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Solar Project Description

FACILITIES DEVELOPMENT CORPORATION'S CONDIMINIUM
San Diego, California
May 7, 1979

MASTER

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

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SOLAR PROJECT DESCRIPTION
FOR
FACILITIES DEVELOPMENT CORPORATION'S
CONDOMINIUM - SAN DIEGO, CALIFORNIA

Department of Housing and Urban Development

Under Contract Number

H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

The Boeing Company
David Beers, Program Manager

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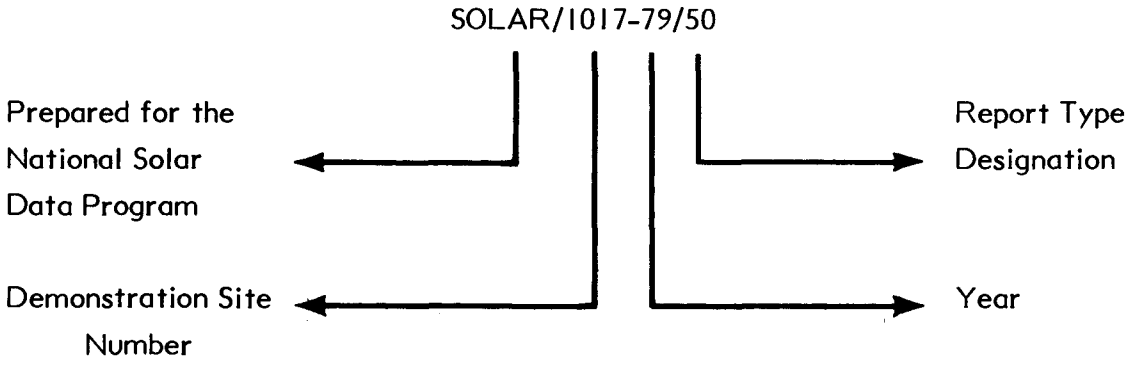
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Facilities Development Corporation. Condominiums project site is designated as SOLAR/1017-79/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The Facilities Development Corporation solar energy demonstration project is located in San Diego, California. The solar system used on this project is designed to provide preheated water to 31 individual domestic hot water tanks in service for the 31 unit condominium development.

Salient features of the solar system are as follows:

- o Collector Type -- Liquid, double glazed. flat plate with integrated tube construction
- o Freeze Protection -- Circulation of preheated storage fluid
- o Application -- Preheat the domestic hot water
- o Solar Energy Storage -- In underground tank
- o Type of Building -- New construction, Multi-family low rise
- o Solar System Performance Evaluation -- System is instrumented and performance data being compiled
- o Site-Specific Features -- A single central storage tank supplying thirty one individual domestic hot water tanks

The system was designed by James L. Blakely, Inc. of Escondido, California.

The solar system has 524 square feet of double glazed flat plate collectors. Potable water is used as the medium for transferring solar energy from the collector array to a 1,000 gallon buried storage tank. The collector array consists of two banks of fourteen collectors interconnected by long runs of piping. The individual panels are each equipped with isolation valves on the inlet and outlet connections.

The collector pump controller is set to activate when a temperature difference of 9^{o} F exists between the collector outlet temperature and the reference sensor located near the bottom of the storage tank.

Water is circulated through the collectors and returned to storage. When the temperature difference between the collector mounted sensor and the storage sensor drops to 3^{o} F, the circulating pump is automatically turned off.

The underground storage tank is glass lined and insulated with two inches of polyurethane foam. A gravity return circulation loop delivers preheated water from the storage tank to individual domestic hot water (DHW) tanks in each of the 31 unit. Each unit is provided with a conventional electric immersion heater to boost the inlet water temperature to the level required for usage.

The Performance of the Facilities Development Solar Energy System has been monitored since November 1977.

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

III. SITE AND BUILDING DESCRIPTION

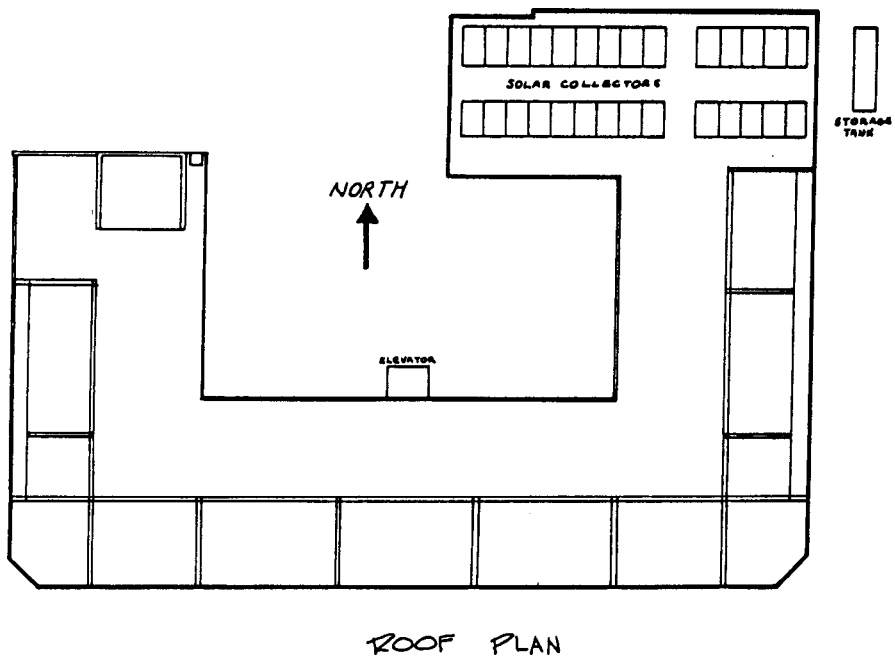


Figure III-1. Site Plan

Site Description

- Special topographic or climatic conditions - Freezing weather seldom experienced
- Latitude - 32° N
- Longitude - 117°
- Elevation - 50 feet
- Annual degree days (65° F base)
  - Heating - 1507
  - Data location - San Diego, California
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

- Average horizontal insolation
  - January - 842 Btu/ft^2/day
  - July - 2200 Btu/ft^2/day
  - Data location - San Diego, California
  - Data reference - Engineers calculations
- Shading - 1 percent or less

Building Description

- Occupancy
  - Multi-family, low rise
  - 31 units
- Solar system application - Supply of preheated water to 31 units
- Average stories above ground - Three
- Roof slope at collector - Flat
- Special features - Condominiums with integrated solar system

Mechanical System

- Domestic Hot Water
  - Daily water demand - 1550 gallons per day
  - Yearly average preheat water supply temperature - 50° F
  - Source of auxiliary energy - Electricity
  - Output design temperature - 150° F
  - Auxiliary - 40 gallon electric water heaters, each of 31 units

Electrical System

- Appliance, lighting and equipment load - 23,250 Btu/hr

IV. Solar System Description

A. General Overview

The solar energy system used at the Facilities Development Corporation Condominium is an active liquid system. See figure IV-A-1. The major components in the system include 520 square feet of double glazed flat plate collectors, 1,000 gallon storage tank, and a siphon-driven circulation loop which delivers preheated water from the storage tank to individual domestic hot water (DHW) tanks in each of the 31 units.

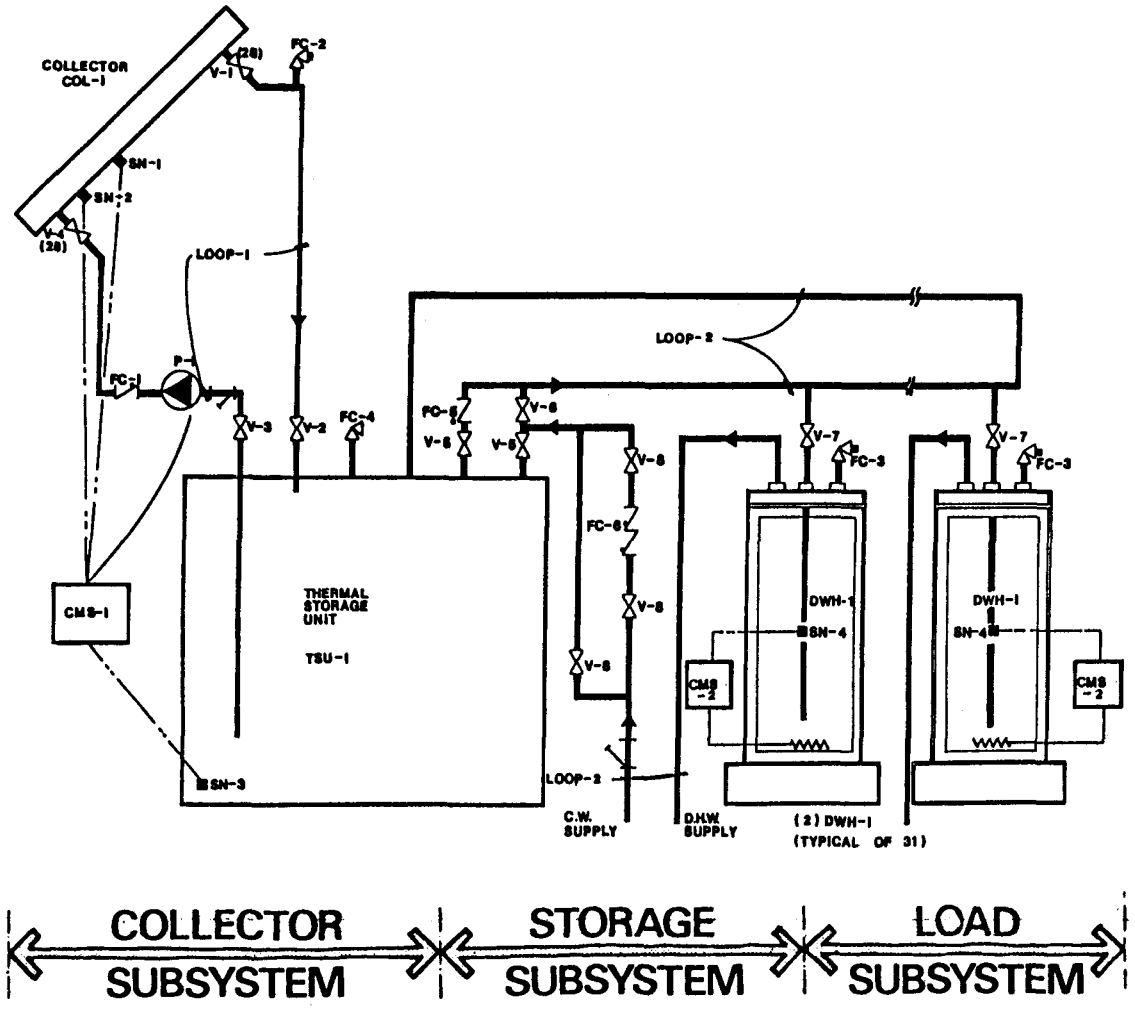


Figure IV-A-1. General Overview

Subsequent sections describe the collector, storage, energy-to-load and auxiliary subsystems. Specific details of the operating modes and system controls are described in the final section. Appendices A and B present a glossary and a legend of symbols.

Solar System and Component Summary

- Number of collector types - One
- Number of circulation loops
  - Liquid - Two
  - Air - None
- Number of storage units - One
- Number of operational modes - Four

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

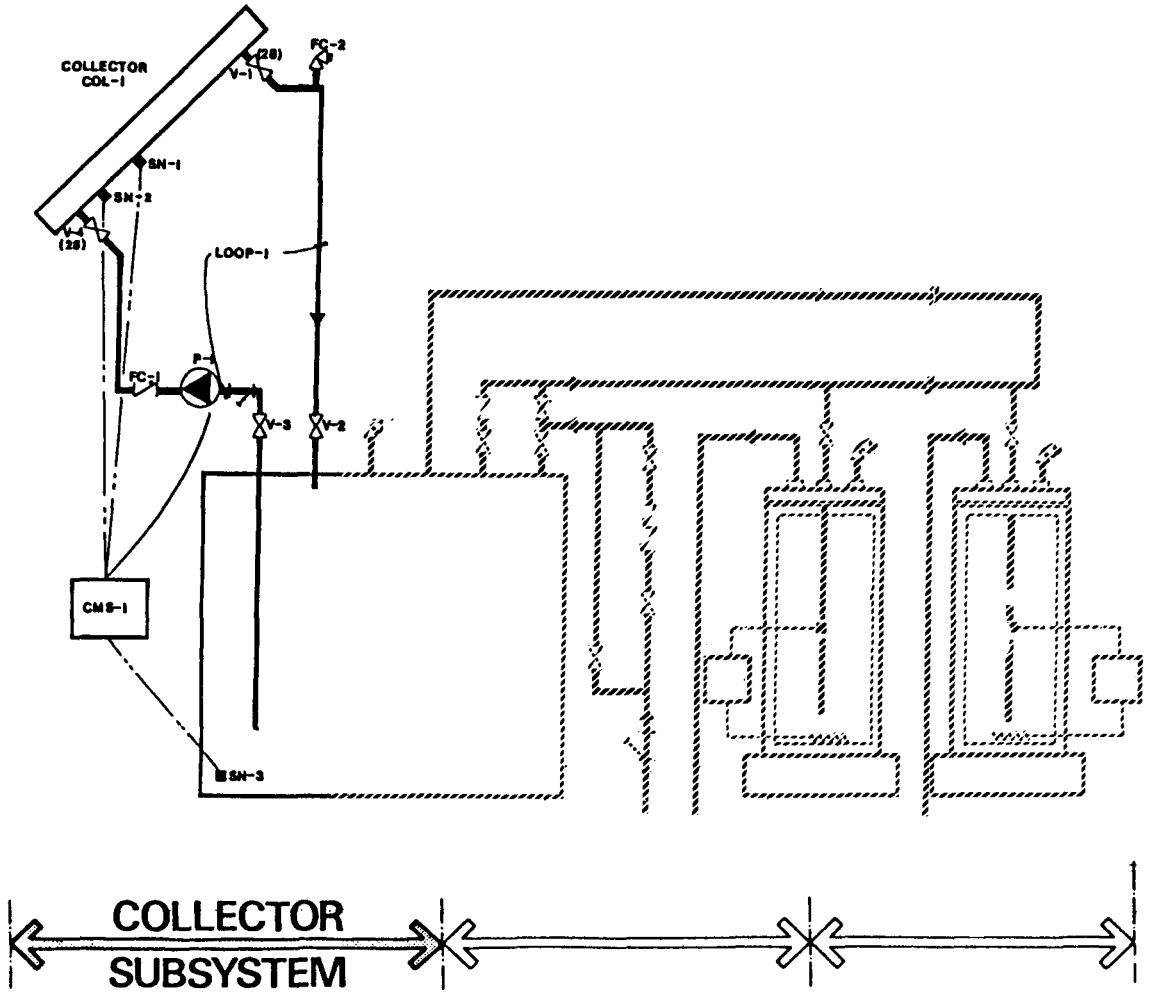


Figure IV-B-1. Collector Subsystem

The collector array for the Facilities Development Condominium (HUD Grant H-2794) is mounted on the roof with a tilt of 42 degrees from horizontal. The 524 square foot collector array faces 5 degrees east of true south. This subsystem consists of the pump, piping and collector panels. The two banks of fourteen collectors each, are interconnected by long runs of piping. The individual panels are equipped with uninsulated isolation valves on the inlet and outlet connections.

Collector (COL-1)

- Manufacturer - Revere
- Model Name/Number - Sun-Aid, No. 211
- Type - Liquid flat plate, tube and plate
- Location - Roof
- Orientation - 5^{o} east and west of south
- Tilt angle - 42^{o} from the horizontal
- Number of collector panels - 28
- Array configuration - Two separate standing rows of fourteen panels
- Collector
  - Total gross area of array - 524 square feet
  - Net aperture area - 482 square feet
  - Net absorber area - 491 square feet
  - Weight per panel, empty - 120 pounds
  - Weight per panel, full - 122 pounds
  - Panel length - 77 inches
  - Panel width - 35 inches
  - Frame depth - 4.5 inches
  - Standoff height - 60 inches
- Glazing (cover plate)
  - Number of cover plates - Two
- Cover plate No. 1 - Outer layer
  - Material - Low iron tempered glass
  - Thickness - 0.125 inches

- Optical properties (solar region) (infrared region)
  - Transmittance 86% 86%
  - Reflectance 8% 8%
  - Emittance 93% 93%
- Edge or surface treatment, other than coating - Mechanical ground, swiped with gasket enclosure and frame
- Coating on cover plate material - None

- Cover plate No. 2 - Inner layer
  - Material - Low iron tempered glass
  - Thickness - .125 inches
  - Optical properties (solar region) (infrared region)
    - Transmittance 86% 86%
    - Reflectance 8% 8%
    - Emittance 93% 93%
  - Edge treatment, or other than coating - Mechanical ground, sealed with gasket enclosure and frame
  - Coating on cover plate material - None

- Absorber
  - Manufacturer - Revere
  - Material - DHP cooper No. 122
  - Substrate dimensions
    - Thickness - .032 inches
    - Length - 76.5 inches, includes headers
    - Width - 33.0 $\pm$ .5 inches

- Coating
  - Manufacturer - 3M Company
  - Model Name/Number - NEXTEL Black Velvet
  - Material - Black Velvet flat paint
  - Application method - Painted
  - Absorptance - Solar region 96%; infrared 89%
  - Reflectance - Solar region 4%; infrared 11%
  - Emittance - 96%
- Heat transfer fluid passages
  - Location - In absorber
  - Pattern - Parallel
  - Materials - DHP copper No. 122
  - Wall thickness - .016 inches
  - Internal diameter - 0.377 inches (equivalent)
  - Spacing - 5.0 inch on center
  - Maximum operating pressure - 120 psi
  - Fluid passage bond to substrate - Integral
  - Protective coating inside fluid passage - None
- Insulation
  - One layer - Sides
    - Manufacturer - Certain-Teed
    - Product Name/Number - Ultra Lite
    - Material - Glass fiber
    - Binder type - Phenol resin
    - Thermal resistance - R-6

- Layer one - Back
  - Manufacturer - Certain-Teed
  - Product Name/Number - Ultralite
  - Material - Glass fiber
  - Binder type - Phenol resin
  - Thermal resistance - R-10
- Layer two - None

- Gaskets and sealants
  - Inner cover - Plastic gasket
  - Outer cover - Plastic gasket
  - Frame joint - Dow gun silicon
  - Backing plate - Dow gun silicon
  - Penetrations - EPDM rubber grommet
- Frame
  - Manufacturer - Revere
  - Product Name/Number - Aluminum extruded frame
  - Material - Aluminum 6063-T5
  - Protective coating - Anodized, mill finish
  - Number of structure attach points per module to building - 4

Collector Performance

- Method of evaluation - ASHRAE $(t_i-t_a)/I_t$
- y intercept - $.67^{o}$ F hr ft^2/Btu

- Slope - 0.82

Point Number	1	2	3	4
n = Collector thermal efficiency (%) -	58.8	50.6	42.4	34.2
t_i = Collector inlet temperature (^oF) -	--	--	--	--
t_a = Ambient air temperature (^oF) -	--	--	--	--
I_t = Insolation intensity (Btu/hr/ft^2) -	--	--	--	--
ASHRAE $(t_i-t_a)/I_t$ -	0.1	0.2	0.3	0.4

- Test flow rate - 396.8 pounds per hour
- Test wind speed - 1.75 mph
- Test collector area
  - Gross - 18.7 square feet
  - Net - 17.2 square feet
- Back side thermal loss - 0.13 Btu/hr ft^2 ^oF
- Edge thermal loss - 0.38 Btu/hr ft^2 ^oF
- Thermal response time constant - 2.1 minutes
- Fluid specific heat - 0.80 Btu/lb^{o}lb
- Test fluid medium - 50% water, 50% ethylene glycol

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

- Design maximum operating temperature - 160^o F
- Heating design liquid flow
  - Maximum - 14 gal/min
- Heat transfer medium - Water, 100% of total volume
- Specific heat - 1.00 Btu/lb ^oF
- Density - 62 lb/ft^3
- Heat capacity - 62.4 Btu/ft^3 ^oF
- Viscosity over working range - .5 poises/100

- Boiling point - 212° F
- Freezing point - 32° F
- Maximum recommmended use temperature - 200° F
- Toxicity - Potable
- Chemical feeder - None
- Inhibitor - No
- Piping
  - Location - Above grade
  - Exterior finish - Integral, non-cellular rubber membrane
  - Piping insulation - Aerobond, cellular rubber
  - Joint insulation and finish - Pressure sensitive tape
  - Type - Rigid, Copper, type K, hard drawn
  - Interior coating - None
  - Filters - Pump inlet, one
- Circulation Pump (P-1)
  - Manufacturer - Bell and Gossett
  - Model Name/Number - HD-3 inch (high delivery)
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 125 psi
    - Temperature - 225° F
  - Material exposed to heat transfer fluid - Brass
  - Motor size - 0.33 hp, 115 volts, 1 phase, 60 Hz
  - Circulating volume
    - Low head mode - 15 gal/min
  - Operating head (dynamic) - 7.8 psi

- Distribution Valve (V-1)
  - Function - ON-OFF
  - Type - Gate
- Distributiion Valve (V-2)
  - Function - Flow adjusting
  - Type - Gate
- Distribution Valve (V-3)
  - Function - Flow adjusting
  - Type - Ball
- Distribution Vavle (V-4)
  - Function - Flow adjusting
  - Type - Gate

Control Mode Selector (CMS-1)

- Modes controlled
  - Collector to storage
    - ON - (SN-01) 9° F greater than (SN-03)
  - Storage to hot water
    - ON - On demand for hot water
- Sensors (SN-01), (SN-02) and SN-03)
  - Type - Differential thermostat
- Flow Control (FC-1)
  - Type - Check valve
- Fail Safe Control (FC-2)
  - Type - Temperature relief valve
  - Operating set point - 200° F

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

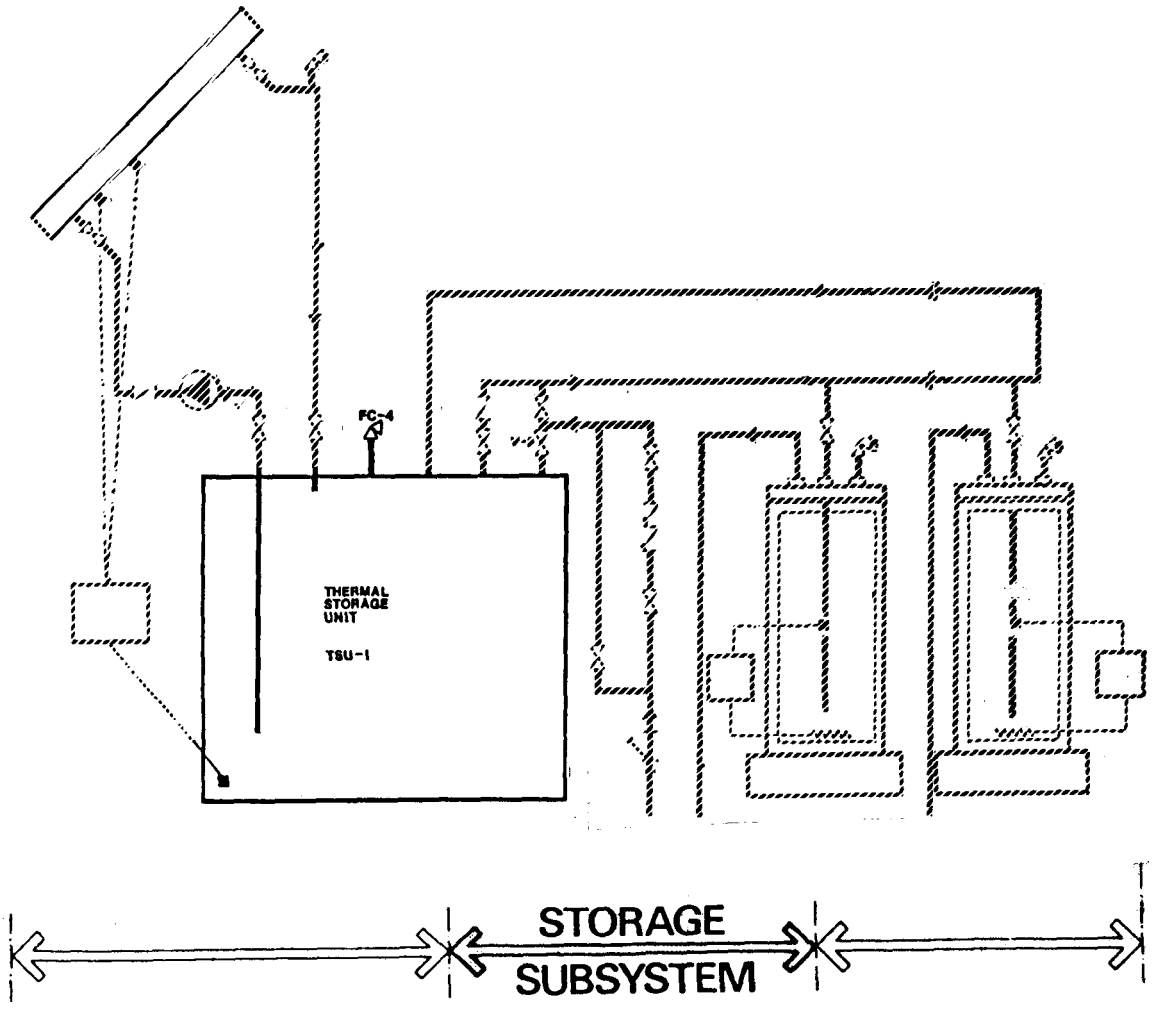


Figure IV-C-1. Storage Subsystem

The storage tank holds 1,000 gallons and is buried in the condominium courtyard. The tank is glass lined and insulated with two inches of polyurethane foam. Potable water serves as the heat transfer and storage medium.

Thermal Storage Unit (TSU-1)

- Container
  - Manufacturer - Sante Fe
  - Total storage volume - 126 cubic feet
    - Length - 10.0 feet
    - Diameter - 4.0 feet
- Storage Medium
  - Maximum design heating temperature - 130° F
  - Medium - 100% water
  - Specific heat - 1.000 Btu/lb °F
  - Density - 62 lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3 °F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 212° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Inhibitor - None
- Container Construction
  - Type - Steel tank, glass interior lining
  - Location - On site, below grade
  - Auxiliary heaters - None
  - Insulation - Polyurethane
  - Exterior finish - Wrapped with polyurethane film and an asphaltic enamel final finish
  - Filters - At inlet of container

- Fail Safe Control - (FC-4)
  - Manufacturer - RHEEM
  - Product Name/Number - Spring loaded
  - Type - Temperature and pressure relief

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

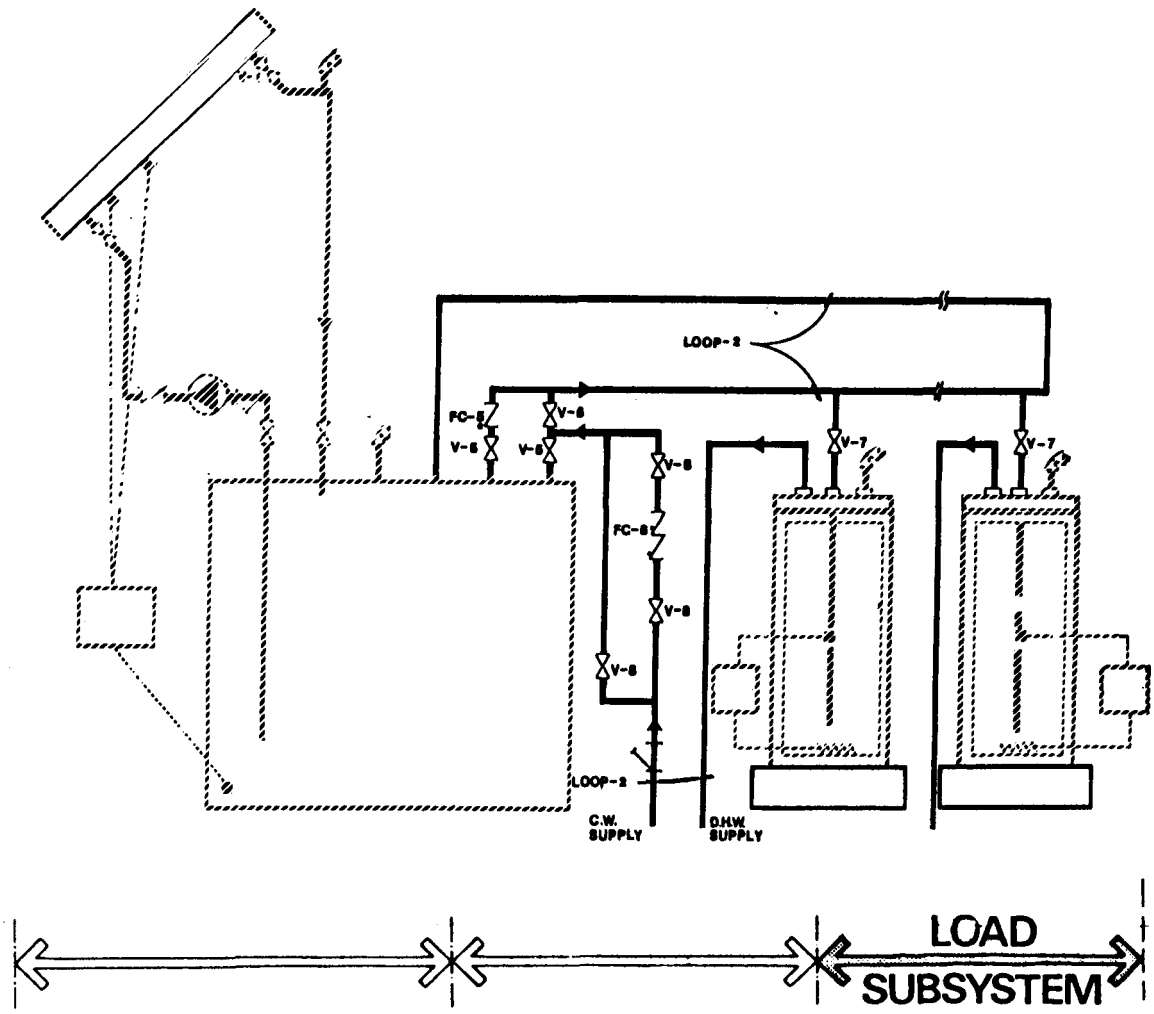


Figure IV-D-1. Energy-to-Load Subsystem

The 31 individual DHW units are supplied with water from a single circulating loop. This loop is designed to take advantage of the building elevations so that when water os drawn from any unit, an unidirectional flow is established which will continue to circulate the medium after demand ceases. Preheated water is thus drawn from storage and is available in the circulation loop at all times.

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

- Design maximum operation temperature - 140° F
- Heating design liquid flow - 50 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 - 140° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder - None
  - Inhibitor - None
  - Loop description - TSU-1 to DHW (31 units)
  - Piping
    - Location - Above grade
    - Exterior finish - Integral skin of insulation
    - Finish insulating joints type - Pressure sensitive tape
    - Type - Rigid, hard copper, type K
- Distribution Valve (V-5) and (V-6)
  - Function - Flow adjusting
  - Type - Gate
- Distribution Valve (V-7)
  - Function - Flow adjusting
  - Type - Ball

- Distribution Valve (V-8)
  - Function - ON-OFF
  - Operation - Manual
  - Type - Gate
- Flow Control (FC-5)
  - Type - Check valve
- Flow Control (FC-6)
  - Type - Backflow preventer

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

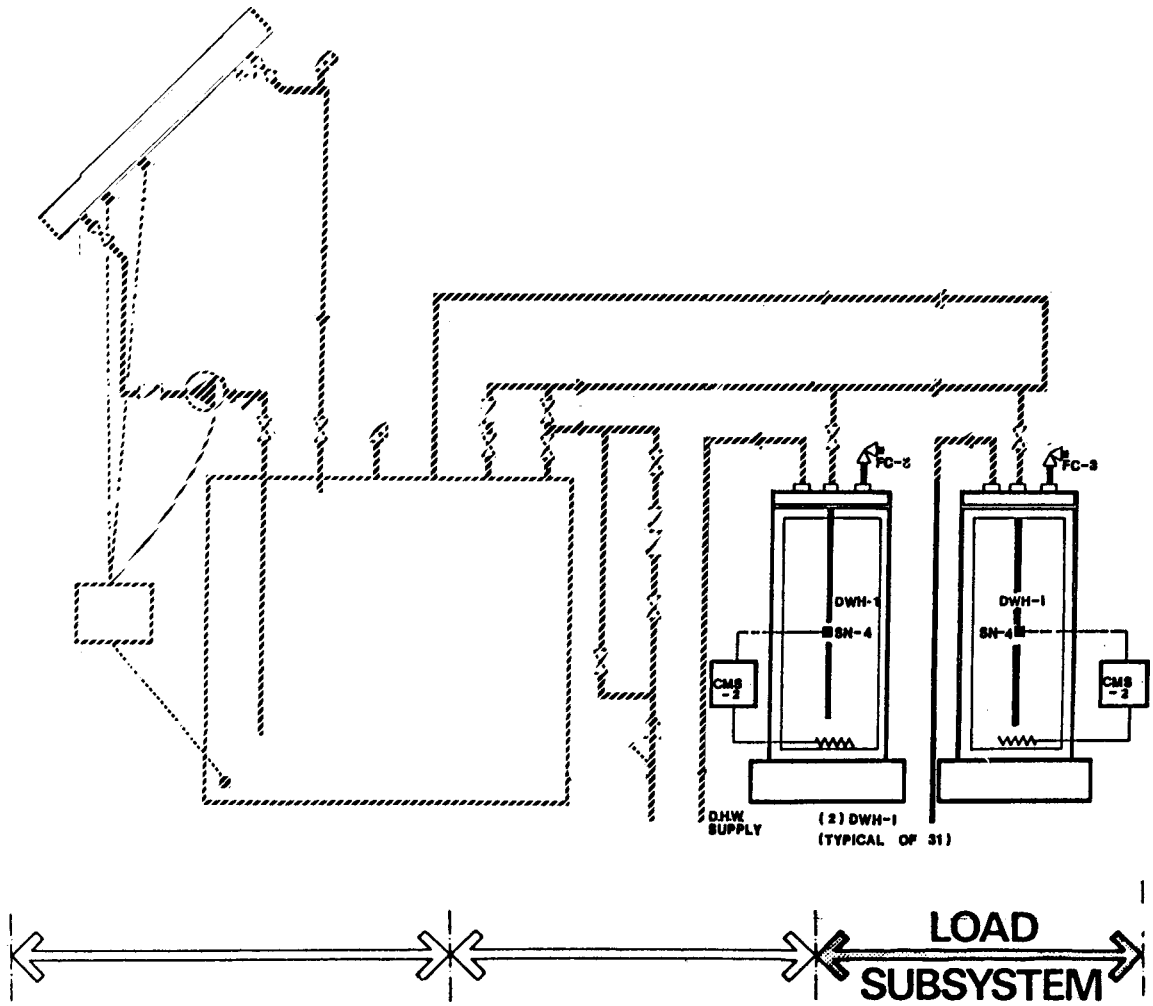


Figure IV-E-1. Auxiliary-to-Load Subsystem

Each unit is provided with a conventional electric immersion heater to boost the inlet water temperature to the level required for usage. The domestic hot water tanks receive preheated water from the storage tank. A gravity siphon-driven circulation loop delivers this preheated water.

Domestic Water Heater (DHW-1)

- Manufacturer - Ruudglas
- Model - 40 gallon
- Energy source - Electric: 115 volt, 1 phase, 60 Hz
- Tank size - 40 gallons
- Energy input - 30,000 Btu/hr
- Energy output - 30,000 Btu/hr
- Maximum temperature rating - 162° F
- Heating stages - Two stages
- Maximum recovery rate - 18.5 gallson per hour
- Yearly average input water temperature - 50° F
- Design output temperature - 150° F

Control Mode Selector (CMS-2)

- Modes controlled
  - Auxiliary heat to hot water tanks
  - Operation - ON, when (SN-04) is less than 140° F
- Sensors (SN-04)
  - Type - Temperature, resistance thermometer
- Fail Safe Control (FC-3)
  - Manufacturer - Rheem
  - Product Name/Number - Spring loaded
  - Type - Relief valve
    - Temperature - 200° F
    - Pressure - 125 psi

F. Modes of Operation

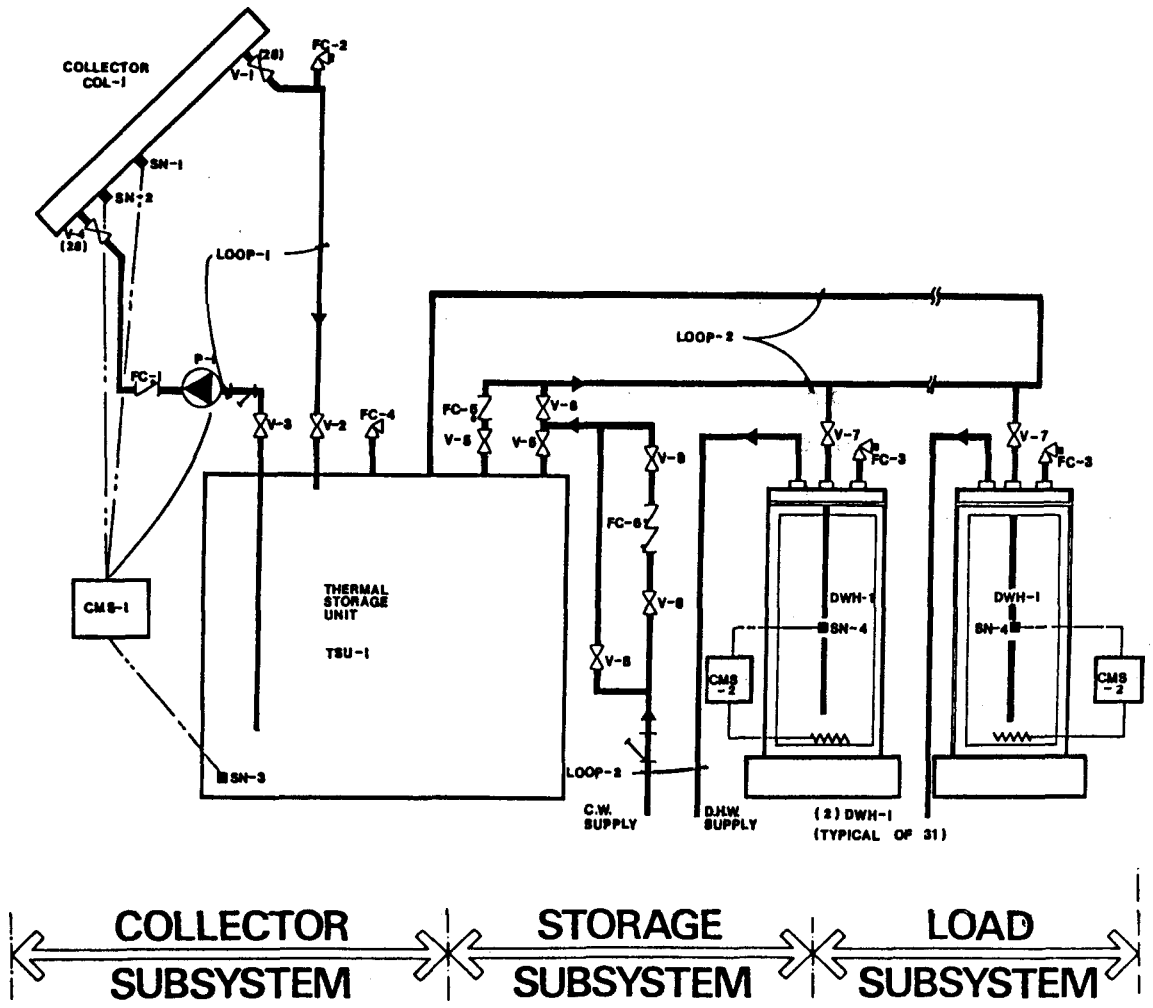


Figure IV-F-1. Controls Diagram

The Facilities Development solar system is shown on figure IV-F-1. The system has three major subsystems, namely, collector arrays, storage, and loads. Potable water is used as the medium for transferring solar energy fron one subsystem to another in all modes of operation. The collector subsystem utilizes a pump for its transfer of energy while a gravity return circulation loop delivers preheated water from the storage tank to the individual domestic hot water (DHW) tanks in each of

the 31 units. The auxiliary energy is provided with a conventional electric immersion heater within individual hot water tank. There are no heat exchanger is the system because the working fluid is potable water. San Diego seldom experiences freezing weather, so the risk from using potable water as the heat transfer fluid is considered minimal.

The four basic modes of operation of this system are as follows:

Mode 1 - Collector to Storage:

This mode of operation begins when the control temperature measured at the sensor at the output of the collector array is 9^{o} F higher than the temperature measured at the bottom of the storage tank. Water is circulated through the collectors and returned to storage. When the temperature difference between the collector mounted sensor and the storage sensor drops to 3^{o} F, the circulating pump is turned off.

Mode 2 - Storage to DHW Tanks:

The 31 individual apartment DHW units are supplied with water wfrom a single circulating loop. This loop is designed to take advantaage of the building elevations and the difference in temperature of the supply/return columns to the DHW tanks so that when water is drawn from any apartment, an Unidirectional flow is established and continue to circulate the preheated water after the demand ceases. Preheated water is thus drawn from storage and is always available in the circulation loop. Conventional electric immersion heaters provide additional energy to raise the water temperature to a usable level.

Mode 3 - Freeze Protection:

Whenever ambient temperature approaches 32^{o} F, sensors at the collector activates the circulation pump for recirculation of warm storage water through the collector, thereby preventing collector liquid freeze-up.

Mode 4 - Overheat Protection:

During extraordinary heating conditions of the collector liquid, the pressure relief valve at the collector loop will release evaporated vapor and thereby reducing vapor pressure protects the collector system from overheating conditions and damages.

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 analyuses of the solar system performance. Collectead data are both applicable and practical in calculating thermal performance factors that describe the behavior of the solar system (see NBSIR 76-1137, National Bureau of Standards). Additional instrumentation may also be included as a result of site-specific requirements. Typically, the instrumentation includes sensors that monitor the following:

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

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

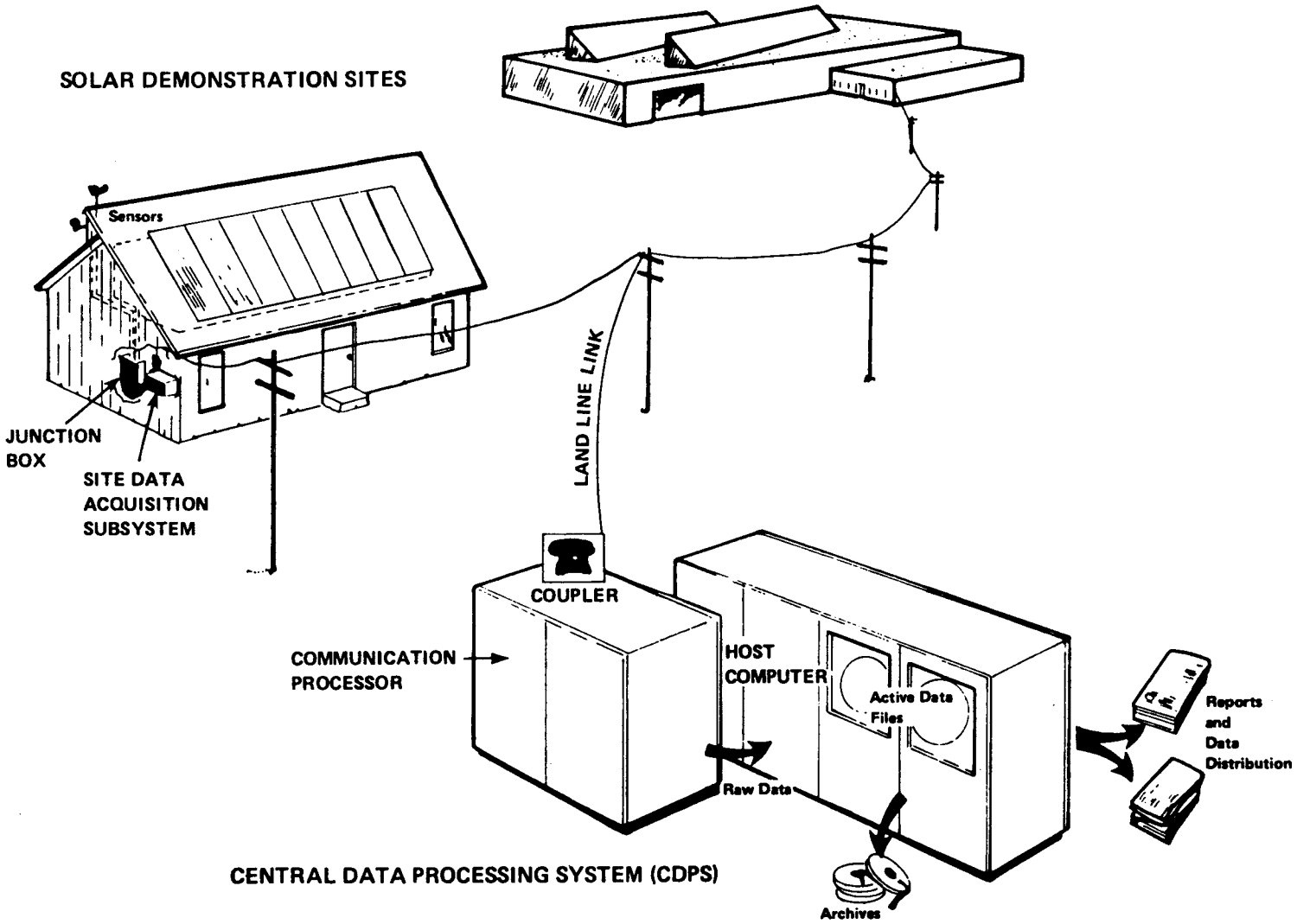


Figure V-A-1. The National Solar Data Network

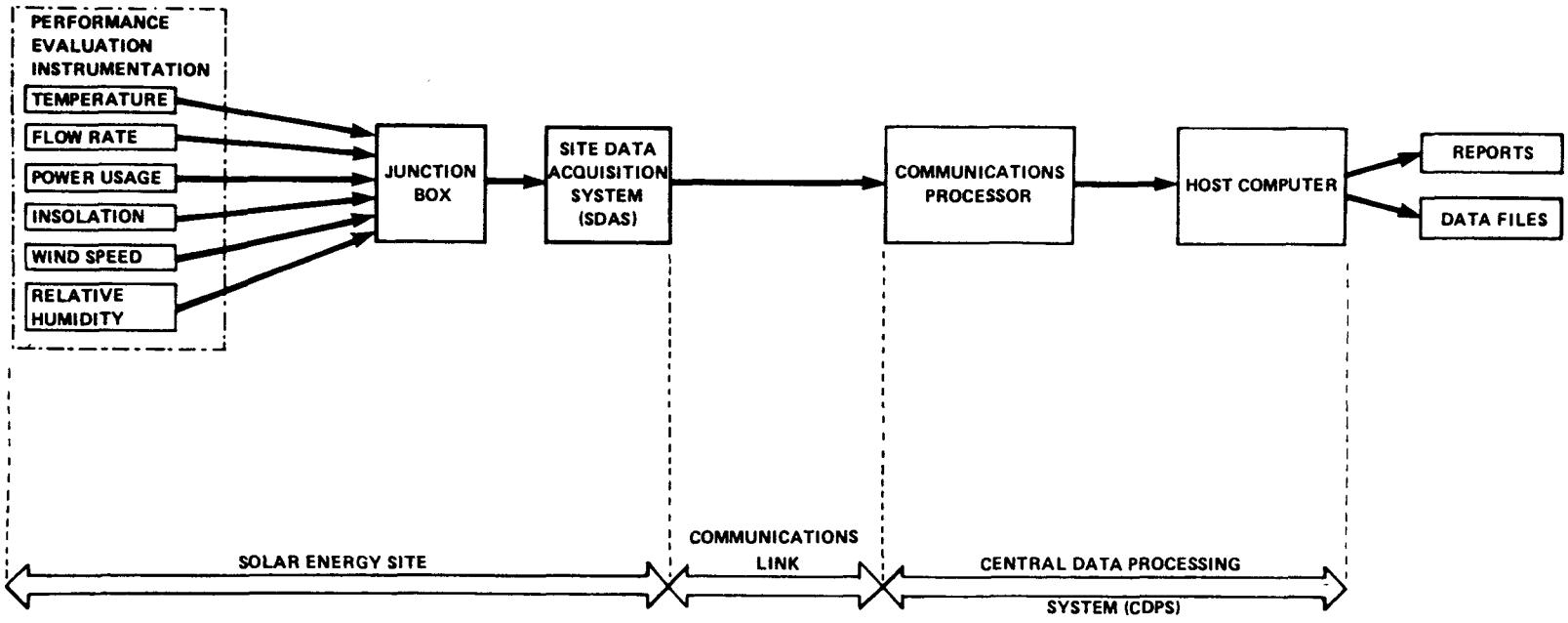


Figure V-A-2. Data Flow Path for the National Solar Data Network

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

Appropriate equations were formulated and programmed to define desired performance factors for the solar energy systems at each selected demonstration site. A performance factor is a number that describes either the efficiency or the quantity of energy lost, gained, or converted by a solar energy system or by a component. All 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
TD100	Temperature, collector outlet	S53P-60
T101	Temperature, collector outlet, upper bank	S53P-60
T102	Temperature, storage tank outlet	S57P-60
TD102	Temperature, storage tank inlet	S53P-60
W100	Flow, total collector	MDV-1 1/4,2-20
EP100	Power, collector pump	PC5-1
T200	Temperature, storage tank, top	S53P-120
T201	Temperature, storage tank, middle	S53P-270
T202	Temperature, storage tank, bottom	S53P-430
T300	Temperature, storage tank inlet, DHW	S57P-60
TD300	Temperature, storage tank outlet DHW	S53P-60
W300	Flow, total domestic hot water	Hersey 560
W301	Flow, DHW, living unit "A"	MKV-3/4,.7-7
T301	Temperature, DHW tank inlet, living unit "A"	S57P-60
TD301	Temperature, DHW tank outlet, living unit "A"	S53P-60
EP301	Power, DHW heater, living unit "A"	PC5-29
W302	Flow, DHW, living unit "B"	MKV-3/4,.7-7
T302	Temperature, DHW tank inlet, living unit "B"	S57P-60
TD302	Temperature, DHW tank outlet, living unit "B"	S53P-60
EP302	Power, DHW heater, living unit "B"	PC5-29
W303	Flow, DHW, living unit "C"	MKV-3/4,.7-7
T303	Temperature, DHW tank inlet, living unit "C"	S57P-60
TD303	Temperature, DHW tank outlet, living unit "C"	S53P-60
EP303	Power, DHW heater, living unit "C"	PC5-29
W304	Flow, DHW, living unit "D"	MKV-3/4,.7-7
T304	Temperature, DHW tank outlet, living unit "D"	S57P-60
TD304	Temperature, DHW tank outlet, living unit "D"	S53P-60
EP304	Power, DHW heater, living unit "D"	PC5-29
W305	Flow, DHW, living unit "E"	MKV-3/4,.7-7
T305	Temperature, DHW tank inlet, living unit "E"	S57P-60

TD305	Temperature, DHW tank outlet, living unit "E"	S53P-60
EP305	Power, DHW heater, living unit "E"	PC5-29
W306	Flow, DHW, living unit "F"	MKV-3/4,.7-7
T306	Temperature, DHW tank inlet, living unit "F"	S57P-60
TD306	Temperature, DHW tank outlet, living unit "F"	S53P-60
EP306	Power, DHW heater, living unit "F"	PC5-29
W307	Flow, DHW, living unit "G"	MKV-3/4,.7-7
T307	Temperature, DHW tank inlet, living unit "G"	S57P-60
TD307	Temperature, DHW tank outlet, living unit "G"	S53P-60
EP307	Power, DHW heater, living unit "G"	PC5-29
T103	Temperature, collector outlet, lower bank	S53P-60

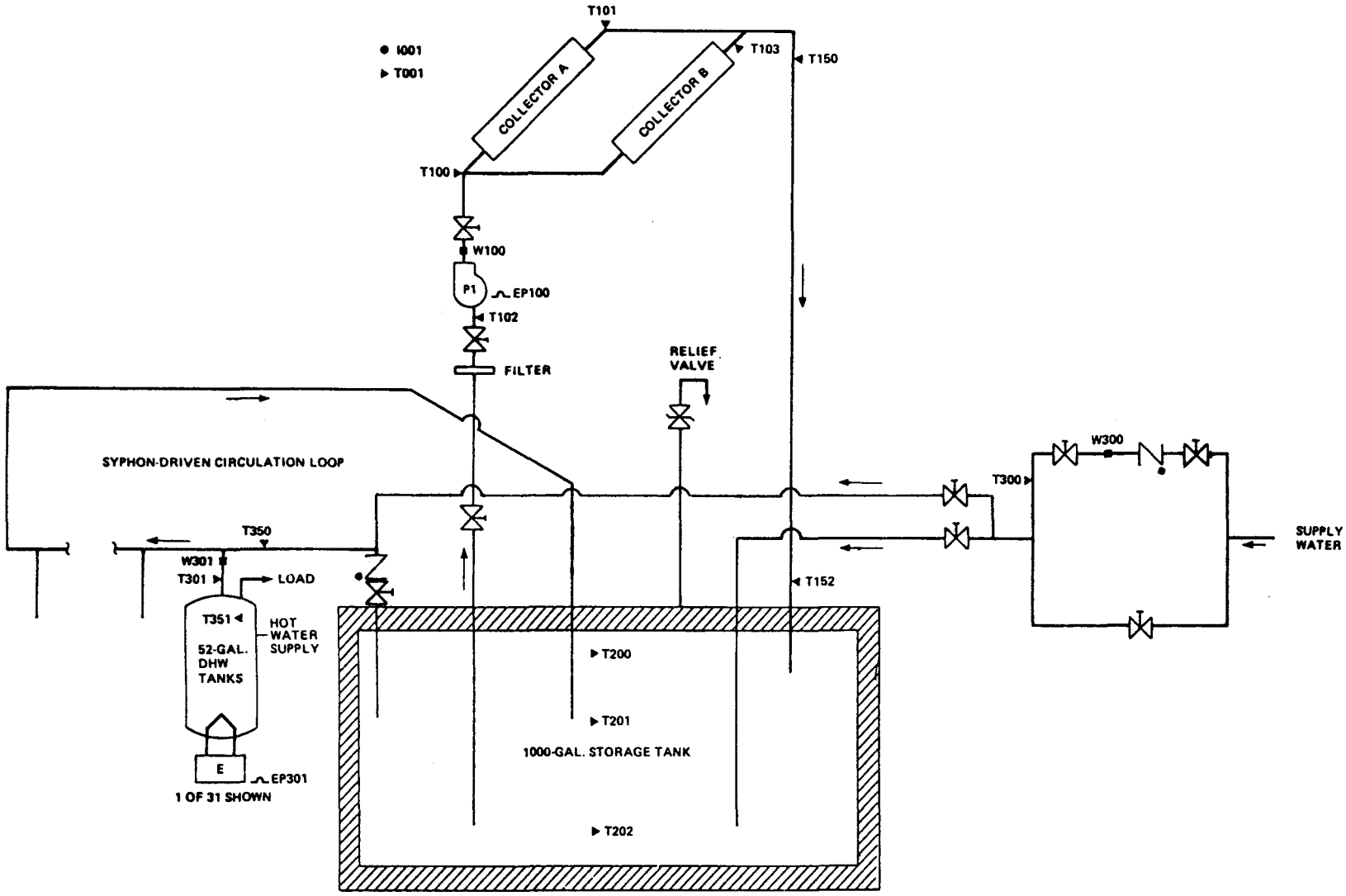


Figure V-B-1. Sensor and Control Diagram

VI. COST DATA

A. General

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

B. Construction Grant Funds

Solar Sub-System	Applicants Request	(percent of total)	Construction Grant
Collectors	$ 8,602	(28.0)	$ 7,840
Energy Storage	4,184	(13.7)	3,836
Distribution and Controls	9,641	(31.5)	8,820
Installation	8,209	(26.8)	7,504
TOTAL	$30,636	(100)	$28,000

C. Construction Period: December 1976 through August 1977

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