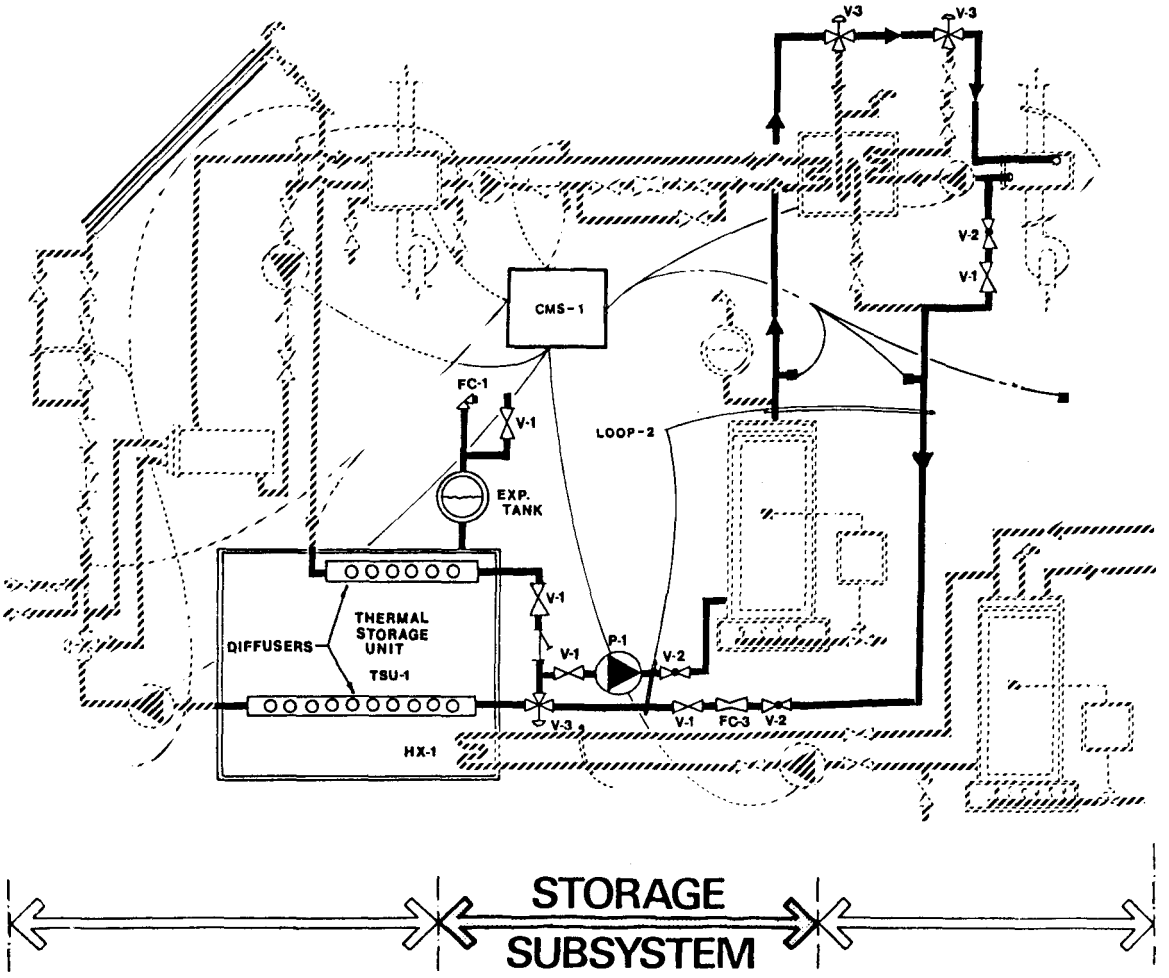


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by a 1,350 gallon underground storage tank. This tank is made of steel with a phenolic interior. It measures 5 feet in diameter, 10 feet in length and is covered with 6 inches of insulation. Diffuser tubes are attached to both the inlet from the collector array and the outlet to the heating/cooling subsystem. A short circuit through this tube is provided when the collector pump and the load pump are both circulating water through storage. Two diffuser tubes installed within the storage tank are designed to mix the supply and return liquid in the tank.

Thermal Storage Unit (TSU-1)

- Container
  - Total storage volume - 181 ft^3 (1350 gallons)
    - Length - 9.3 feet
    - Diameter - 5.0 feet
- Storage medium
  - Heating design temperature - 225° F, maximum
  - Medium - 100% water
  - Specific heat - 1.000 Btu/ lb °F
  - Density - 62 lb/ft^2
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Recommended medium temperature - 225° F, maximum
  - Toxicity - Inhibitor
  - pH Factor - 7.0
  - Inhibitor - Yes
- Container construction
  - Type - Steel tank, phenolic lining
  - Location - On site, below grade
  - Auxiliary heaters - No
  - Insulation - Polyurethane block
  - Exterior finish - Biluminous Mastic
  - Filters - At inlet of container

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

- Design operating temperature 225° F, maximum
- Heating design liquid flow - 16 gal/min, maximum

- Heat transfer medium
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb ^{o}F
  - Density - 63 lb/ft^3
  - Boiling point - 240^{o} F
  - Freezing point - 32^{o} F
  - Maximum recommended use temperature - 225^{o} F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - Pot/Batch
  - Inhibitor - Yes
  - Piping
    - Rigid - Copper
    - Insulation - Glass fiber
    - Location - Above grade
- Circulator pump (P-1), TSU-1-to-BOIL-1
  - Manufacturer - Bell and Gossett
  - Model Name/Number - 1 IN PR
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 8.5 psi
    - Temperature - 225^{o} F
  - Material exposed to heat transfer fluid - Bronze
  - Motor size - 0.166 hp, 115 volts, 1 phase, 60 Hz
  - Maximum motor speed - 1750 rpm
  - Drive - Direct
  - Speed Single

- Pump speed - 1750 rpm
- Circulating volume - Low head mode - 11 gal/min
- Operating head (dynamic) - Low head mode - 125 psi
- Motor operation - .17 bhp

- Distribution Valve (V-1)
  - Function - ON-OFF, drain
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Brass
- Distribution Valve (V-2)
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid - Brass
- Distribution Valve (V-3)
  - Manufacturer - Honeywell
  - Model Name/Number - M734K1014
  - Function - Flow switching and 3 way mixing
  - Operation - Automatic, motorized
  - Type - Ball, 3 way
  - Materials exposed to heat transfer fluid - Brass

Control Mode Selector (CMS-1)

- Modes controlled
  - Collector to storage - ON - 10^{o} F differential
  - Storage to space - ON -
  - Storage to hot water - ON -

- Sensors (SN-3) and (SN-4)
- Sensor (SN-8)
  - Type - House thermostat
- Fail Safe Control (FC-1)
  - Manufacturer - Bell and Gossett
  - Product Name/Number - A-8
  - Type - Pressure relief valve
- Flow Control (FC-3)
  - Product Name/Number - Flow meter
  - Type - Flow sensor

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

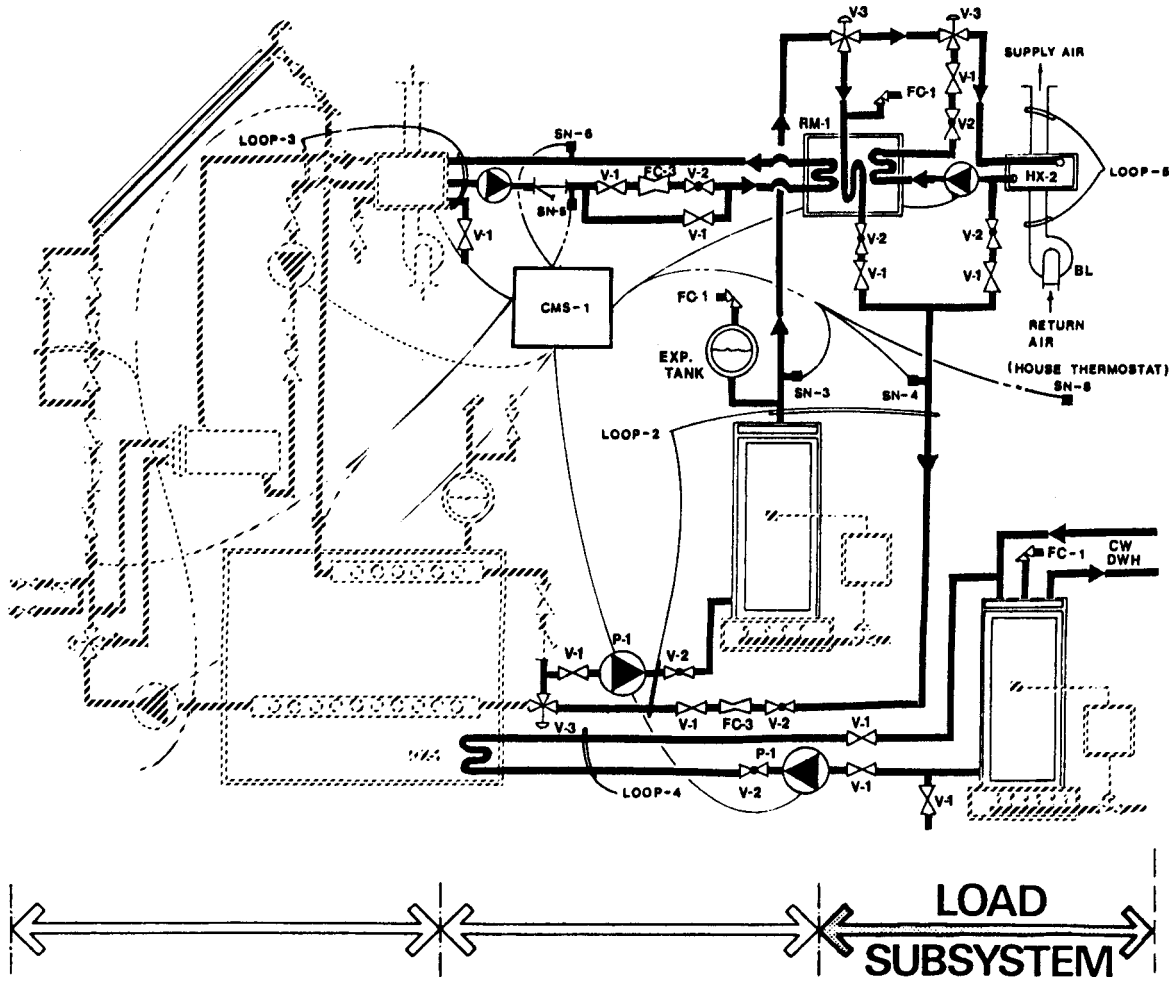


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy stored in the 1350 gallon storage tank is used to meet the space heating demands by circulating it through heating coils in the air distribution system. Auxiliary space heating, supplementing this source, is provided by a natural gas-fired boiler. Space cooling is provided by an Arkla model WF-36 3-ton absorption with a cycle chiller. The solar thermal energy is supplied to the chiller from the solar storage whenever the temperature of the top of the storage exceeds 170 degrees. When solar energy is not available, a gas boiler is activated to supply

energy to the absorption machine and storage is bypassed. Condenser water is provided by a conventional cooling tower. The fan on this tower is controlled by an aquastat. Chilled water produced by the absorption machine is circulated through a heat exchanger located in the central air distribution system of the house.

Liquid Circulation Loop No. 3 (RM-1 to HR-1)

- Design maximum operation temperature - 100° F
- Heating design liquid flow - 10 gal/min
- Heat transfer medium
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb °F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 210° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - Pot type
  - Inhibitor - Yes
- Piping
  - Rigid - Plastic, PVC
  - Location - Above grade
  - Filters - Yes

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

- Design maximum operating temperature - 160° F
- Heating design liquid flow - 2 gal/min maximum

- Heat transfer medium
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb ^{o}F
  - Density - 63 lb/ft^3
  - Boiling point - 240^{o} F
  - Freezing point - 32^{o} F
  - Maximum recommended use temperature - 160^{o} F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - None
  - Inhibitor - None
- Piping
  - Rigid - Copper, type L
  - Insulation - Glass fiber
  - Location - Above grade
- Heat Exchanger (HX-1)
  - Manufacturer - Taco
  - Type of exchanger - Liquid to liquid
  - Type of flow - Natural convection on outside, forced flow inside
  - Heat exchanger design - Tube inside tank
  - Number of separations - Single
  - Convection
    - Side one - Forced
    - Side two - Natural
  - Heating design capacity - 50,000 Btu/hr

- Effectiveness - 75% at 2 gal/min
- Material - Copper

- Circulator pump (P-1), TSU-1-to-BOIL-1
  - Manufacturer - Bell and Gossett
  - Model Name/Number - 1 IN PR
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 8.5 psi
    - Temperature - 225° F
  - Material exposed to heat transfer fluid - Bronze
  - Motor size - 0.166 hp, 115 volts, 1 phase, 60 Hz
  - Maximum motor speed - 1750 rpm
  - Drive - Direct
  - Speed Single
  - Pump speed - 1750 rpm
  - Circulating volume - Low head mode - 30 gal/min
  - Operating head (dynamic) - Low head mode - 125 psi
  - Motor operation - .17 bhp
- Distribution Valve (V-1)
  - Function - ON-OFF, drain
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Brass

- Distribution Valve (V-2)
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid - Brass
- Flow Control (FC-1)
  - Manufacturer - Bell & Gossett
  - Product Name/Number - A-8
  - Type - Pressure relief valve
- Flow Control (FC-3)
  - Type - Flow meter

Air Circulation Loop No. 5 (HX-2 to Space Heating)

- Location - Above grade, inside building
- Ducting
  - Rigid ducting - Aluminum
  - Joint type - Pressure sensitive tape
- Heat Exchanger (HX-2)
  - Type of flow - Cross
  - Heat exchanger design - Fin coil, coil in duct
  - Type of exchanger - Liquid-tAir
  - Convection
    - Air side - Forced
    - Liquid side - Forced
    - Effectiveness - 72% at 12 gal/min
    - Material - Copper

Control Mode Selector (CMS-1)

- Modes controlled
  - Collector to storage - ON - 10^{o} F differential
  - Storage to space - ON -
  - Storage to hot water - ON -
- Sensors (SN-5) and (SN-6)
  - Type - Thermostat
- Sensor (SN-8)
  - Type - House thermostat
- Fail Safe Control (FC-1)
  - Manufacturer - Bell and Gossett
  - Product Name/Number - A-8
  - Type - Pressure relief valve
- Flow Control (FC-3)
  - Product Name/Number - Flow meter
  - Type - Flow sensor

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

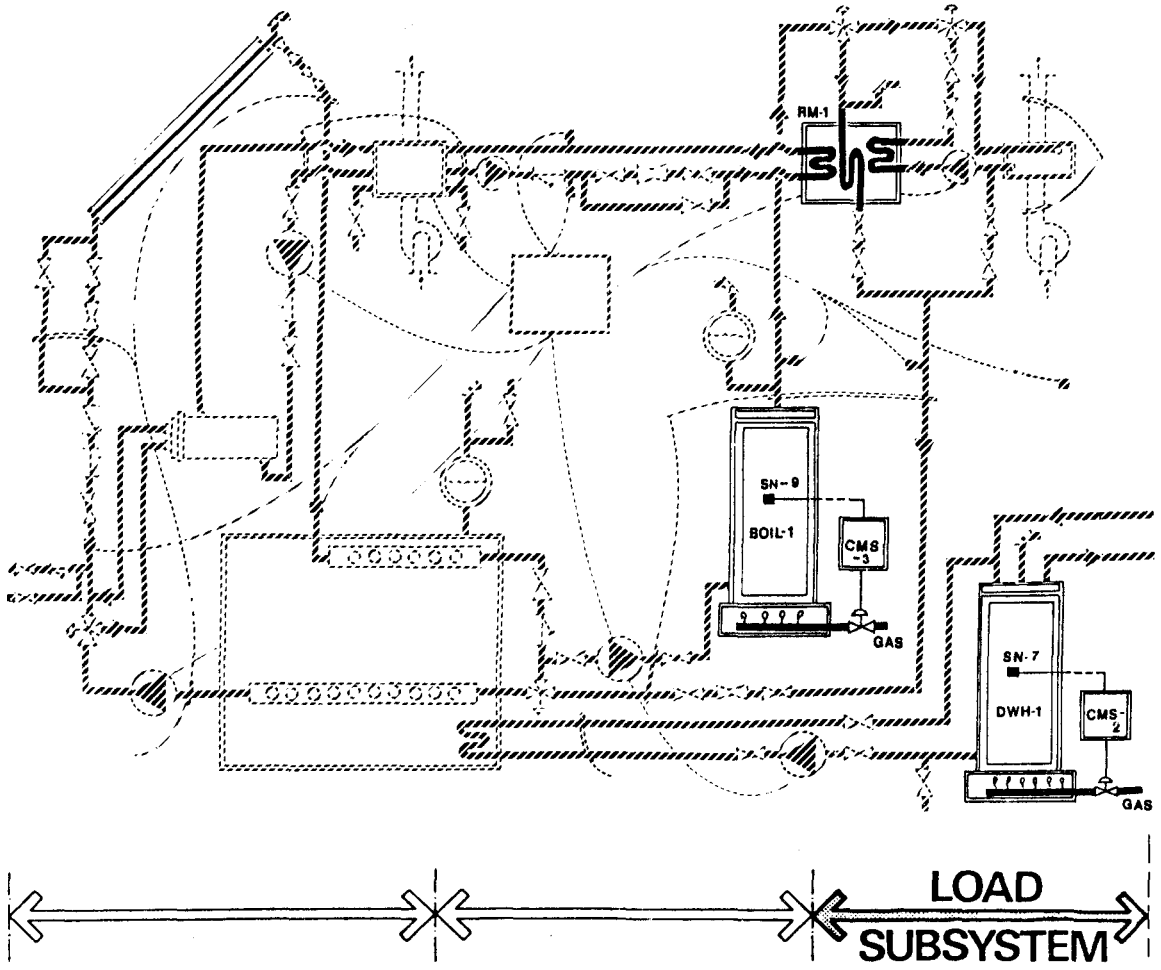


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystems, domestic hot water tank, boiler and air conditioner 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, RM-1 and HR-1)

- Domestic Water Heater (DWH-1)
  - Manufacturer - Ruud
  - Model - RP50-33-1
  - Energy source - Natural gas
  - Tank size - 50 gallons
  - Energy input - 33,000 Btu/hr
  - Energy output - 27,000 Btu/hr
  - Maximum pressure rating - 300 psi
  - Maximum temperature rating - 200° F
  - Design operating pressure - 150 psi
  - Heating stages - Single
  - Maximum recovery rate - 56 gal/hr
  - Yearly average inlet temperature - 60° F
  - Design output temperature - 120° F
  - Thermal resistance - R-6
  - Standby heat loss - 1.5% per hour
  - Corrosion protection anodes - Magnesium
  - Burner ignition method - Pilot
  - Flue vent - Open
- Boiler (BOIL-1)
  - Manufacturer - Ruud
  - Model Name/Number - GL 13-108 boiler
  - Energy source - Natural gas

- Energy input - 108,000 Btu/hr
- Energy output - 86,000 Btu/hr
- Burner ignition method - Pilot
- Flue vent - Open

- Refrigeration Machine (RM-1)
  - Manufacturer - Arklar, modified by Chrysler
  - Model Name/Number - WF-501
  - Type - Absorption
  - Refrigeration fluid - Water
  - Absorber fluid - Lithium Bromide
  - Power source - Boiler assisted solar
  - Design total cooling capacity - 36,000 Btu/hr
  - Demand side, Circulation Loop - No. 2
  - Heat rejection side, Convection Loop - No. 4
- Heat Rejection Device (HR-1)
  - Manufacturer - Goodfellow
  - Model Name/Number - Model P8
  - Type - Water cooling tower, mechanical draft
- Control Mode Selector (CMS-2)
  - Modes controlled - Auxiliary hot water heater
- Sensor (SN-7)
  - Type - Thermostat

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

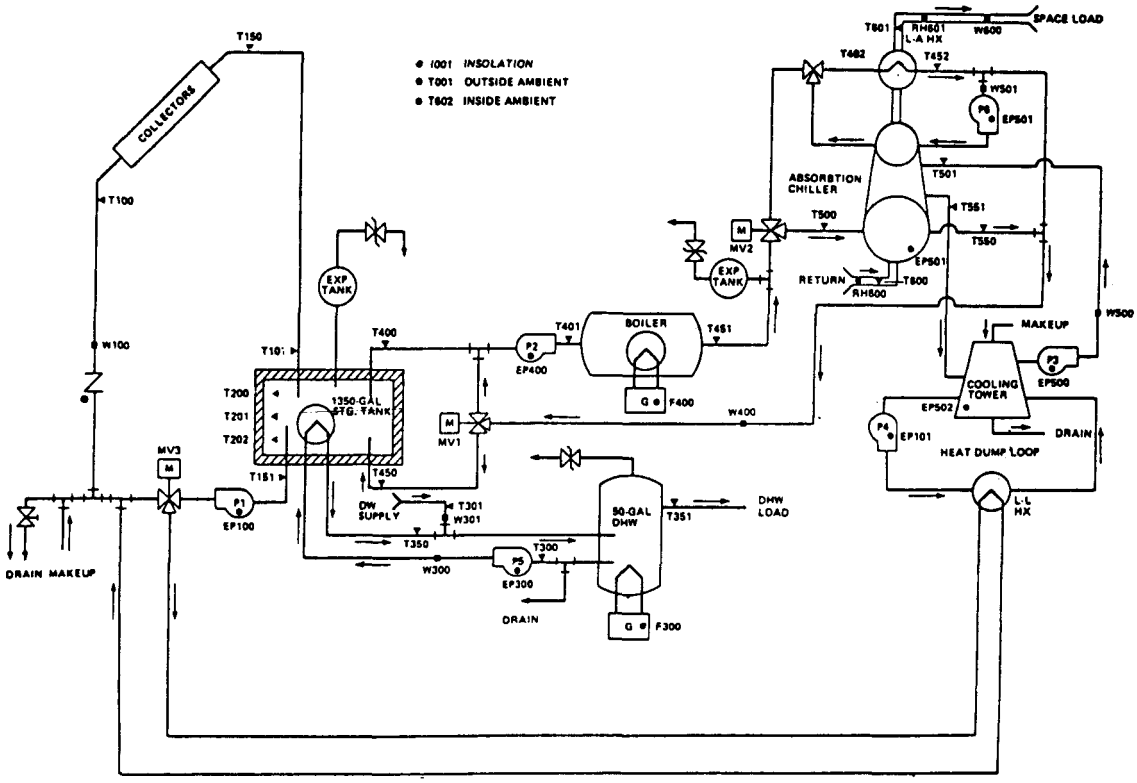


Figure IV-F-1. Controls Diagram

The Florida Gas Company's solar system is shown on Figure IV-F-1. The system consists of the following four subsystems: a) Collector subsystem, b) storage subsystem, c) load (space heating and cooling) subsystem and d) auxiliary loads subsystem. A heat rejection subsystem is incorporated in the collector subsystem to provide for heat rejection preventing overheat conditions. Among the auxiliary subsystems is an absorption chiller unit which utilizes storage water, in conjunction with chiller unit to supply chilled water to the cooler heat exchanger.

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

Mode 1 - Collector-to-Storage:

When the collector temperature control sensor, located in the collector outlet manifold, indicates a temperature 7^{o} F greater than the storage temperature control sensor, located at the bottom of the storage tank, collector pump (P-1) is activated and will circulate water through the storage tank and the collectors. Collector pump (P-1) continues to run until the collector temperature becomes less than 1^{o} F greater than the storage temperature.

Mode 2 Space Heating-from-Storage:

Solar energy from storage is used for space heating when there is a demand from the space heating thermostat and there is sufficient thermal energy in storage, as indicated by the storage tank top temperature, being greater than 140^{o} F. In this mode space heating pump (P-2) and the fan in the air distribution system are activated. Valves MV-1 and MV-2 are positioned to allow flow from the storage tank through the heating coils of the heat exchanger and back to the storage tank. The gas boiler is disabled in this mode.

Mode 3 - Auxiliary-Space Heating:

The auxiliary heating mode is used when there is a demand for space heating from the space thermostat and there is not sufficient thermal energy in storage to meet the demand. In this mode pump P-2 and the fan are activated, valve MV-1 is positioned to allow flow to bypass storage, valve MV-2 is positioned to allow flow through the heating coils, and the gas-fired boiler is enabled to provide the required thermal energy.

Mode 4 - Space Cooling-from-Storage:

Solar energy from storage is used to meet a space cooling demand when there is a call for cooling from the conditioned space thermostat and there is sufficient

thermal energy in storage to operate the absorption chiller, indicated by the storage tank top temperature being greater than 170 ^{o} F. In this mode, space heating pump (P-2) is activated, valve MV-1 is positioned to allow flow through storage tank, valve MV-2 is positioned to allow hot water flow through the absorption chiller. The absorpoion chiller, fan, the chilled-water pump, and the condenser water pump are all activated during this mode. The cooling tower blower is activated by an aquastat. The gas boiler is disabled in this mode.

Mode 5 - Space Cooling-from-Auxiliary:

When demand for cooling is required (through space thermostat) and the storage tank top temperature is less than 170^{o} F (not sufficient energy to operate chiller), the system mode configuration will be similar to that of Mode 4, except that the gas-fired boiler will be activated to provide hot water to chiller and the MV-1 valve will be positioned to by-pass the storage tank.

Mode 6 - Domestic Hot Water Heating:

Energy from storage is used to heat domestic hot water when the temperature in the DHW heater is below 160^{o} F and is also 15^{o} F less than the storage tank top temperature. When both of these conditions are met, pump P-5 is activated, circulating water from the DHW heater through a heat exchanger located in the solar storage tank. Auxiliary gas-fired DHW heating occurs if the temperature of the hot water in the tank drops below 130^{o} F.

Mode 7 - Excess Heat Rejection

Whenever the storage tank bottom temperature exceeds 220^{o} F, the heat rejection mode will be initiated. In this mode, valve MV-3 is positioned to allow flow through the heat rejection heat exchanger and pump P-4 is activated to remove the heat. The cooling tower fan is controlled by an aquastat.

Mode 8 - Freeze Protection

When the absorber plate temperature drops to 38^{o} F, pump P-1 will turn ON, to circulate warmer water from storage through the collectors in order to prevent them from freezing.

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:

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

Site data are recorded sutomatically 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.

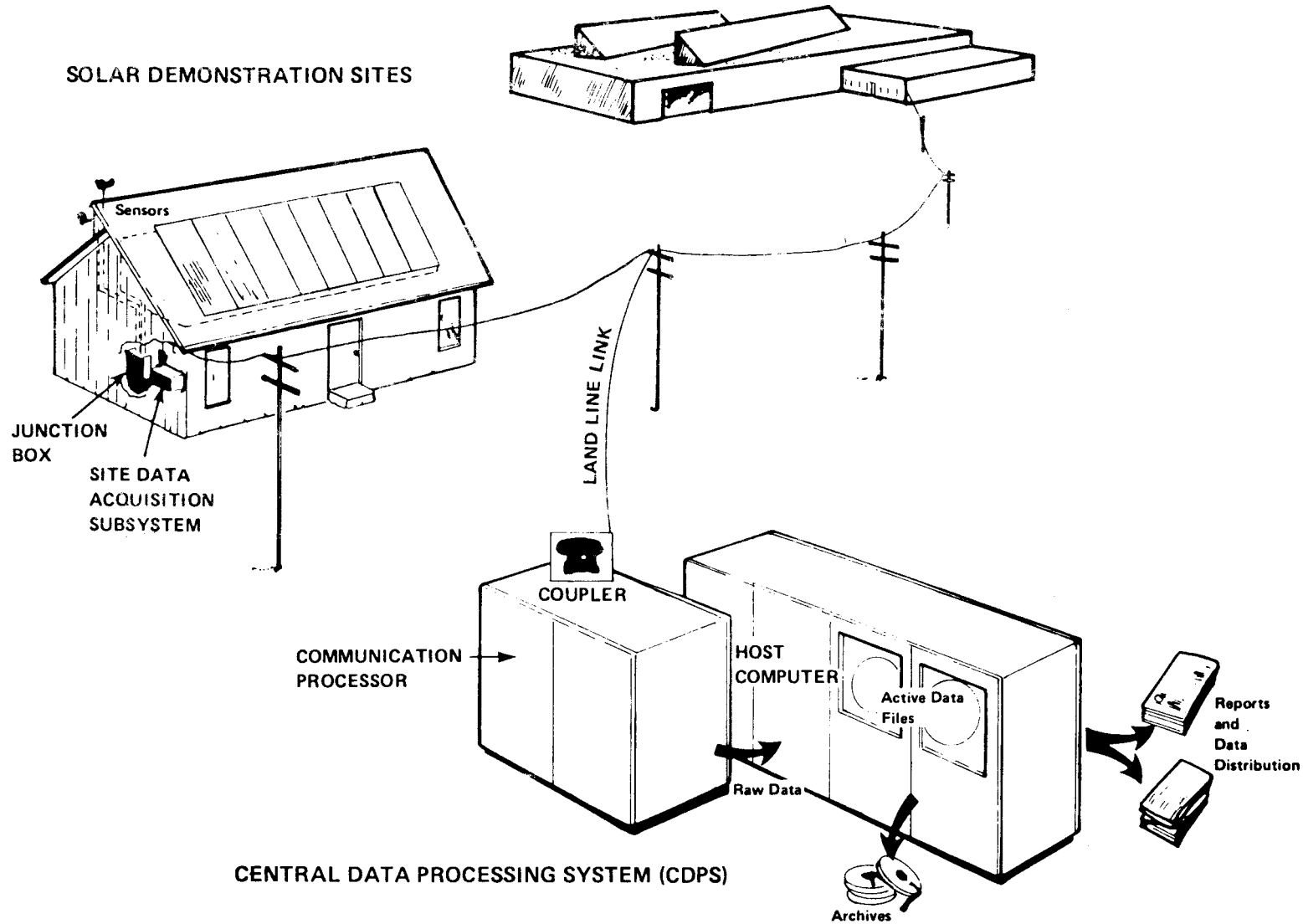


Figure V-A-1. The National Solar Data Network

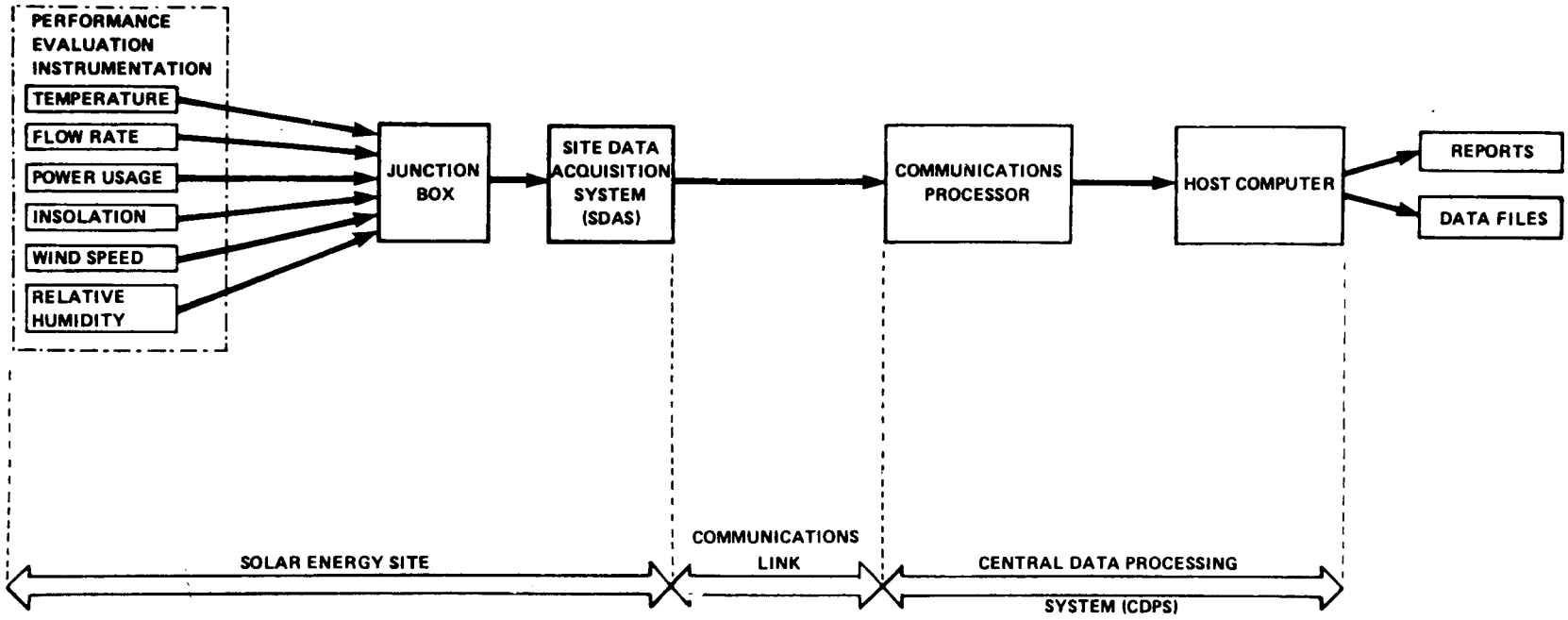


Figure V-A-2. Data Flow Path for the National Solar Data Network

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 vaid 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	Insolation, total	Eppley PSP
T001	Temperature, outside ambient	S53P-60
T100	Temperature, collector inlet	S57P-60
T150	Temperature, collector outlet	S53P-60
T101	Temperature, storage inlet	S57P-60
T151	Temperature, storage outlet	S53P-60
W100	Flow, collector loop	MKV-1 1/4-30
EP100	Power,collector pump	PC5-10
T200	Temperature, storage tank, upper	S53P-160
T201	Temperature, storage tank, middle	S53P-320
T202	Temperature, storage tank, bottom	S53P-480
T300	Temperature, outlet preheat tank to storage	S57P-60
T350	Temperature, inlet to preheat tank	S53P-60
W300	Flow, preheat loop	FloScan 300-3
EP300	Power, preheat loop pump and controls	PC5-1
T301	Temperature, cold water inlet	S57P-60
T351	Temperature, DHW supply	S53P-60
W301	Flow, cold water makeup	Hersey 430
F300	Fuel consumption, 53,000 Btu/hr input	Dwyer 1996--20
T400	Temperature, outlet storage to space	HXS57P-60
T450	Temperature, inlet to storage	S53P-60
T451	Temperature, inlet to auxiliary boiler	S57P-60
F400	Fuel consumption, 108,000 Btu/hr input	Dwyer 1996-20
T402	Temperature, inlet space	HXS57P-60
T452	Temperature, outlet space	HXS53P-60
W400	Flow, space heat and cool loop	MKV-1 1/4-20
EP400	Power, space heat loop pump	PC5-1
T500	Temperature, inlet to A/C unit	S57P-60
T550	Temperature, outlet of A/C unit	S53P-60
T501	Temperature, inlet to A/C from cooling tower	S57P-60
T551	Temperature, outlet of A/C unit	S53P-60
W500	Flow, cooling water	MKV-1 1/4-20

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
EP500	Power, cooling water pump	PC5-1
EP501	Power, A/C unit	PC5-19
EP502	Power, cooling tower blower	PC5-10
T600	Temperature, return air from heat space	S57P-100
T651	Temperature, air supply	S53P-100
W600	Air flow to heated space	TSI 1610(12")
EP101	Power, heat dump pump	PC5-1
T602	Temperature, ambient heated space	S53P-60
RH600	Relative humidity, return air duct	HM-111P
RH601	Relative humidity after cooling coil	HM-111P
W401	Flow, through cooling-heating loop	1.5-15

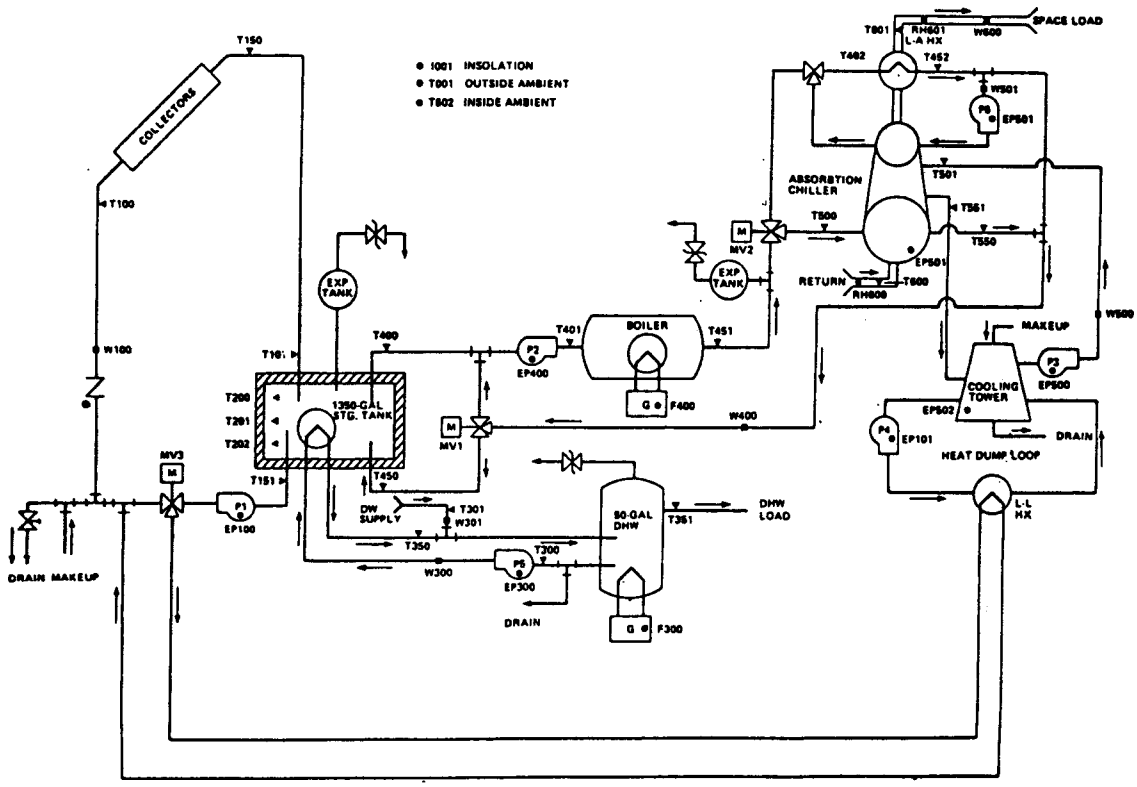


Figure V-B-1. Sensor and Control Diagram

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	$ 4,609	$
Energy Storage	1,600	
Distribution and Controls	9,077	
Installation	13,650	
Other	7,689	1,064
Total	$36,625	$26,000

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° F to 60° F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

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

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

COLLECTOR PLATE - A term used for an absorber plate.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

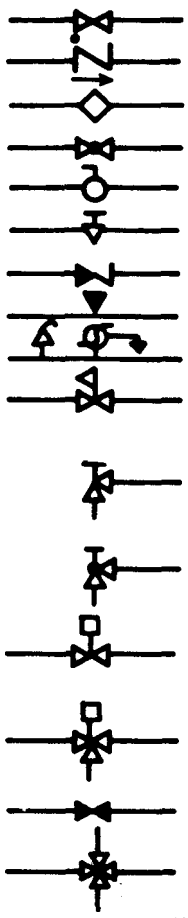
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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

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

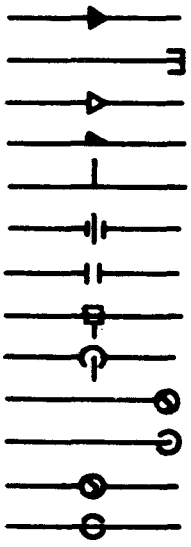
B. Legend For Solar System Schematics

VALVES



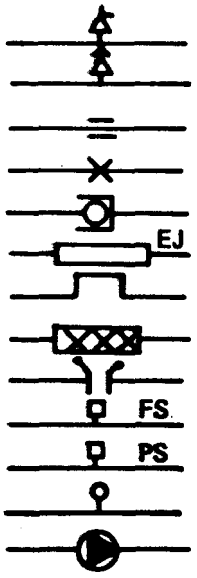
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS



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

PIPING SPECIALITIES



AUTOMATIC AIR VENT
MANUAL AIR VENT
ALIGNMENT GUIDE
ANCHOR
BALL JOINT
EXPANSION JOINT
EXPANSION LOOP
FLEXIBLE CONNECTION
FLOWMETER FITTING
FLOW SWITCH
PRESSURE SWITCH
PRESSURE GAUGE
PUMP
PIPE SLOPE
STRAINER
STRAINER, W/BLOW OFF
TRAP
CONTROL SENSOR
INSTRUMENTATION SENSOR
THERMOMETER
THERMOMETER WELL ONLY

COLD WATER SUPPLY

AS	AIR SEPARATOR
EXP TK	EXPANSION TANK
WS	WATER SOFTENER
HED	HOSE END DRAIN