715
1/17/80

Hs. 6043

SOLAR/1001-79/50

Solar Project Description

MASTER

WASHINGTON NATURAL GAS COMPANY'S SINGLE FAMILY RESIDENCE
Kirkland, Washington
September 12, 1979

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

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Solar/1001-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION FOR WASHINGTON NATURAL GAS COMPANY'S SINGLE FAMILY RESIDENCE - KIRKLAND, WASHINGTON

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Prepared for the
Department of Housing and Urban Development

Under Contract Number
H-2372

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By

The Boeing Company
David Beers, Program Manager

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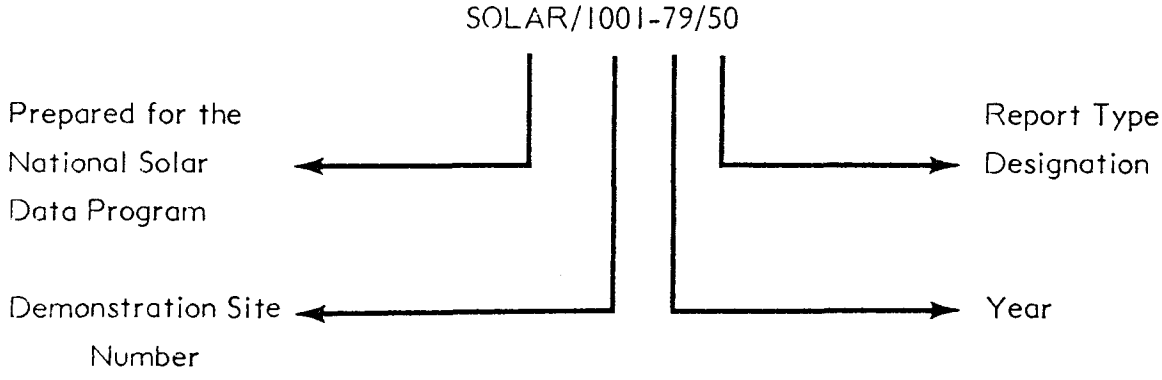
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Washington Natural Gas Company's single family residence project site is designated as SOLAR/1001-79/50. 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 -- Air
- o Freeze Protection -- None required
- o Application -- Heating and hot water
- o Storage -- Rock and preheated water tank
- o New/Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- Forced air, gas fired auxiliary furnace and hot water

The solar energy system for a new single family detached residence in Kirkland, Washington, (Grant H-2801), preheats domestic hot water (DHW) and heats 2607 square feet of occupied space. The building was designed by The Mithun Associates, Architects and its Solaron solar system was designed and installed by the Solaron Corporation of Commerce City, Colorado.

The 546 square foot collector array was manufactured by Solaron Corporation. The Collector Panels are installed, in a mosaic pattern, on a slanted room on the south side of the house bordering a steep ravine. The 28 collectors are flush mounted and therefore, are integrated part of the roofing. No on-site changes are made to the collectors to modify their thermal characteristics, or their heat transfer properties. The collector back is insulated with fiberglass insulation batt, providing an R-12 insulation value. The collector mosaic is installed at a 57^{o} tilt to the horizontal.

These collectors utilize air as heat transfer media and require no freeze protection provisions.

The air Thermal Storage Unit consists of a container filled with 27,300 pounds of smooth surfaced stones of 1 to 1 1/2 inch average diameter. The total volume of storage container is 273 (6' x 6' x 7' 7") cubic feet. The container has concrete walls and bottom which are insualted with preformed styrofoam panels.

The 11 cubic foot water storage tank has fiberglass insulation and is located in the mechanical room in the basement.

Service hot water is preheated by a heat exchanger coil installed in the air duct from the collectors to the air storage. The preheated water is recirculated through the preheat water storage tank as required by temperature differential settings in the control system.

The domestic hot water tank, supplied with the preheated water from water storage tank, is a 50 gallon gas-fired tank with a thermal insuallation value (R) of 4.

Space heating is provided by air circulation using collectors, storage bin and gas-fired furnace. An Air Handler Unit controls overall air flow in the system.

The house has been fully instrumented to compile solar system performance data since November 1977. The data is integrated into the National Solar Data Network.

III. SITE AND BUILDING DESCRIPTION

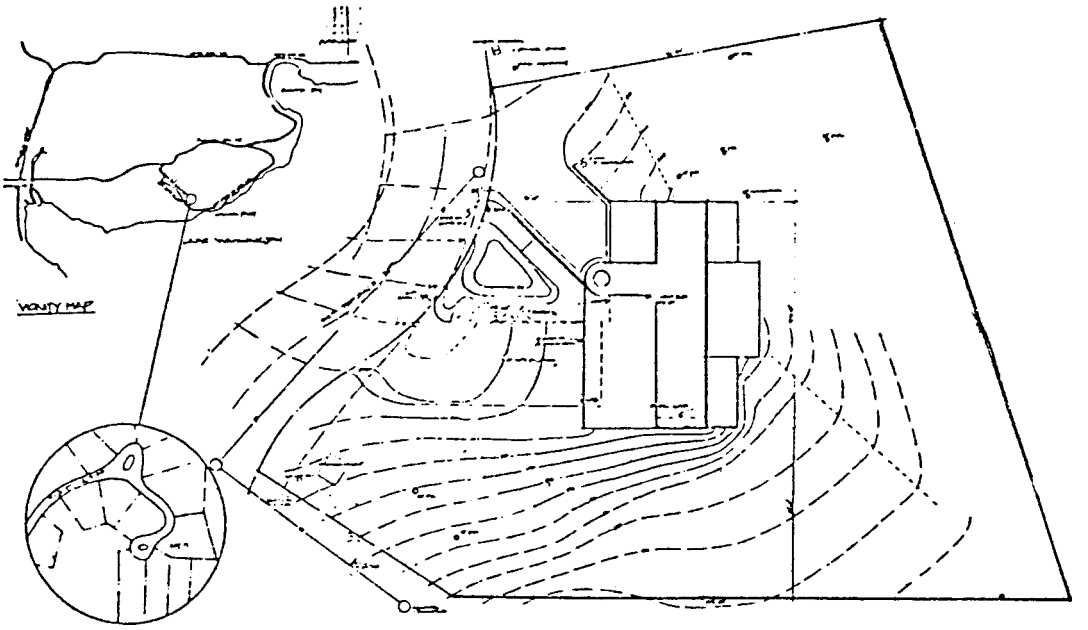


Figure III-1. Site Plan

Site Description. (See Figure III-1 Site Plan)

- Special topographic or climatic conditions - None
- Latitude - 47° N
- Longitude - 122°
- Altitude - 200 ft
- Annual degree days (65° F base)
  - Heating - 5145
  - Data location - Seattle, Washington
  - Data reference - Local Climitological Data Annual Summaries for 1976, Department of Commerce, National Oceanic and Atmospheric Administration.
- Average Insolation
  - January - 283 Btu/ft^2 day
  - July - 2111 Btu/ft^2 day
  - Data location - Seattle, Washington
  - Data reference - ASHRAE System Handbook
- Site topographic description - Hillside, with earth bank running down southerly towards a ravine
- Shading - Minimal to none

Building Description

- Occupancy
  - Single family detached
  - Family of three
  - Three bedrooms, living room, dining room, 1-1/2 bathrooms kitchen/dinette, family room, two car attached garage and basement
- Total area - 3000 square feet (approximately)
- Conditioned floor area - 2607 square feet
- Height - Two stories plus daylight basement
- Roof slope - Partly flat, partly sloped

- Special features - South facing balconies, both floors

Structure

- Walls (Solar conditioned space)
  - Frame Concrete block with wood framing
  - Exterior finish - Cedar shingles
  - Insulation - 6 inches of fiberglass batt between 2 x 6 studs on exterior walls
  - Interior finish - Gypsum wallboard
  - Windows
    - Double glaze
    - Less than 25% of exterior wall area
  - Doors
    - Front door - Solid wood with weatherstripping
    - Garage door - Opens into non-conditioned area
    - Sliding glass door - Both balconies
- Roof
  - Structural frame - Structural wood with built up asphalt and wood decking
  - Exterior finish - Cedar shingle
  - Insulation - 6 inch injection foam (2% phenol and glass fiber)
  - Interior finish - Gypsum board

Mechanical System

- Heating
  - Solar - Air through duct
  - Auxiliary - Gas-fired furnace with forced air
  - Distribution - Ducting, insulated
- Cooling - (Non-existing)
- Domestic hot water

- o Design water demand - 80 gallons
- o Preheat storage capacity - 82 gallons
- o Preheat heat exchanger - preheat coil in the duct from air collectors to rock storage
- o Auxiliary
  - Gas-fired, 50 gallons capacity HW tank

Solar system design lifetime estimates

- o System design life - 30 years
- o Collectors design life - 20 years

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

The solar heating demonstration system used at the Washington Natural Gas Company's Grant, (Grant #H-2801), is shown in figure IV-A-1. Major components in the solar system are a) 546 square feet of prefabricated Solaron collectors; b) 273 cubic foot rock storage bin; c) preheat water storage tank of 11 cubic foot capacity; and d) a preheat coil installed in the collector return air duct.

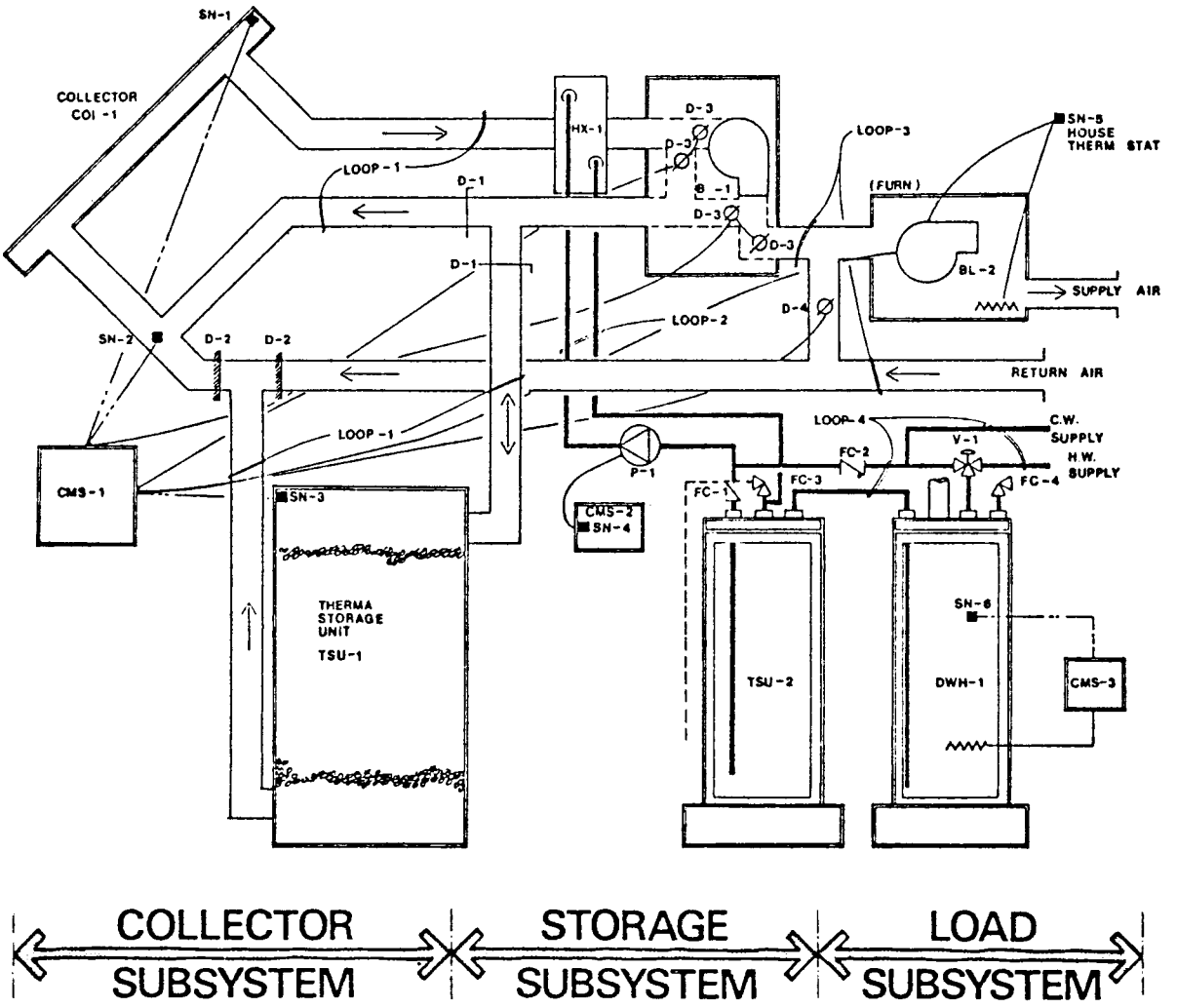


Figure IV-A-1. General Overview

The system includes a conventional auxiliary gas-fired furnace, a gas-fired water heater and an Air Handler unit controlling overall flow distribution.

Subsequent sections of this report describe details of the collector, storage, storage-to-load, and auxiliary energy subsystems. Specific details of the operating modes are described in the final section.

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

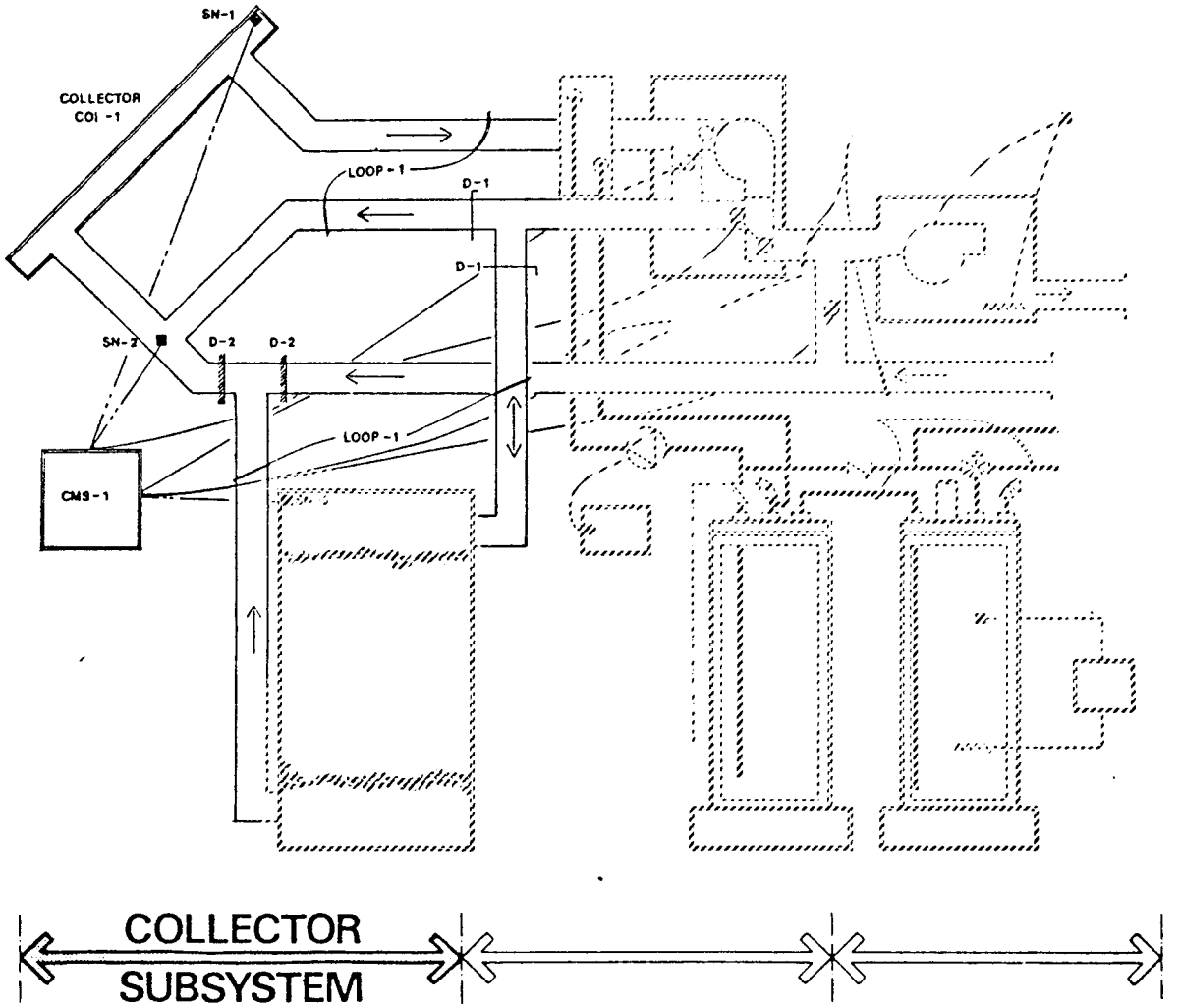
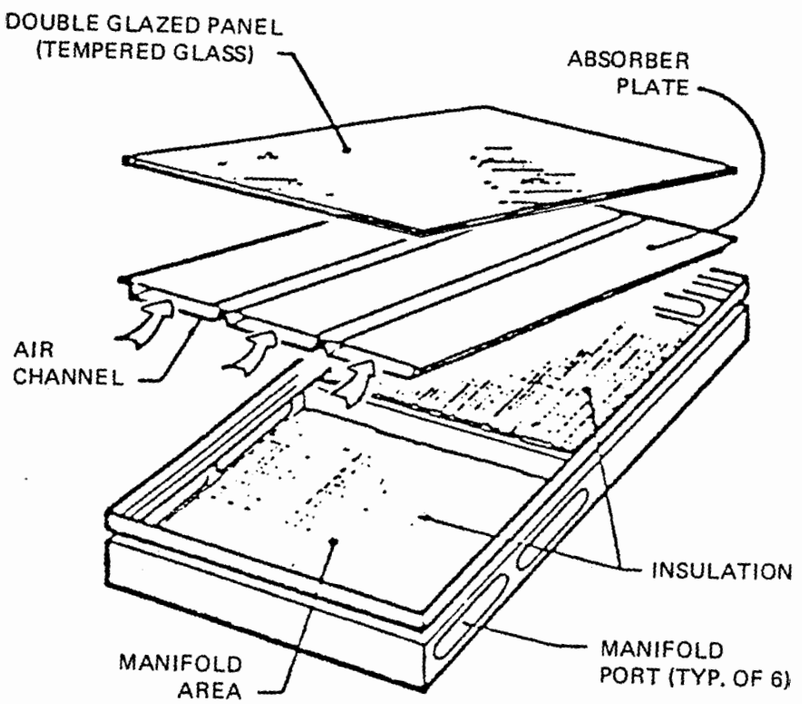


Figure IV-B-1. Collector Subsystem

The 546 square feet of collector mosaic (see figure IV-B-2) is mounted at a 57° slope to the horizontal, on a sloped part of a roof on the south side of the house. The collector installation and framing structure supports are integrated in the roofing structure. The 28 collector panels are made by Solaron Corporation. The back of the collector panel is insulated with fiberglass insulation.

No freeze protection of the collector array was used since air is used as heat transfer medium in this system.



PANEL DIMENSIONS
3'-0" W x 6'-6" L x 7¼" H

NOTE: AIR FLOWS THROUGH THE CHANNELS BENEATH THE ABSORBER PLATE

Figure IV-B-2. Collector Construction detail

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

- Manufacturer - Solaron Corporation
- Model Name/Number - 2000 series
- Type - Air, flat plate, black non-selective
- Location - Integral part of sloped roof
- Orientation - Due south
- Tilt angle - 57^{o} from the horizontal
- Number of collector panels - Twenty eight
- Array configuration - Four rows of seven collectors
- Collector enclosure (See Figure IV-B-3)
  - Frame Material - Wooden frame, integrated with roof structure and flush with roof finish. Backing material is Phenol-glass fiber
  - Gross area - 546 square feet
  - Net aperature area - 498 square feet
  - Weight
    - Unit panel - 153 pounds
    - Total array mosaic - 4284 pounds
  - Panel length - 78 inches
  - Panel width - 36 inches
  - Panel depth - 7.3 inches
  - Shading - Minimal
- Cover plate
  - Number of cover plates - Two
  - Manufacturer - ASG Industries
  - Product Name/Number - True-Temp
  - Material - Tempered glass, double strength
  - Thickness - .125 inches

- Optical properties (solar region) (infrared region)
  - Transmittance 89% ---
  - Reflectance 8% 12%
- Edge or surface treatment other than coating - Mechanical ground coat
- Coating on cover plate material - None
- Sealant - Long life neoprene gasket

- Absorber
  - Manufacturer - Solaron Corporation
  - Model Name/Number - Series 2000 absorber
  - Material - Substrate
    - Thickness - 0.015 inches
  - Coating
    - Material - Ceramic enamel
    - Applicating - Baked on
  - Coating properties (solar region) (infrared region)
    - Absorptance 94% 89%
    - Reflectance 6% 11%
    - Emittance 94% ---
  - Heat transfer fluid passages
    - Fluid medium - Air
    - Location - Beneath absorber
    - Material - Steel
    - Wall thickness - .015 inches
    - Internal diameter - 1.18 inches
    - Spacing - 10.75 inches on center
    - Internal protective coating - Paintlok

- Insulation - Back side
  - Material - Glass fiber, Thermal resistance - R-12
  - Binder - Phenol @ 2%
- Sealant
  - Manufacturer - Pawling Rubber and Dow Corning
  - Product Name/Number - EDOM and 732
  - Location - Inner cover, outer cover, frame joint, backing plate and penetrations
- Frame
  - Number of structural attach points - 6
  - Built-in collector
    - Frame is not part of the structure
- Dessicant - Silica gel
- Freeze protection - None, (air system)
- Overheat protection - Air cooling

Collector Performance

- Method of evaluation - ASHRAE
- y intercept - .48° F/hr ft^2/Btu
- Slope - .85

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

- Test flow rate - 80.8 cfm
- U_L = total heat loss coefficient - 1.32 Btu/hr ft^2 ° F

- Test wind speed - 5 mph
- Test collector area
  - Gross - 19.5 square feet
  - Net - 17.8 square feet
- Thermal response time constant - .0005 minutes
- Incidence angle modifier
  - 45^{o} - 0.94
  - 60^{o} - 0.88
  - 75^{o} - 0.67
- Fluid specific heat - 0.24 Btu/lb^{o} F
- Test fluid medium - Air

Air Circulation Loop No. 1

- Design air flow - 1092 cfm
- Blower speed
  - Maximum - 2750 rpm
  - Minimum - 2650 rpm
- Ducting - Galvanized steel and aluminum with duct wrap
  - Location of ducting - Above grade, inside building
- Ducting joints - Pressure sensitive tape, clamped
- External duct insulation
  - Material - Glass fiber
  - Thermal resistance - R-4.65
- Internal duct insulation
  - Manufacturer - Certainteed
  - Product Name/Number - Ultralite

- Damper (D-1)
  - Function - On-Off
  - Type - Single blade
  - Operation - Manual
- Damper (D-2)
  - Manufacturer - Soloran
  - Model Name/Number - DV0028
  - Type - Backdraft
  - Blade edges - No seal

Control Mode Selector (CMS-1)

- Manufacturer - Honeywell
- Modes controlled - Collector-to-space
  Collector-to-hot water
  Storage-to-space
  Storage-to-auxiliary-to-space
  Heating on auxiliary
- Sensor (SN-01), (SN-02) and (SN-03)
  - Type - Temperature, thermomister
- Sensor (SN-05)
  - Type - 3 stage room thermostat

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

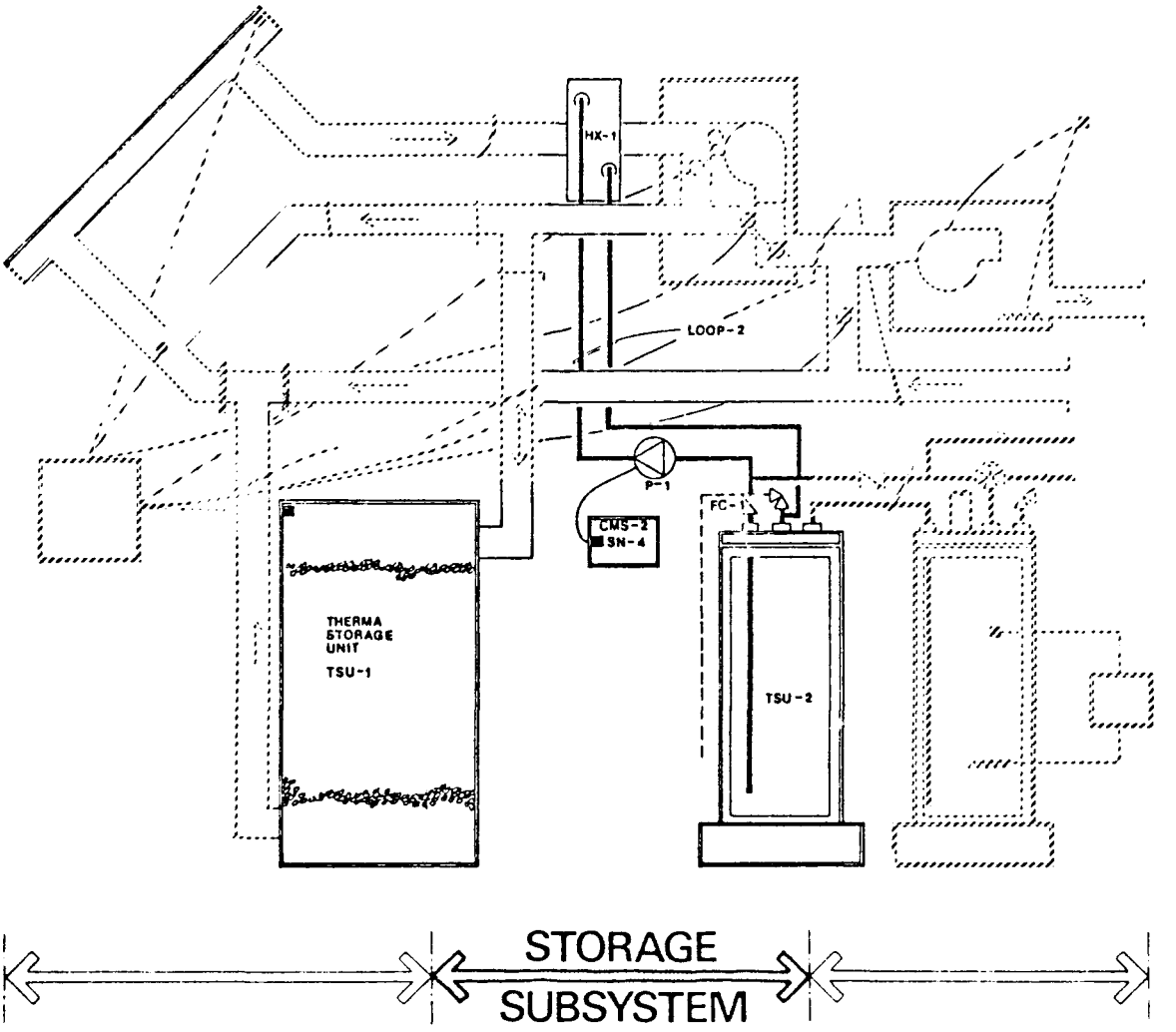


Figure IV-C-1. Storage Subsystem

Solar energy is stored in a bin containing 27,300 pounds of 1 to 1-1/2 inch maximum diameter rocks. The solar heated air passing through a heat exchanger, also preheats incoming domestic water which is stored in a 11 cubic foot capacity preheat storage tank that supplied, on demand, to a coventional 50 gallon domestic hot water tank.

Air Thermal Storage Unit (TSU-1)

- Container
  - Manufacturer - Site built
  - Total storage volume - 273 cubic feet
  - Volume of storage medium - 273 cubic feet
    - Length - 6 feet
    - Width - 7'-7"
    - Height - 6 feet
- Storage medium
  - Design operating temperatures
    - Maximum - 180° F
    - Normal - 140° F
    - Minimum - None
  - Design pressure drop (inlet to outlet) - .14 psi
  - Material - Stone
  - Weight per cubic foot - 100 pounds
  - Total weight of storage medium - 27,300 pounds
  - Specific heat of solid material - .20 Btu/lb °F
  - Heat capacity of packed material - 20.0 Btu/ft^3 °F
- Construction container
  - Material - Concrete
  - Internal lining - None
  - Insulation material and thermal resistance
    - Top - Fiberglass, R-19
    - Side - Styrofoam, R-12.5
    - Bottom - Styrofoam, R-12.5

- Location - Below basement
- Filter - Other location

Liquid Thermal Storage Unit (TSU-2)

- Container
  - Manufacturer - A. O. Smith
  - Model Name/Number - T-80
  - Total storage container volume - 11 cubic feet
  - Volume of storage medium - 11.11 cubic feet, 82 gallons
    - Length - 5.0 feet
    - Diameter - 2.1 feet
  - Maximum rated operating conditions of container
    - Temperature - 160° F
    - Pressure - 65 psi
  - Insulation - Glass fiber
  - Auxiliary heaters - None
  - Exterior finish - Enamel
- Storage medium
  - Design operating temperature - Maximum, 160° F
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb° F
  - Density - 62.5 lb/ft^3
  - Heat capacity at 70° F - 62.5 Btu/ft^3)
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Inhibitor - None

- Container construction
  - Type - Steel tank, glass lining
  - Location - Basement
  - Filters - None

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

- Design maximum operation temperature - 205° F
- Flow rate
  - Liquid flow (design) - 2 gal/max.
- Heat transfer medium - 100% water
- Anticipated lilquid temperature - 205° F maximum
- Provision for expansion - Pressure release valve in loop
- Piping
  - Location - Above ground
  - Insulation - Cellular rubber
  - Material - Copper
  - Connection - Solder
  - Operating temperature - 205° F
- Heat Exchanger (HX-1)
  - Manufacturer - Pace
  - Type - Air/liquid
  - Type of flow - Cross (serpentile booster)
  - Type of design - Fin coil
  - Convection - Forced air/forced water
  - Heat transfer surface
    - Material - 10 SPI with .17 wall, aluminum fins
  - Effectiveness - .25 to .30

- Flow rates
  - Air, 1092 cfm
  - Liquid, 2 gal/min
- Circulation Pump (P-1)
  - Manufacturer - Grundfos
  - Model Name/Number - W 306
  - Type - Centrifugal
  - Maximum operating conditions
    - Static - 5.6 psi
    - Temperature - 230° F
    - Dynamic - 6.5 psi @ 10 gal/min
  - Material exposed to heat transfer fluid - Stainless steel
  - Motor size - 0.102 kw, 120V
  - Circulating volume
    - High head mode - 2 gal/min
  - Operating heat (dynamic)
    - High head mode - 5.636 psi

Control Mode Selector (CMS-2)

- Manufacturer - Honeywell
- Modes controlled
  - Flow circulation through liquid side of HX-1 to TSU-2
- Sensors (SN-04)
  - Manufacturer - Honeywell
  - Product Name/Number - L40008 A 105
  - Type - Aquastat

- Flow Control (FC-1), (FC-2)
  - Type - Check valve
- Flow Control (FC-3), (FC-4)
  - Type - Check valve

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

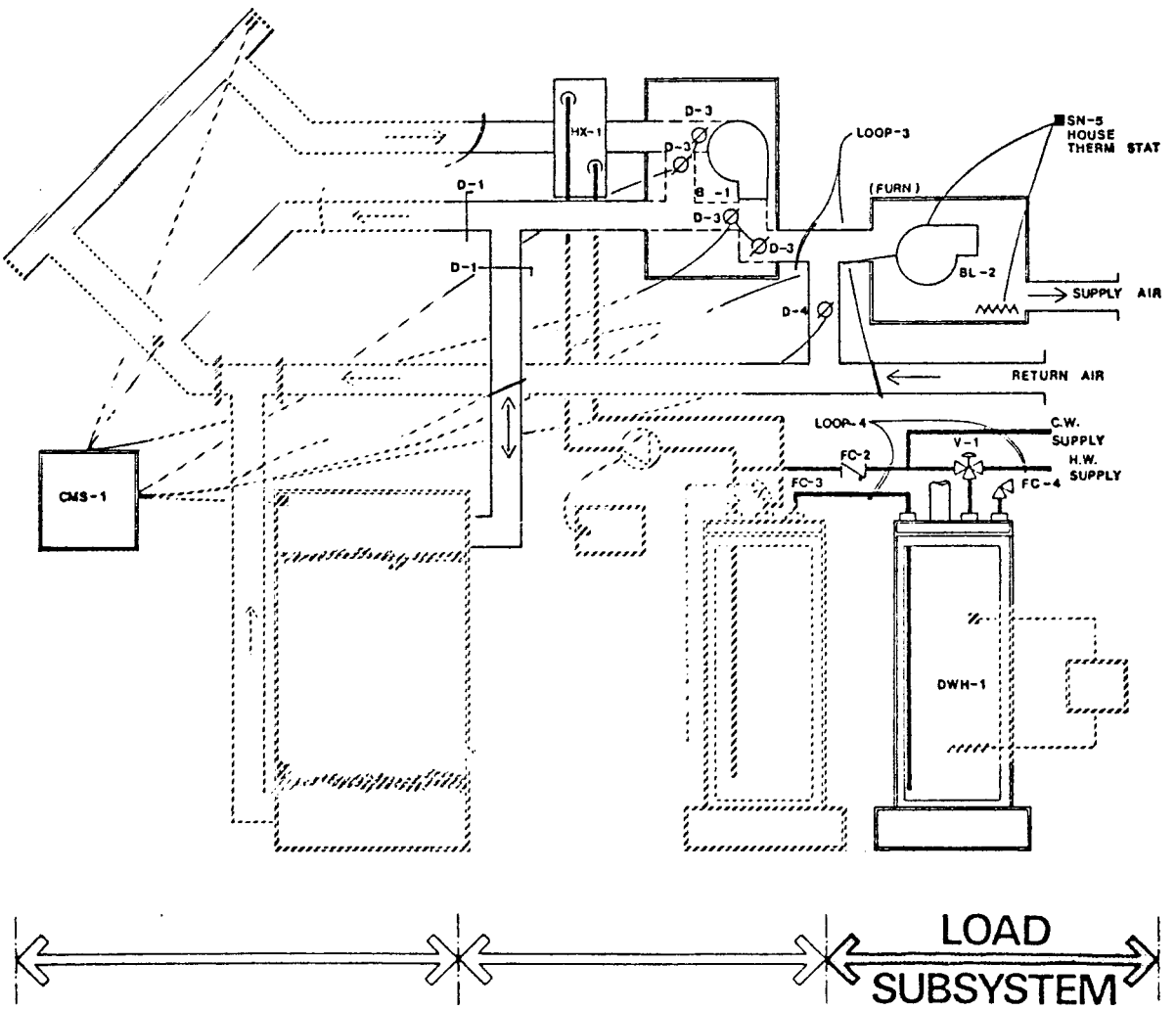


Figure IV-D-1. Energy-to-Load Subsystem

Air Circulation Loop No. 3 (TSU-1 and/or Col-1 to Space Heating)

- Damper (D-1)
  - Function - ON-OFF
  - Type - ON-OFF
  - Operation - Manual
- Damper (D-3)
  - Manufacturer - Blake ZIA
  - Model name/number - DV 0028
  - Type - Multi Shutter
  - Function - Flow switching
  - Operation - Motorized (Motor; Dayton,1/100 hp)
- Damper (D-4)
  - Function - Flow adjusting
  - Operation - Manual
- Blower (BL-1)

Control Mode Selector (CMS-1)

- Manufacturer - Honeywell
- Modes controlled:
  Collector-to-space
  Collector-to-HW
  Storage-to-space
  Storage-to-Auxiliary-to-space
  Heating on auxiliary
- Sensor (SN-01), (SN-02), and (SN-03)
  - Manufacturer - Dan Mar Company
  - Product Name/Number - TC-10-17-150
  - Type - Temperature, resistance thermometer
- Sensors (SN-05)
  - Type - 3 stage room thermostat

Liquid Circulation Loop No. 4 (TSU-2 to DWH-1 to Load)

- Design temperature - 140° F maximum
- Heating design flow - 80 gallons per day
    - Medium - 100% water
- Chemical feeder - None
- Inhibitor - None
- pH Factor - 7.0
- Piping
    - Rigid - Copper, solder connections
- Distribution Valve (V-1)
    - Function - 3 way mixing
    - Operation - Automatic
    - Type - Tempering
- Flow Control (FC-2)
    - Type - Check valve
- Flow Control (FC-3), and (FC-4)
    - Type - Pressure relief

E. Auxiliary Energy Subsystem (See Figure IV-E-1)

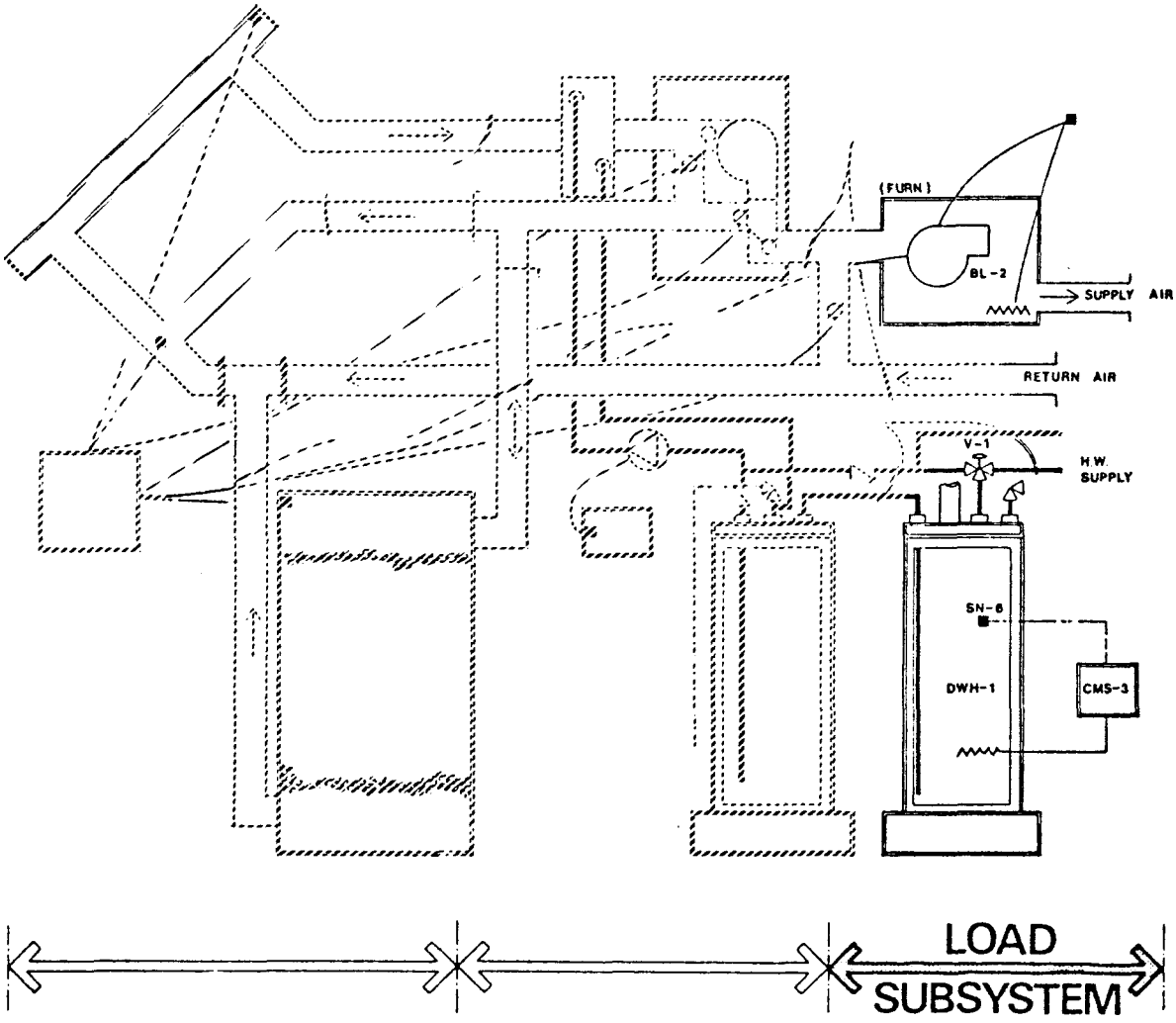


Figure IV-E-1. Auxiliary-to-Load Subsystem

Furnace (FURN-1)

- Manufacturer - Payne
- Model Name/Number - Delux 19X #125448
- Energy source - Natural gas
- Energy output - 100,000 Btu/hr
- Energy input - 125,000 Btu/hr

Domestic Hot Water Heater (DHW-1)

- Manufacturer - A. O. Smith
- Model Name/Number - PGC-50
- Energy source - Natural gas
- Tank volume - 50 gallons
- Energy input - 44,000 Btu/hr
- Energy output - 30,800 Btu/hr
- Maximum recovery rate - 48 gallons per hour
- Yearly average cold water inlet temperature - 60° F
- Design water output temperature - 140° F
- Thermal resistance - R-4
- Blower (BL-2)

Control Mode Selector (CMS-3)

- Manufacturer - A. O. Smith
- Modes Controlled - Auxiliary-to-storage TSU-2
  - ON - (SN-06) less than 140° F
  - OFF -
- Sensors (SN-06)
  - Manufacturer - A. O. Smith
  - Type - Aquastat

F. Modes of Operation

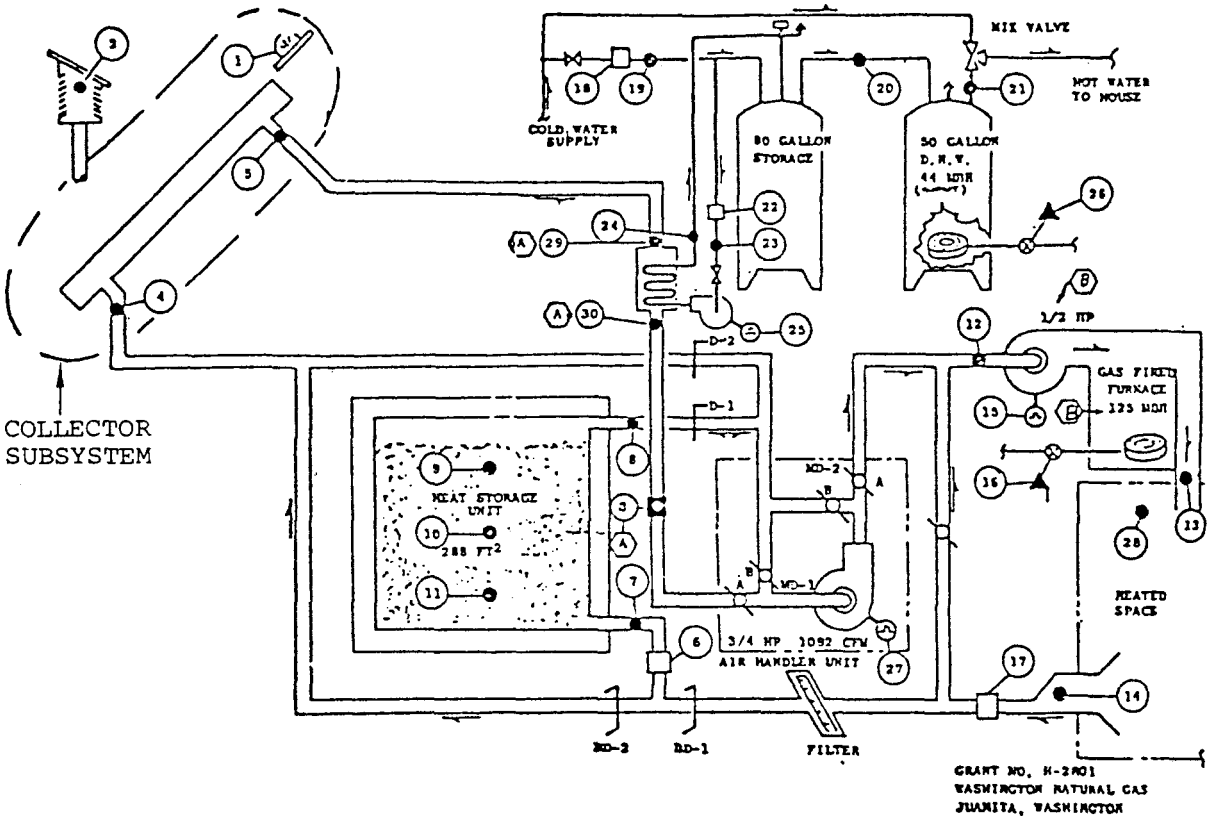


Figure IV-F-1. Controls Diagram

The Washington Natural Gas Company's "Solar Home" is designed to utilize an active solar energy system. The "Solar Home" is built with a North-South orientation providing an optimum Southern exposure for its 28 Solaron heat collecting panels. The active system is designed to store heat beneath the house in a bin filled with rocks, 1 to 1 1/2 inch maximum dimension. The overall design of the "Solar Home" provides for considerations to prevent heat loss as much as construction economics allow. Windows, an important source of heat loss, are purposefully kept to a minimum in number and each is strategically placed. The windows are double-glazed to prevent heat loss and all but two are on the south

side to achieve maximum use of natural sunlight and heat. The "Home" 's construction optimizes the use of ceiling and sidewall insulation. The "Home" utilizes a sealed-combustion fireplace which draws outside air for combustion.

The Solaron collectors are designed to last the life of this residence and are guaranteed for ten years.

Included in the solar system are an array of solar collectors, an air to water heat exchanger, a rock storage unit, an air handler with motorized dampers, a conventional gas-fired furnace for backup heat, a control system and several sensors which provide information to the control system, a hot water preheat tank, a conventional gas-fired hot water heater, a pump to circulate the water, and the necessary ductwork and plumbing to tie all components into a working system.

System Operation - The solar collectors are equipped with sensors that activate the system to operate at any one of its four modes. Direct and indirect sunlight is absorbed when the thermostat in the "Home" 's living area calls for heat, the heated air is diverted to the rock bin for storage. When insolation heat is unavailable, heat is drawn from the storage are for circulation through the "Home". In the event of insufficient storage of usable heat, a 125,000 BTU natural gas forced-air furnace is activated as the auxiliary source.

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

Mode 1 - Heating from Collector

The circulating heat transfer medium (air) is drawn through the collector where it is normally heated to $135^{\circ} \pm 15^{\circ}$ F. When the residence requires heat, the solar heated air is drawn through the air handling unit in which motorized dampers are automatically opened or closed to direct the warm air to the space. The air then returns to the collectors where it is again heated and the cycle is repeated. In this mode, when sunshine is available and heat is demanded in the heated space, the dampers in the air handler are positioned so that the air is removed from the heated space and passed through the collectors where it is heated. From the collectors the heated air passes through the "air-to-water" heat exchanger where some of the heat is removed and added to the domestic hot water supply. The air

continues through the duct to the air handler. The blower in the air handler pushes the air on to the conventional furnace. The blower in the furnace then moves the heated air to the house through the normal distribution duct work.

Mode 2 - Heating from Storage

At night or on a cloudy day, when solar energy is unavailable, and when heat is needed in the space, the automatic control system directs the house return air into the bottom of the heat storage unit, up through the rocks where the air is heated, then through the air handling unit into the space. When the solar heated storage air temperature is not adequate to maintain the space thermostat setting, the automatic control turns on the auxillary heater (gas-fired furnace) to meet the required heating load. This switch-over takes place when the storage air temperature drops below 90^{o} F.

Mode 3 - Storing heat

When the demand for heat is satisfied and the solar energy is still available, then the furnace blower shuts off and the air handler dampers change position to divert the flow to the rock storage. The heated air enters the upper storage plenum and passes down through the rocks losing heat to the rocks as it passes. The air then passes from the bottom of the rock storage back to the collectors to be reheated. This cycle continues until the solar energy striking the collectors becomes inadequate to maintain the air exiting the collectors at a temperature of 25^{o} F above that of the air returning to the collectors. The air handler is shut down by the controller when this conditions occurs.

Mode 4 - Heating Water in the Preheat Storage Tank

Whenever ample solar energy is available, the air, drawn through the collectors, passes through the water heat exchanger coil, and the solar heated air transfers its heat to the water in the preheat storage tank which is being circulated through the coil. The air passes through the heat exchanger and returns to the collector unit. The cycle is repeated.

The solar heating system may be used exclusively for heating the domestic hot water supply by putting the system into this mode manually. This requires openihg the damper in the summer bypass duct, closing the damper in the duct to rock storage and moving a switch on the controller from the winter to summer position.

When solar energy is available the air handler will now draw heated air from the collectors, pass it through the "water-to-air" heat exchanger, then through the air handler and back to the collectors. Water is circulated from a preheat tank through the heat exchanger by a small pump. When water in the preheat tank reaches a predetermined temperature (140^{o} to 160^{o} F) a sensor in the tank will shut the system down. As hot water is used from the conventional tank it is replaced by preheated water rather than cold water.

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.

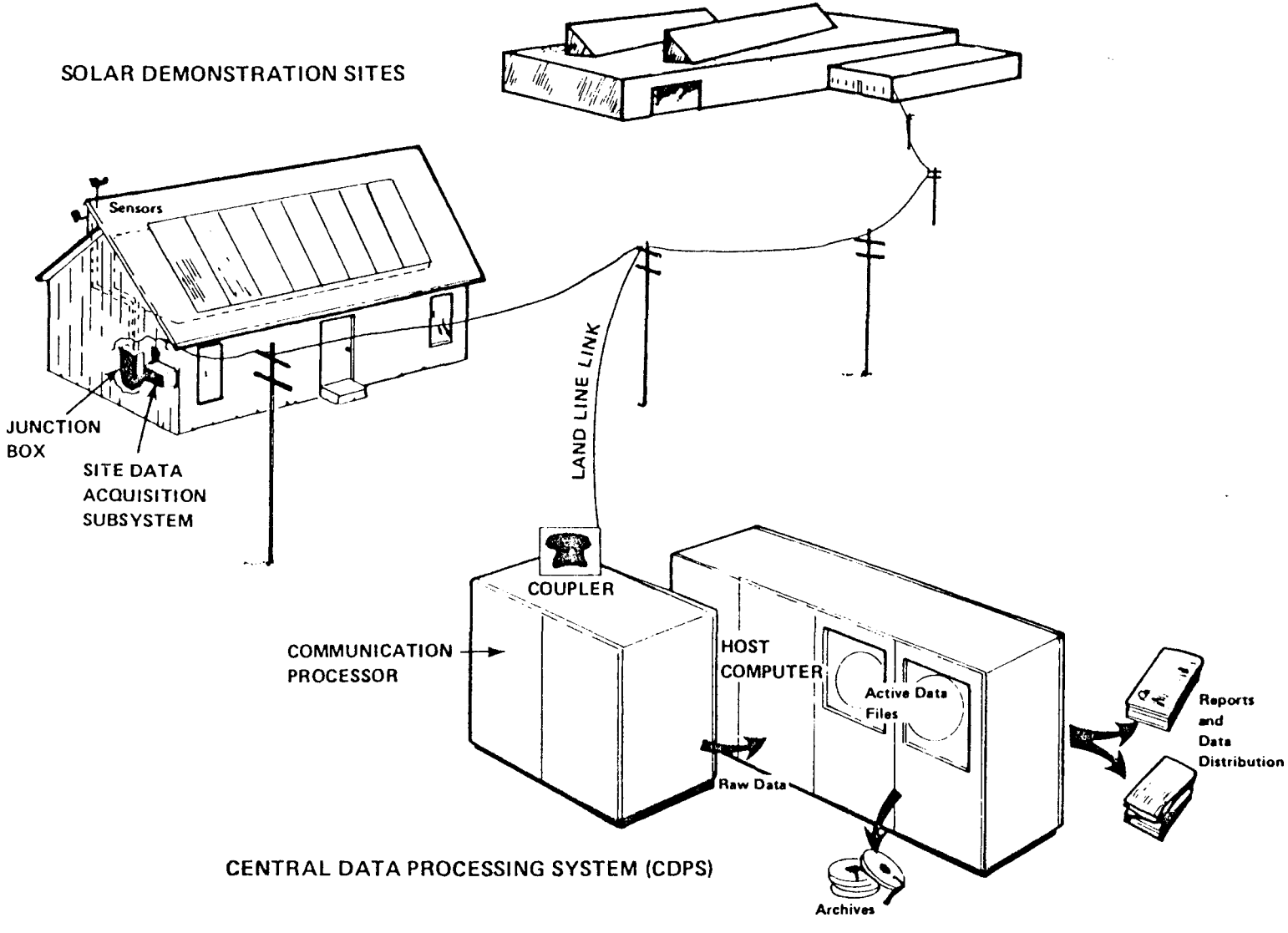


Figure V-A-1. The National Solar Data Network

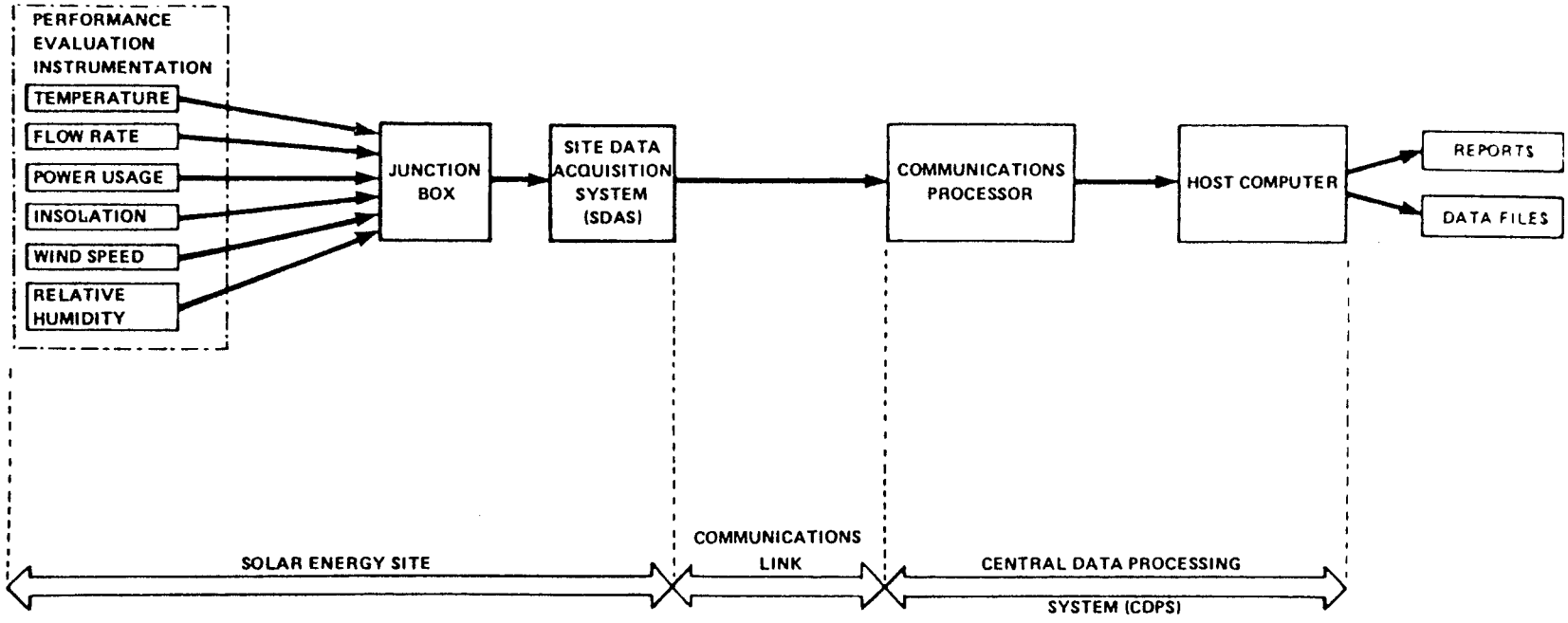


Figure V-A-2. Data Flow Path for the National Solar Data Network

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, ambient	S53P-60
W100	Flow, collector	TSI 1610-12"
T100	Temperature, collector return	S57P-100
T150	Temperature, collector supply	S53P-100
W200	Flow, rock storage unit	TSI 1610-12"
T200	Temperature, rock storage, low	S57P-100
T250	Temperature, rock storage high	S53P-100
T201	Temperature, rock storage, upper	S53P-60
T202	Temperature, rock storage, center	S53P-60
T203	Temperature, rock storage, lower	S53P-60
T400	Temperature, furnace air return	S57P-100
T450	Temperature, furnace supply	S53P-100
T401	Temperature, cold air return	S53P-100
EP400	Power, domestic furnace	O-H, PC5-10
F400	Contact closure, totalizing fuel consumption, furnace	American Meter Co. AL 175
W600	Flow, building load	TSI 1610-12"
W300	Flow, cold water supply	Hersey 430, modified
T300	Temperature, cold water supply	S57P-60
T350	Temperature, water storage tank outlet	S57P-60
T351	Temperature, DHW tank outlet	S53P-60
W301	Flow, hot water heat exchanger	Flo scan 300-3
T302	Temperature, return to heat exchanger	S57P-60
T352	Temperature, supply from heat exchanger	S53P-60
EP300	Power, heat exchanger pump	O-H, PC5-1
F300	Contact closure, totalizing fuel consumption, DHW tank	American Meter Co. AL 175
EP100	Power, air handler unit	O-H, PC5-19
T600	Temperature, building thermostat	S53P-60
T101	Temperature, transfer coil inlet	S57P-100
T151	Temperature, transfer coil outlet	S53P-100

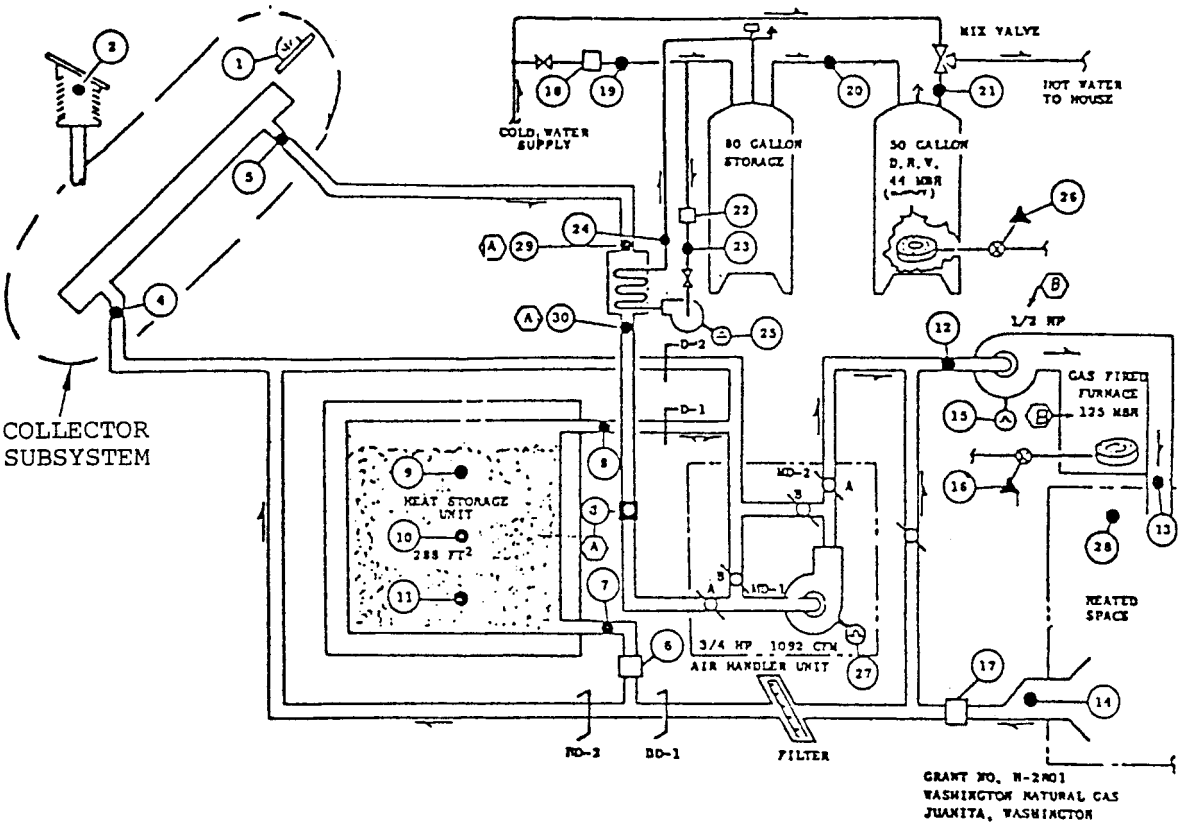


Figure V-B-1. Sensor Locations

IV. 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 Sub-System	Applicants Request	Construction Grant
Collectors	$4,700	
Energy Storage	640	
Distribution & Controls	3,320	
Installation	3,450	
Others *	640	
Total	$12,766	$12,766
Additional cost to complete		8,938
Estimated Final Cost		$21,704

C. Construction Period: February 18, 1977 through October 7, 1978

* Miscellaneous Hardware

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.

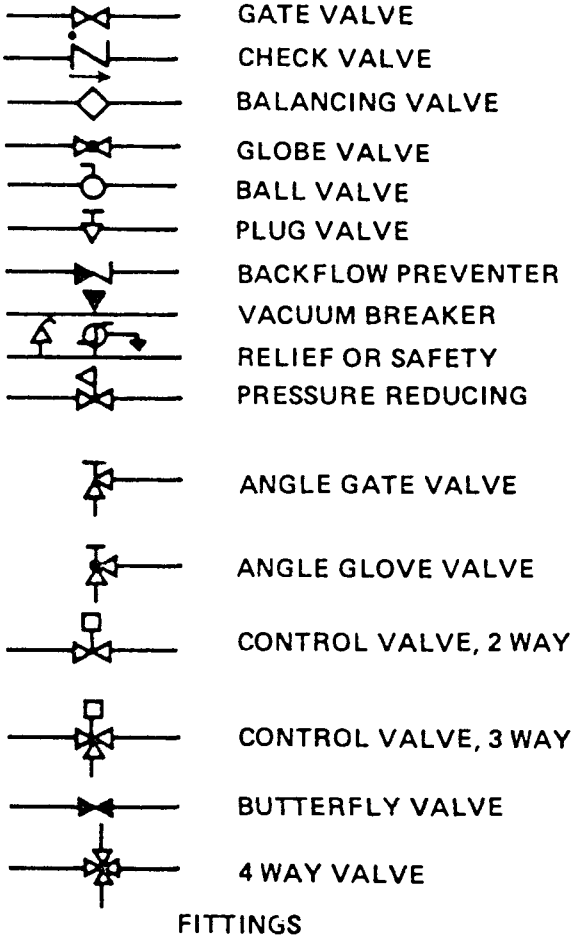
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

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



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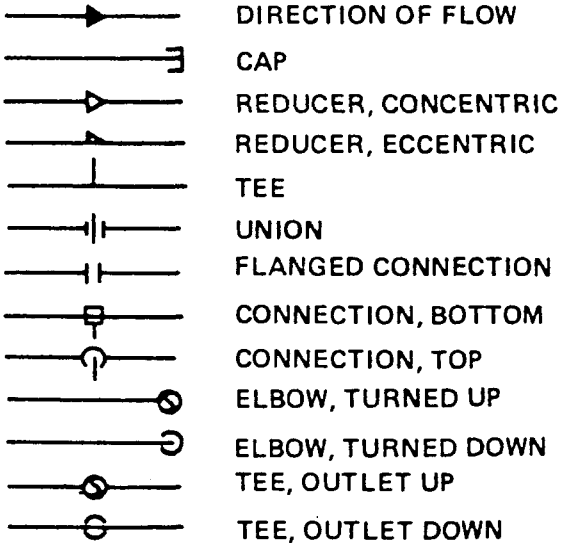

PIPING SPECIALITIES