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HQ. 604

SOLAR/1034-79/50

MASTER

Solar Project Description

ALPHA CONSTRUCTION COMPANY'S SINGLE FAMILY RESIDENCE Canton, Ohio September 21, 1979

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

Solar/1034-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
ALPHA CONSTRUCTION COMPANY'S
SINGLE FAMILY RESIDENCE - CANTON, OHIO

Prepared for the
Department of Housing and Urban Development

Under Contract Number
H-2372

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By

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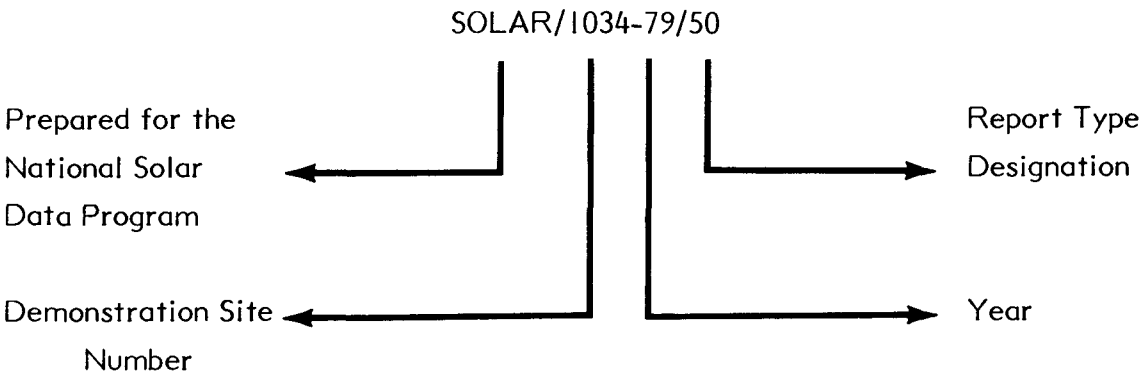
TABLE OF CONTENTS

LIST OF FIGURES

NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Alpha Construction Company's single family residence project site is designated as SOLAR/1034-79/50. 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:

- Solar Project Description.
- Operational Experience.
- System Performance Evaluation.
- 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, flat plate
- o Freeze Protection -- None required
- o Application -- Heating and hot water
- o Storage -- Rock and preheater water tank
- o New/Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- Forced air, split system heat pump, three stage auxiliary electric resistance heater, and auxiliary electric hot water heater

The solar energy system for a new single family detached residence in Canton, Ohio, preheats domestic hot water (DHW) and supplements heating energy for 2460 square feet of occupied space. The building was designed by Alpha Construction Company (H-8104) of Canton, Ohio, and its Rome Aire solar system was designed by Solar Energy Products Company of Avon Lake, Ohio.

The solar energy system is designed to provide approximately 50 percent of the space heating and 70 percent of the hot water energy requirements for the home.

The 432 square feet collector array was fabricated by Solar Energy Products Company. The collectors are installed, in a mosaic pattern, on a slanted roof on the south side of the house. The 17 SEPCO EF-212 "Rom-Aire" flat plate collectors are mounted on the roof, forming an integral 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 sides and back are insulated with 7/8 inch Celotex Thermax sheathing, providing an R-7 insulation value. The collector mosaic faces south and is installed at a 37 degree tilt to the horizon.

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

The air thermal storage unit consists of a concrete container filled with approximately 38,000 pounds of rocks. The total volume of 400 cubic feet in a 740 cubic foot container. The concrete walls and floor are insulated with preformed styrofoam panels.

The domestic hot water preheat storage is a 24 cubic foot (80 gal.) tank with fiberglass insulation and is located in the basement. An air-to-water heat exchanger is installed in the preheat storage loop. The heated air to exchanger is supplied from the air thermal storage utilizing a 250 cfm blower. The heated water in the exchanger coil is circulated through the preheat storage tank utilizing a pump. The heat exchanger loop remains active as long as the temperature of the preheat tank is less than 135^{o} F and the temperature in the air heat storage tank is greater than the preheat tank temperature.

The supply to the domestic hot water tank is through the preheated water storage tank. The DHW tank capacity is 52 gallons and is an insulated tank with electric heater elements for auxiliary energy supply.

Space heating is provided by an air circulation loop using air from collectors and/or the thermal storage unit including electric heating elements in a furnace/blower/heat pump combination system.

When solar energy is insufficient, a liquid-to-air heat exchanger of a 2.5 ton heat pump and a three-stage electric heater in the air handling unit provides the necessary energy for space heating.

The dwelling has been fully instrumented for monitoring solar system performance since February 1978. The data is compiled and integrated into the National Solar Data Network.

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

III. SITE AND BUILDING DESCRIPTION

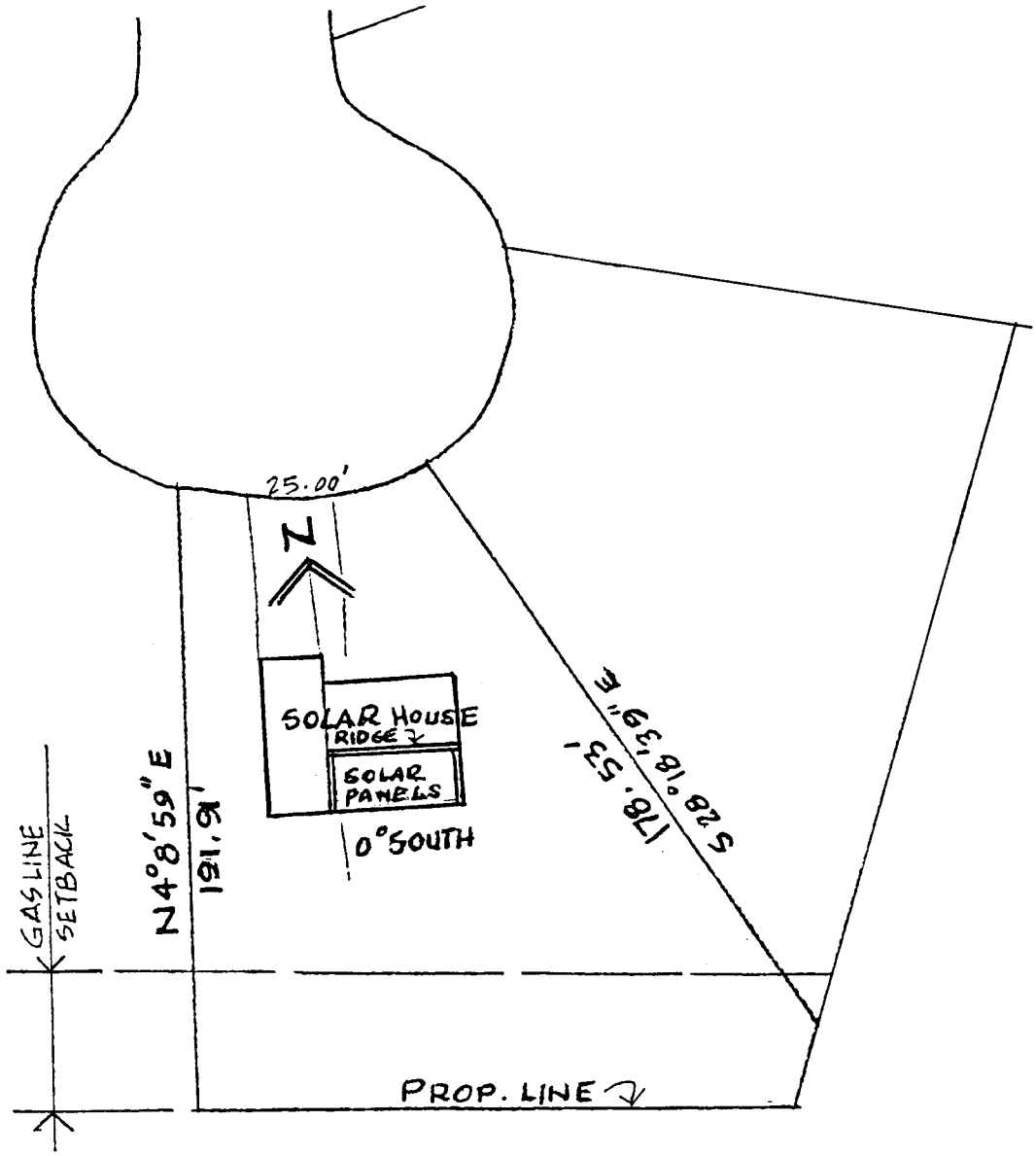


Figure III-1. Site Plan

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

- Special topographic or climatic conditions - None
- Latitude - 40°N
- Longitude - 82°
- Altitude - 560 feet
- Annual degree days (65° F base)
  - Heating - 6037
  - Data location - Canton, Ohio
  - Data reference - Local Climitological Data Annual Summaries for 1976, Department of Commerce, National Oceanic and Atmospheric Administration.
- Average Insolation
  - January - 450 Btu/ft^2 day
  - July - 1920 Btu/ft^2 day
  - Data location - Cleveland, Ohio
  - Data reference - ASHRAE System Handbook
- Site topographic description - Flat
- Shading - None

Building Description

- Occupancy
  - Single family detached
  - Family of four
  - Four bedrooms, living room, dining room, 2 1/2 bathrooms kitchen/dinette, family room, two car attached garage and partial basement
- Total area - 3320 square feet
- Conditioned floor area - 2460 square feet
- Height - Two stories above ground (26 feet high)

- Roof slope at collector - 37^{o} (9/12 pitch)
- Special features - Fireplace in family room

Structure

- Walls (Solar conditioned space)
  - Frame - Concrete block with wood framing
  - Exterior finish - Cedar siding
  - Interior finish - Gypsum wallboard
  - Windows
    - Single glaze, double hung
- Roof
  - Structural frame - Structural wood and plywood sheathing
  - Exterior finish - Asphalt shingle

Mechanical System

- Heating
  - Solar energy storage in a 740 cubic foot thermal rock storage bin, containing approximately 400 cu.ft. of rocks
  - Auxiliary source using heat pump with three stage electric heat furnace
  - Distribution - Hot air ducting between rock storage bin, auxiliary space heating system, and throughout conditioned area
- Cooling (Non-solar)
  - Auxiliary - Heat pump air conditioner
  - Distribution - Utilizes hot air ducting
- Domestic hot water
  - Daily water demand - 80 gallons
  - Solar - Heat exchanger in preheat ducting and an 80 gallon storage tank
  - Auxiliary - 52 gallon hot water tank with electric elements

IV. Solar System Description

A. General Overview

The Alpha Construction Company project (Grant No. H-8104) consists of four single-family dwellings, (SFD), in Canton, Ohio. Additional grant was awarded for installation of instrumentations in one of the dwellings. This report is a compilation of available data on the instrumented site and its solar system.

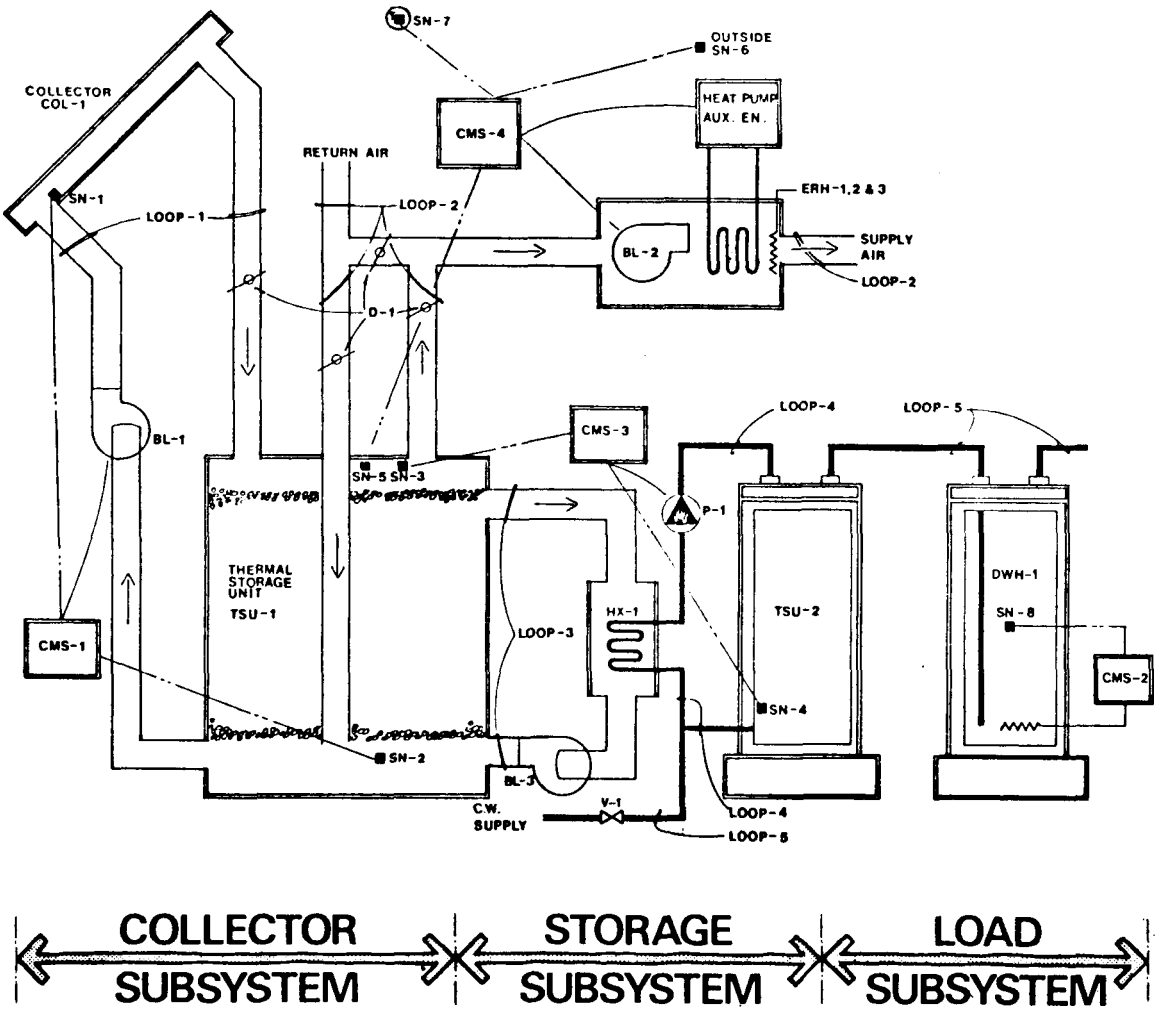


Figure IV-A-1. General Overview

The solar energy system in this house is an active air system with three air circulation loops (collector-to-storage, energy-to-load, and hot water preheat) and two water circulation loops (preheat and domestic hot water supply). The system is designed to provide approximately 50 percent of the space heating and 70 percent of the hot water energy requirements for the home. It has an array of seventeen SEPCO EF-212 "Rom-Aire" flat plate collectors with a gross area of 432 square feet. The array faces south at an angle of 37 degrees from the horizontal. Air is used as the medium for delivering solar energy from the collector array to storage. Solar energy is stored in a bin containing approximately 38,000 pounds of rock. The solar heated air, passing through a heat exchanger, also preheats incoming city water which is stored in an 80 gallon preheat storage tank and supplied, on demand, to a conventional 52 gallon domestic hot water (DHW) tank. When solar energy is insufficient, a liquid-to-air heat exchanger within a 2.5-ton heat pump and a three-stage electric heater in the air handling unit provide additional energy for space heating. An electric heating element in the 52 gallon DHW tank provides auxiliary energy for water heating.

Solar System and Component Summary

- Number of collector types - One
- Number of circulation loops - Five
- Number of thermal storage units - Two (rock storage and preheat water storage)
- Number of operational modes - Four
- Number of valves - One
- Number of blowers - Three
- Number of dampers - Four
- Number of sensors - Eight

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

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

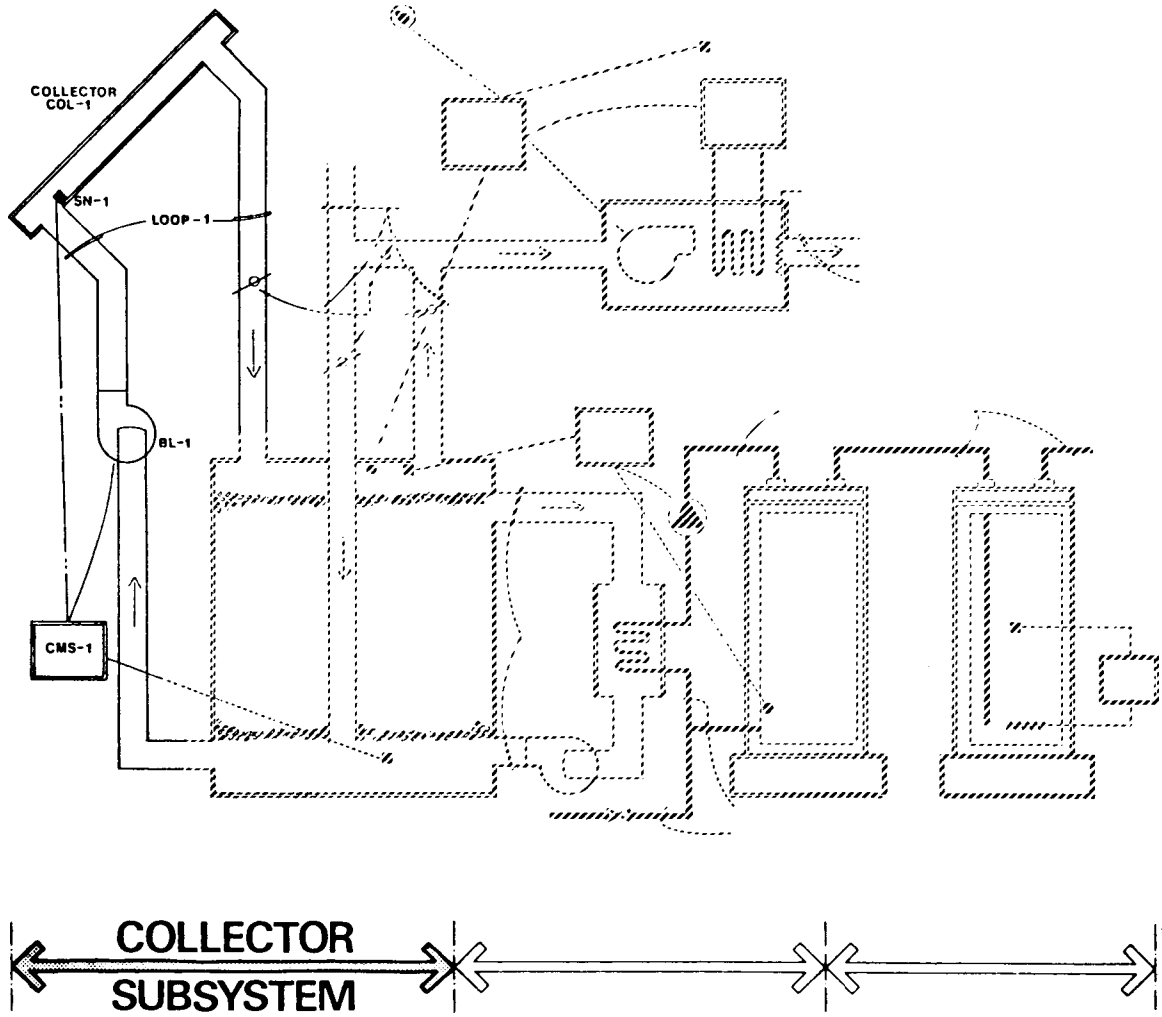


Figure IV-B-1. Collector Subsystem

The 432 square foot collector array is mounted at 37 degrees to the horizontal an an integral part of the roof structure. A pair of 260 square inch air ducts are installed in a vertical insulated chase, connecting the collectors to the basement thermal storage unit. Sensors located in the collector and the storage subsystems control various modes of the solar system operation.

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

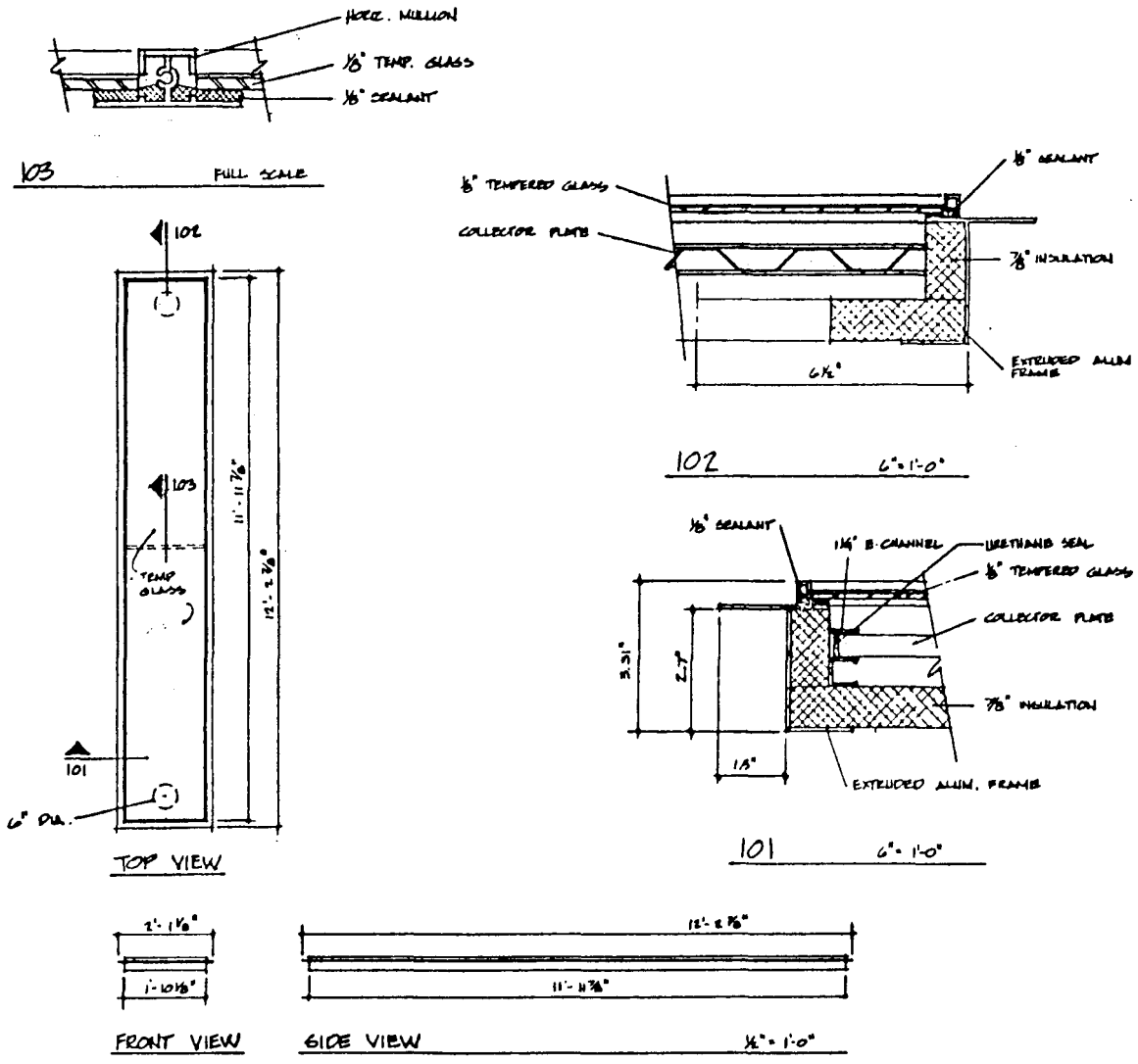


Figure IV-B-2. Solar Collector

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

- o Manufacturer - Solar Energy Products
- o Model Name/Number - SEPCO EF-212 "Rom-Aire"
- o Type - Air, flat plate
- o Location - Integral part of roof
- o Orientation - Due south

- Tilt angle - 37^{o} from the horizontal
- Number of collector panels - Seventeen
- Array configuration - One row of seventeen collectors
- Collector enclosure
  - Material - Extruded aluminum frame, with 7/8 inch insulation on sides and back, single glass cover plate, and a corrugated collector plate
  - Gross area - 432 square feet
  - Net aperature area - 378 square feet
  - Net absorber area - 396 square feet
  - Weight
    - Empty panel - 60 pounds
    - Full panel - 60 pounds
    - Filled array and support structure - 1,080 pounds
  - Panel length - 146.8 inches
  - Panel width - 25.1 inches
  - Frame depth - 3.3 inches
  - Standoff height - 3 inches
  - Shading - 1% of aperature area, (max.)
- Cover Plates
  - Number of cover plates - One
  - Manufacturer - ASG Industries
  - Product Name/Number - Low Iron, Tempered Glass
  - Material - Low iron tempered glass
  - Thickness - 0.125 inches

- o Optical properties (solar region) (infrared region)
  - Transmittance 89% 89%
  - Reflectance 8% 8%
  - Emittance 93% 93%
- o Edge or surface treatment - Polished, mechanical
- o Coating on cover plate material - None

o Absorber

- o Manufacturer - Solar Energy Products co.
- o Model Name/Number - Corrugated Aluminum Plate
- o Material - Aluminum
  - Thickness - 0.018 inches
  - Length - 143.125 inches
  - Width - 22.175 inches
- o Coating
  - Manufacturer - Sherwin Williams Paint
  - Model Name/Number - Dull black #F65B50
  - Material - Flat black alkyd enamel paint
- o Coating properties (solar region) (infrared region)
  - Absorptance 96% 88%
  - Reflectance 4% 12%
  - Emittance
  - Method of application - Baked on
- o Heat transfer fluid passages
  - Location - Beneath absorber
  - Pattern - Parallel
  - Material - Aluminum and insulation

- Internal diameter - 1.5 inches (equivalent)
- Maximum operating temperature - 310° F
- Internal protective coating - Polyisocyanurate

- Insulation
  - Manufacturer - Celotex
  - Product Name/Number - Thermax sheathing TF610
  - Material - Isocyanurate
  - Thermal resistance - R-8
  - Location - 7/8 inch thickness on the sides and back of the collector
- Sealant
  - Manufacturer - General Electric (GE)
  - Product Name/Number - Silicone, 1200 series
  - Location - Inner cover, outer cover, frame joint, backing plate and penetrations
- Frame
  - Manufacturer - Norandex Corp.
  - Product Name/Number - Extrusion
  - Material - Aluminum, T5-6063
  - Protective coating - Anodized/painted
  - Standoff used - Yes
  - Number of structural attach points - 4
  - Built-in collector
    - Frame is not part of the load supporting structure
- Other information
  - Reflectors in collector assembly - None
  - Dessicant used - None
  - Freeze protection - None, air system

- Overheat protection -Air cooling

Collector performance

- Method of evaluation - ASHRAE $(t_i-t_a)/I_t$
- y intercept -.82° F hr ft^2/Btu
- Slope - 1.44

Point number	1	2	3	4
n = collector thermal efficiency (%) -	78	73.2	55.3	34.8
t_i = collector inlet temperature (°F) -	90	107	137	185
t_a = abmient air temperature (°F) -	79	81	86	84
I_t = insolation intensity (Btu/hr ft^2) -	252	390	278	292
ASHRAE $(t_i-t_a)/I_t$ -	0.04	0.09	0.18	0.35

- Test flow rate - 120 cfm
- U_L (total heat loss coefficient) - 1.5 Btu/hr ft^2 °F
- Test wind speed - 4 mph
- Test collector area
  - Gross - 24.0 square feet
  - Net - 21.0 square feet
- Thermal response time constant - 4.5 minutes
- Incidence angle modifier
  - 45° - 0.94
  - 60° - 0.85
  - 75° - 0.57
- Fluid specific heat - 0.24 Btu/lb °F
- Test fluid medium - Air, 100%

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

- Design maximum operating conditions
  - Temperature - 170° F

- Pressure - 1.1 inches of water
- Flow rate -Maximum 1500 cfm
- Blower speed
  - Maximum - 2750 rpm
  - Minimum - 2650 rpm
- Ducting
  - Location - Above grade, inside building
  - Exterior finish - None
  - Type - Galvanized steel
  - Joint type - Clamped
  - Internal insulation
    - Type - Glass fiber
    - Thermal resistance - R-17
  - Internal finish - None
  - Maximum rated operating conditions
    - Temperatuer - 170° F
    - Pressure - 1.1 inches of water
- Loop description - Collector-to-storage (Col-1 to TSU-1)
- Blower (BL-1)
  - Model Name/Number - LAU DD 9-7A
  - Fan type - Squirrel cage
  - Motor size - .5 hp; 120 volts; 1 phase; 60 Hz
  - Maximum motor speed - 2750 rpm
  - Drive - Direct
  - Blower speed - Single

- Impeller speed - 2750 rpm
- Circulation volume - 1500 cfm
- Motor size - .5 bhp

- Damper (D-1)
  - Function - Flow switching
  - Type - Multi louver
  - Operation - Automatic, motorized
  - Blade edges - Neoprene
  - Blade/frame contact - Neoprene

Control Mode Selector (CMS-1)

- Manufacturer - Dan Mar Company Inc.
- Model Name/Number - TC-10-5-150
- Modes controlled - Collector-to-storage
  - ON - (SN-01) greater than (SN-02) + 17° F
  - OFF - (SN-02) greater than 150° F
- Sensor (SN-01) and (SN-02)
  - Manufacturer - Dan Mar Company
  - Product Name/Number - TC-10-17-150
  - Type - Temperature, resistance thermometer

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

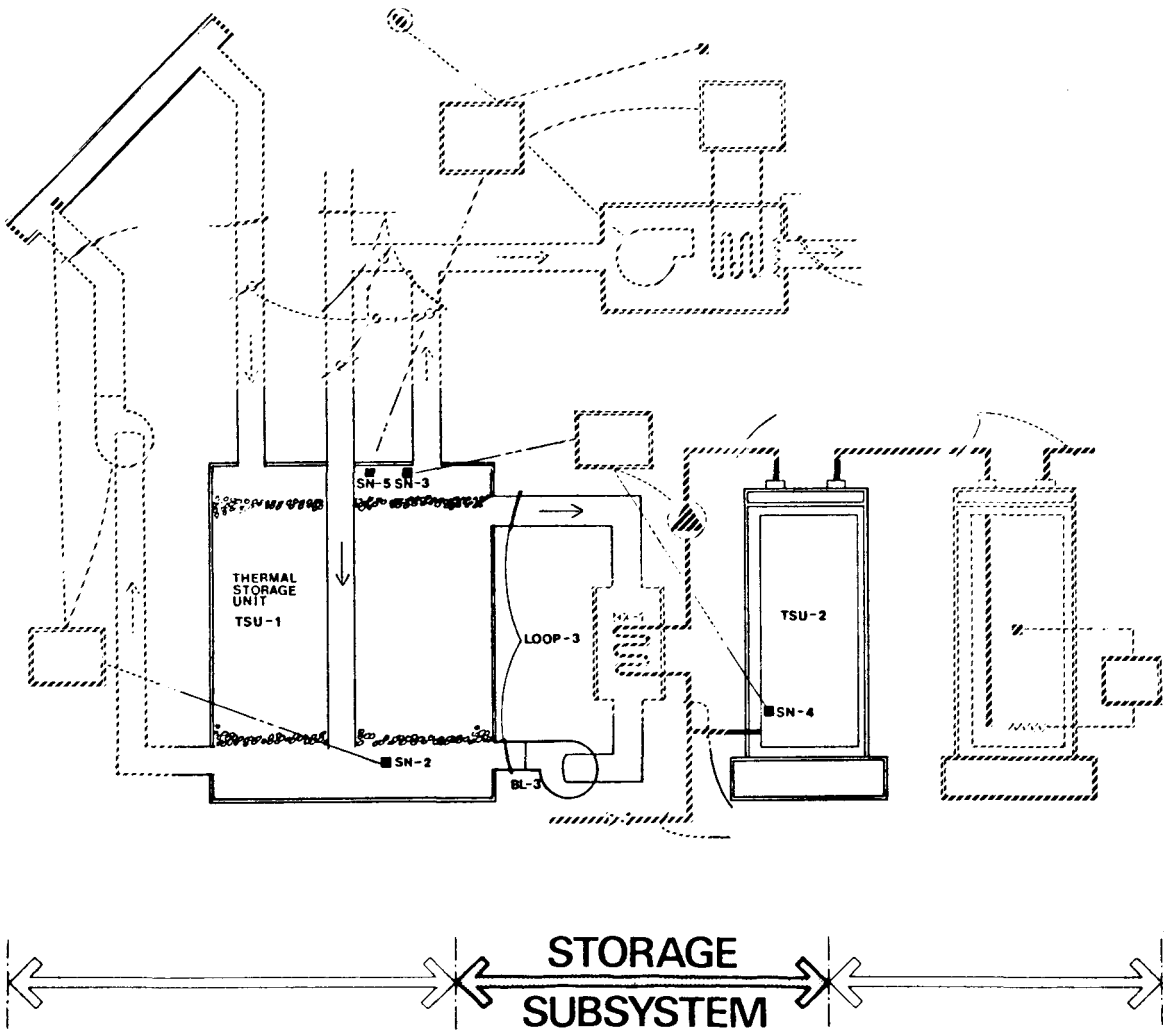


Figure IV-C-1. Storage Subsystem

Solar energy from the collector array is transfered and stored in a bin containing approximately 38,000 pounds of crushed rock, using air as the transfer medium. The solar heated air, passing through an air-to-liquid heat exchanger, also preheats incoming domestic water which is stored in an 80 gallon preheat storage tank. City water is supplied, on demand, to the preheat storage tank. A 52 gallon domestic hot water tank, supplied by the preheated water storage tank, provides the hot water supply for the house.

Air Thermal Storage Unit (TSU-1)

- Container
  - Manufacturer - Site built
  - Total storage volume - 740 cubic feet
  - Storage size
    - Length - 13.0 feet
    - Width - 11.3 feet
    - Height - 5.0 feet
  - Volume to storage medium - 400 cubic feet
  - Design operating temperature - 170° F
- Storage medium
  - Design operating temperatures
    - Maximum - 170° F
    - Minimum - 70° F
  - Material - Crushed rock
  - Weight per cubic foot - 95 pounds
  - Total weight of storage medium - 40,000 pounds
  - Rock size - 1.0 to 1.5 inches
  - Specific heat of solid material - .24 Btu/lb °F
  - Heat capacity of packed material - 22.8 Btu/ft^3 °F
  - Heat exchanger in container - None
- Design pressure drop inlet/outlet - 5 inches of water
- Container construction
  - Top
    - Area - 143 square feet
    - Exterior finish - 2 x 10 and plywood deck, asphalt and one inch styrofoam R-14

- Thickness - 6 inches
- Thermal resistance - R-30

o Side one
- Area - 66 square feet
- Exterior finish - Concrete and styrofoam
- Thickness - 4 inches
- Thermal resistance - R-20

o Side two
- Area - 78 square feet
- Exterior finish - Concrete, asphalt, and styrofoam
- Thickness - 4 inches
- Thermal resistance - R-20

o Side three
- Area - 66 square feet
- Temperature exposure - Indoors
- Exterior finish - Concrete, asphalt and styrofoam
- Thickness - 4 inches
- Thermal resistance - R-20

o Side four
- Area - 78 square feet
- Temperature exposure - Indoors
- Exterior finish - Concrete, asphalt and styrofoam
- Thickness - 4 inches
- Thermal resistance - R-20

- Bottom
  - Area - 143 square feet
  - Temperature exposure - Ground
  - Exterior finish - 3 inches concrete, asphalt and styrofoam
  - Thickness - 4 inches
  - Thermal resistance - R-20
- Location - In basement with two sides and bottom against the ground
- Filters - None

Liquid Thermal Storage Unit (TSU-2)

- Container
  - Manufacturer - F.E. Meyers
  - Model Name/Number - V-82-G
  - Total storage container volume - 24.45 cubic feet
  - Size
    - Length - 5.0 feet
    - Diameter - 2.5 feet
  - Maximum rated operating conditions
    - Temperature - 170° F
    - Pressure - 60 psi
- Storage medium
  - Design operating temperatures
    - Maximum - 170° F
    - Minimum - 50° F
  - Material - Water, 100%
  - Specific heat - 1.00 Btu/lb °F
  - Density - 62.5 lb/ft^3

- Heat capacity at 70^{o} F - 62.5 Btu/ft^3/ ^{o}F
- Boiling point - 212^{o} F
- Freezing point - 32^{o} F
- Recommended use temperature
  - Maximum - 190^{o} F
  - Minimum - 50^{o} F
- Toxicity - Potable
- pH factor - 7.0
- Inhibitor - None

- Container construction
  - Type - Galvanized steel tank, glass lining
  - Overall thermal resistance - R-17
  - Location - Basement
  - Filters - None
  - Design pressure drop between inlet/outlet
    - Air side - 1 inch of water
    - Liquid side - 2 inches of water

Air Circulation Loop No. 3 (TSU-1 to HX-1)

- Loop design conditions
  - Maximum design operating temperature - 190^{o} F
  - Design air flow - 250 cfm
  - Blower speed - 2750 maximum rpm, 2650 minimum rpm
- Ducting
  - Location - Above grade, inside building
  - Type - Galvanized steel
  - Joint type - Clamped
  - Internal duct insulation - Glass fiber
  - Thermal resistance - R-17

- Blower (BL-3)
  - Maximum motor speed - 2750 rpm
  - Drive - Direct
  - Circulation volume - 250 cfm
- Heat exchanger (HX-1)
  - Type of flow - Cross
  - Heat exchanger design - Fin coil
  - Convection
    - Air side - Forced
    - Liquid side - Forced
  - Maximum rated temperature - 190° F
  - Material types - Combination of metals
  - Design flow quantity
    - Air side - 250 cfm
    - Liquid side - 12 gal/min
  - Circulator
    - Air side - Blower (BL-3)
    - Liquid side - Pump (P-1)

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

- Maximum design operating conditions
  - Temperature - 190° F
  - Pressure - 60 psi
- Heating
  - Design liquid flow
    - Maximum - 12 gal/min
    - Minimum - 10 gal/min

- Design pump speed
  - 1750 rpm, maximum
  - 1700 rpm, minimum
- Heat transfer medium
  - Volume of liquid in loop - 32 gallons
  - Anticipated liquid temperature
    - Maximum - 170° F
    - Minimum - 50° F
  - Provisions for expansion - None
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb/°F
  - Density - 62.5 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Recommended use temperatures
    - Maximum - 190° F
    - Minimum - 50° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Inhibitor - None
- Piping
  - Location - Above grade in basement
  - Exterior finish - Natural copper
  - Insulation - None
  - Rigid - Copper, standard .50 inch
  - Coupling reinforcing - Solder
  - Coupling connection - Standard solder

- Piping connection - Standard solder
- Maximum operating conditions
  - Temperature - 190° F
  - Pressure - 60 psi

- Circulation pump (P-1)
  - Manufacturer - Grundfos
  - Model Name/Number - UP 25-420 F
  - Type - Centrifugal
  - Maximum rated operating conditions
    - Static pressure - 150 psi
    - Dynamic pressure - 5 psi
    - Temperature - 230° F
  - Material exposed to heat transfer fluid
    - Steel, type 316 stainless
  - Motor size - .05 hp, 115 volts, 1 phase, 60 Hz
  - Maximum motor speed - 1725 rpm
  - Drive - Direct
  - Speed - Single
  - Pump speed - 1750 rpm
  - Circulating volume
    - Low head mode - 20 gal/min
    - High head mode - 5 gal/min
  - Operating head (dynamic)
    - Low head mode - 1.3 psi
    - High head mode - 5.2 psi
  - Motor operation - 1.05 bhp

- Distribution Valve (V-1)
  - Function - ON - OFF
  - Operation - Automatic motorized
  - Type - Gate
  - Maximum rated operating conditions
    - Pressure - 150 psi
    - Temperature - 220° F
  - Material - Copper

Control Mode Selector (CMS-3)

- Manufacturer - Dan Mar Company Inc.
- Model Name/Number - TC-10-5-150
- Modes Controlled - Air thermal storage-to-liquid thermal storage (TSU-1 to TSU-2)
  - ON - (SN-03) greater than (SN-04) + 17° F
  - OFF - (SN-04) greater than 135° F
- Sensors (SN-03) and (SN-04)
  - Manufacturer - Dan Mar Company Inc.
  - Product Name/Number - TC-10-17-5-150
  - Type - Temperature, resistance thermometer

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

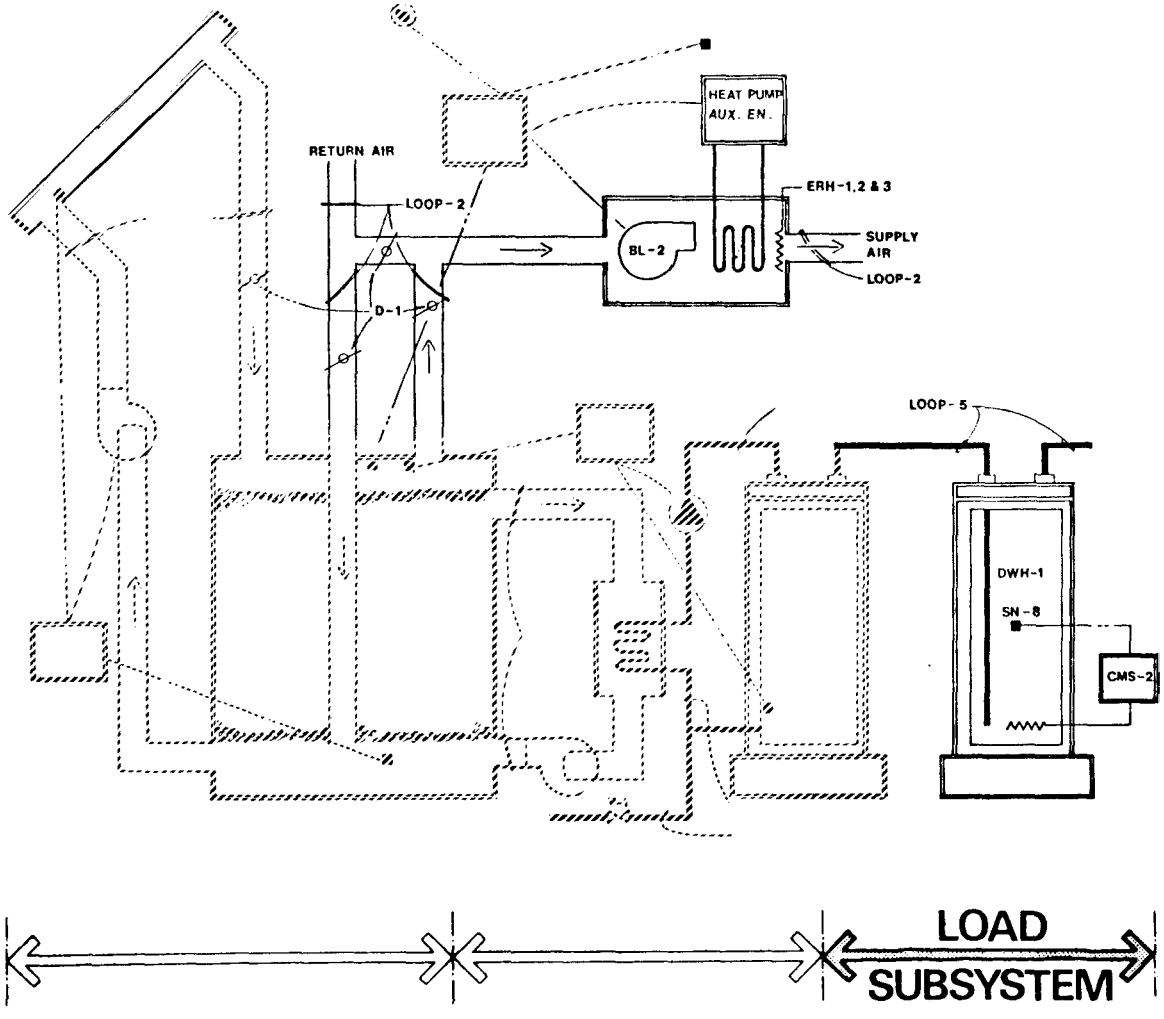


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy stored in the 740 cubic foot storage tank filled with approximately 38,000 lbs of crushed rock is used to meet the space heating demands by circulating it through the air distribution system. Auxiliary space heating, supplementing this source, is provided by electrical elements in the 82 gallon storage tank. Space cooling is provided by an air circulating loop using air from collectors and/or thermal storage unit, including electric heating elements in a furnace/blower/heat pump combination system.

Air Circulation Loop No. 2 (TSU-1 to Space Heating)

- Maximum design operating conditions
  - Temperature - 190° F
  - Pressure - 1.1 inches of water
- Design flow rate
  - Air flow
    - 1000 cfm, maximum
    - 720 cfm, minimum
  - Blower speed
    - 2750 rpm, maximum
    - 2650 rpm, minimum
- Ducting
  - Location - Above grade, inside building
  - Type - Steel, galvanized
  - Ducting joints - Clamped
  - Internal insulation - Glass fiber
  - Thermal resistance value - R-17
  - Rated operating condition
    - Temperature, 170° F, maximum
    - Pressure, 1.1 inches of water, maximum
- Damper (D-1)
  - Function - Flow switching
  - Type - Multi-louver
  - Operation - Automatic, motorized
  - Blade edges - Neoprene
  - Blade/frame contact - Neoprene

- Blower (BL-2)
  - Manufacturer - General Electric
  - Model Name/Number - Weathertron
  - Motor size - 0.33 hp; 120 volts; 1 phase; 60 Hz
  - Circulating volume
    - Low static mode - 750 cfm
    - High static mode - 720 cfm

Control Mode Selector (CMS-4)

- Modes controlled
  - Air thermal storage-to-Space
    - ON - (SN-05) greater than 80^{o} F
  - Storage-to-Auxiliary-to-Space

    ON - (SN-05) less than 80^{o} F and
    (SN-06) greater than 26^{o} F
  - First stage auxiliary heat (5.76 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) less than 26^{o} F and
      greater than 5^{o} F
  - Second stage auxiliary heat (9.56 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) greater than -10^{o} F
      and less than 5^{o} F
  - Third stage auxiliary heat (15.3 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) less than -10^{o} F
- Sensors (SN-05), (SN-06) and (SN-07)
  - Manufacturer - Dan Mar Company Inc.
  - Product Name/Number - TC-10-17-5-150
  - Type - Temperature, resistance thermometer

Liquid Circulation Loop No. 5 (TSU-2 to DWH-1 to Load)

- Flow rate
  - Heating design flow - Hot water demand
- Heat transfer medium
  - Volume of liquid in loop approximately 53 gallons
  - Anticipated liquid temperatures
    - Maximum - 170° F
    - Minimum - 50° F
  - Medium - 100% water
- Chemical feeder - None
- Inhibitor - None
- Piping
  - Type - Rigid
  - Material - Cooper
  - Insulation - None
  - Location - Above grade, inside building
  - Coupling - Solder
  - Maximum operating condition
    - Temperature, 190° F
    - Pressure, 60 psi

E. Auxiliary Energy Subsystem

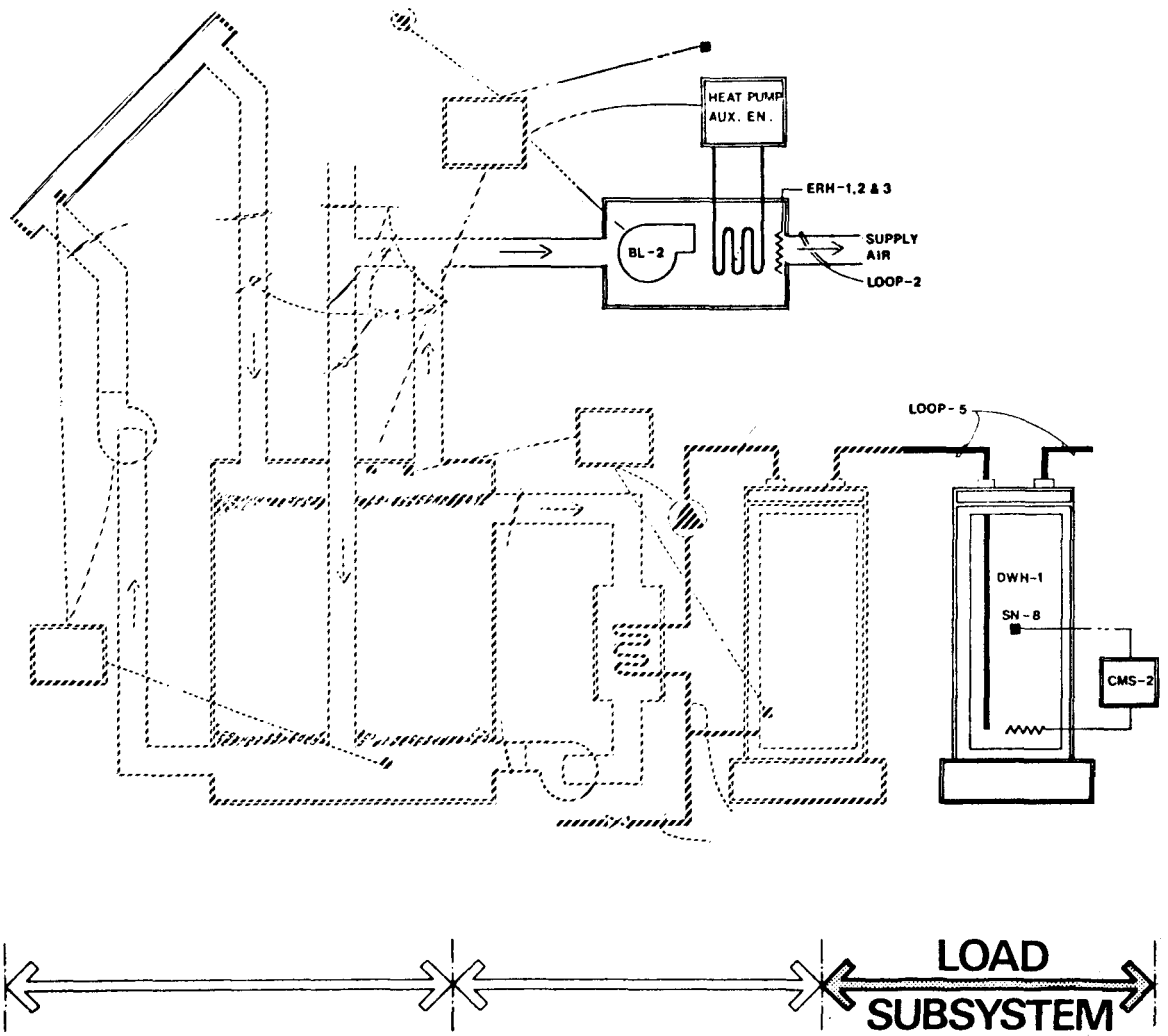


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystems, domestic hot water, tank, furnace/blower/heat pump combination 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.

Furnace (FURN-1)

- Manufacturer - General Electric
- Model Name/Number - Weathertron heat pump
- Energy source - Electric, 240 volts, 1 phase, 60 Hz
- Energy output - 47,800 Btu/hr
- Energy input - 47,800 Btu/hr

Control Mode Selector (CMS-4)

- Modes controlled
  - Air thermal storage-to-Space
    - ON - (SN-05) greater than 80^{o} F
  - Storage-to-Auxiliary-to-Space

    ON - (SN-05) less than 80^{o} F and
    (SN-06) greater than 26^{o} F
  - First stage auxiliary heat (5.76 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) less than 26^{o} F and
      greater than 5^{o} F
  - Second stage auxiliary heat (9.56 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) greater than -10^{o} F
      and less than 5^{o} F
  - Third stage auxiliary heat (15.3 kw)
    - ON - (SN-05) less than 80^{o} F and
      (SN-06) less than -10^{o} F
- Sensors (SN-05), (SN-06) and (SN-07)
  - Manufacturer - Dan Mar Company Inc.
  - Product Name/Number - TC-10-17-5-150
  - Type - Temperature, resistance thermometer

Domestic Hot Water Heater (DHW-1)

- Manufacturer - Rheem Glas
- Energy source - Electric, 240 volts, 1 phase, 60 Hz
- Tank volume - 52 gallons
- Water volume - 52 gallons
- Energy input - 15,345 Btu/hr
- Energy output - 15,345 Btu/hr
- Maximum pressure - 150 psi
- Maximum temperature - 200° F
- Heating stages - Single
- Maximum recovery rate - 30 gallons per hour
- Yearly average cold water inlet temperature - 53° F
- Design Water output temperature - 120° F
- Corrosion protection anodes - Magnesium

Control Mode Selector (CMS-2)

- Manufacturer - Dan Mar Company, Inc.
- Model Name/Number - TC-10-5-150
- Modes controlled
  - Auxiliary heat-to-domestic hot water
    - ON - (SN-08) less than 120° F
- Sensors (SN-08)
  - Type - Thermostat

F. Modes of Operation

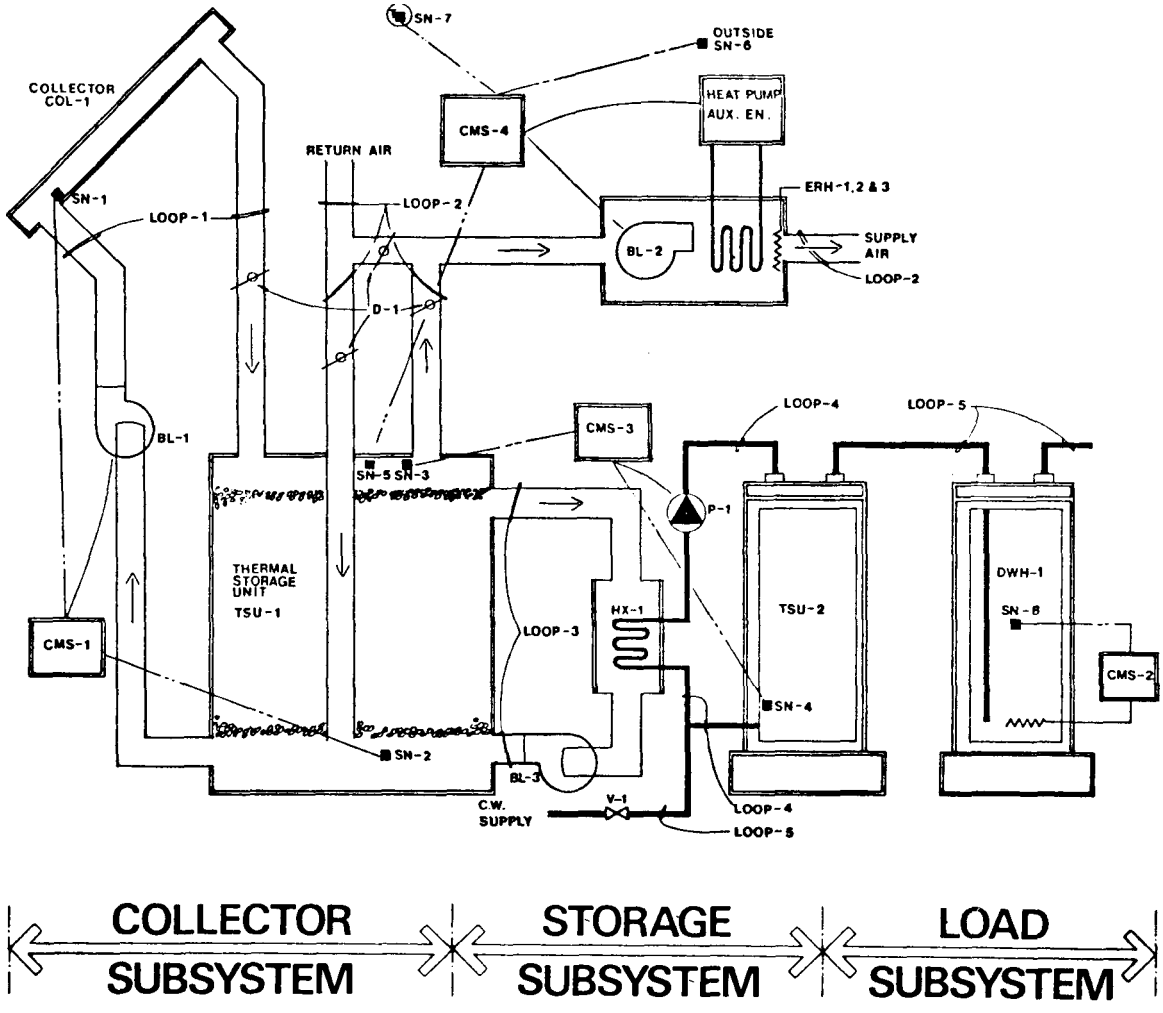


Figure IV-F-1. Controls Diagram

The Alpha Construction Company's solar system is shown on figure IV-F-1. The system consists of four basic subsystems, namely Collector Subsystem, Storage Subsystem, Energy to Load, and finally Auxiliary Subsystems.

The system is designed to provide 50 percent of the space heating and 70 percent of the hot water energy requirements for the home. The Collector subsystem utilizes a blower for the transfer of energy to the storage, utilizing air as the

transfer medium. The stored energy, passing through a heat exchanger also preheats the incoming city water using a liquid storage tank as the preheated storage.

When solar energy is insufficient, a liquid-to-air heat exchanger within a 2.5 ton heat pump and a three stage electric heater in the air handling unit provide auxiliary energy for space heating.

Also, part of the Auxiliary subsystem, is an electric heating element in the DHW tank which provides the supplementary energy for the domestic hot water.

Operation of the solar system in conjunction with the auxiliary subsystems may involve one or more of the six modes of operations described below.

Mode 1 - Collector to Space Heating

This mode exists when the collector is operating, and the plenum temperature at the top of storage is greater than a minimum value suitable for heating the house. The plenum temperature is defined as the temperature in the air space above the rocks inside the storage chamber. Heated air is circulated through the house by the air handling unit before being returned to the collector. During this mode the following conditions are met: a) The collector blower operating, b) the temperature at the top of the rock storage is greater than 80^{o} F, c) the house thermostat is calling for heat, d) dampers D1 and D2 are open, and e) damper D3 is closed and the condition results in flow from collector to the house.

Mode 2 - Collector to Storage

This mode exists when the collector is operating and either there is no demand for space heating or the plenum temperature at the top of storage is below a minimum value suitable for heating the house. If the conditions are satisfied for the collector blower to turn on, and either the house thermostat is not calling for heat or the temperature at the top of the rock storage box is less than 80^{o} F required for space heating, then dampers D1 and D2 will close, resulting in flow circulating through collector and storage tank.

Mode 3 - Storage to Space Heating

This mode exists when there is a demand for space heating, the collectors are not operating, and the plenum temperature at the top of storage is above a minimum value suitable for heating the house. The fan in the air handling unit draws air from the storage and circulates it through the house and back to the storage system. Conditions at this mode are: a) Collector blower not operating, b) the temperature at the top of rock storage is greater than 80^{o} F, c) the house thermostat is calling for heat, d) dampers D1 and D2 are open, e) damper D3 is closed and finally f) flow is from the storage to house.

Mode 4 - Auxiliary Heat to Space Heating

If the house thermostat is calling for heat, and the temperature at the top of the rock storage is less than 80^{o} F, the heat pump will turn on. Dampers D1 and D2 will close, damper D3 will open, resulting in flow circulating from the air handler to the house, bypassing the rock storage box. If the outside ambient temperature falls below 26^{o} F, the first stage of electrical resistance heaters will operate along with the heat pump. If the outside ambient temperature falls below 5^{o} F, the second stage of electrical heaters will turn on in addition to the first stage. When the outside ambient temperature falls below -10^{o} F, all three stages of electrical heaters will operate in addition to the heat pump.

Mode 5 - Domestic Water Preheat

This mode exists when the temperature of the preheat water tank is less than 135 degrees and the temperature in the hot air plenum of storage is at least 17^{o} F greater than the temperature of the preheat tank. At this condition, the hot water loop blower and the circulating pump of the preheat tank will turn on.

Mode 6 - Auxiliary Heat to Domestic Hot Water

This mode exists when the temperature of the domestic hot water tank is below 120 degrees.

Mode 7 - Air-Conditioning

When the air conditioning unit is activated by means of its control setting, the dampers D1 and D2 will close, damper D3 open and conditioned air flows through the heat pump and circulates through the house.

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 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.

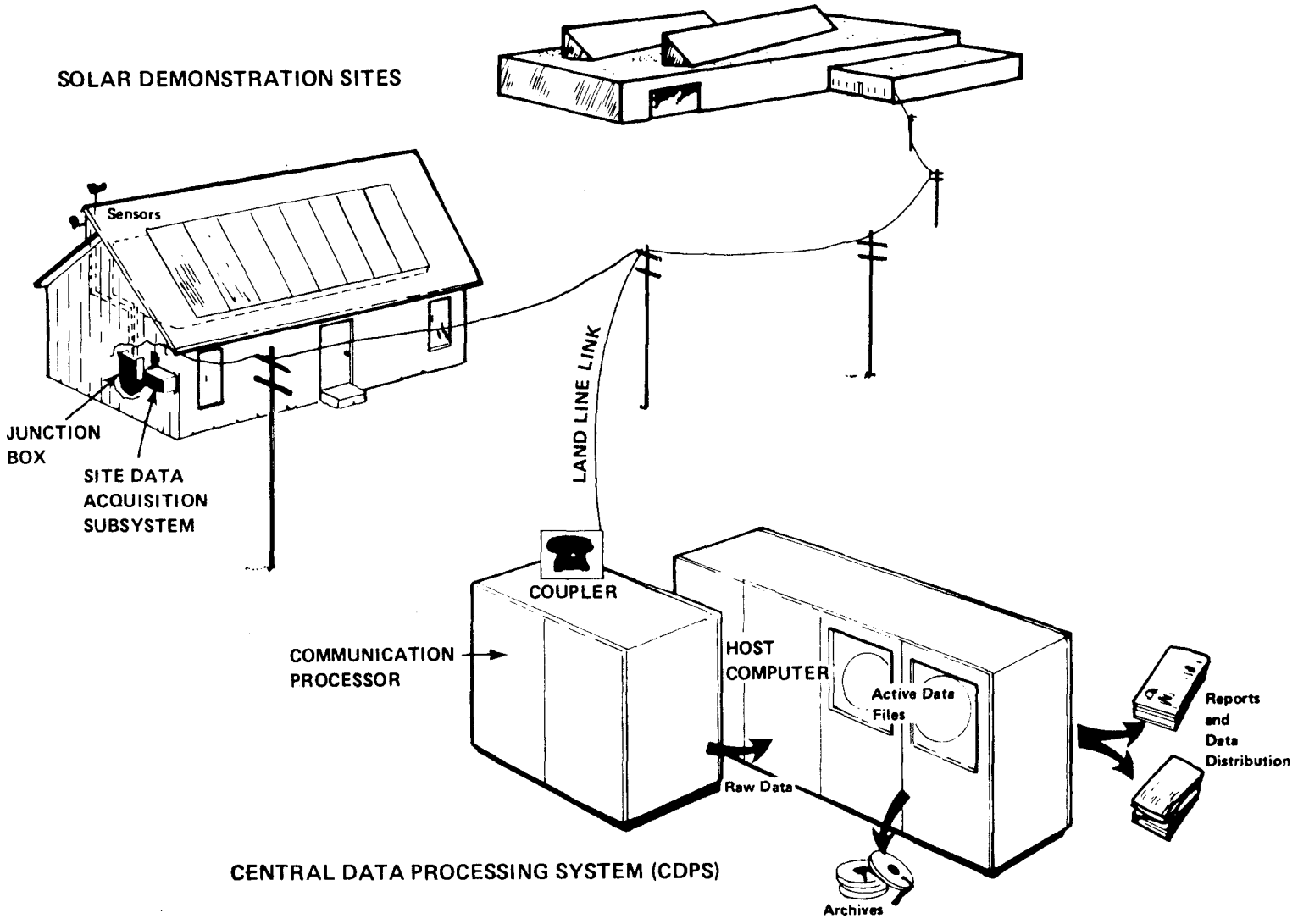


Figure V-A-1. The National Solar Data Network

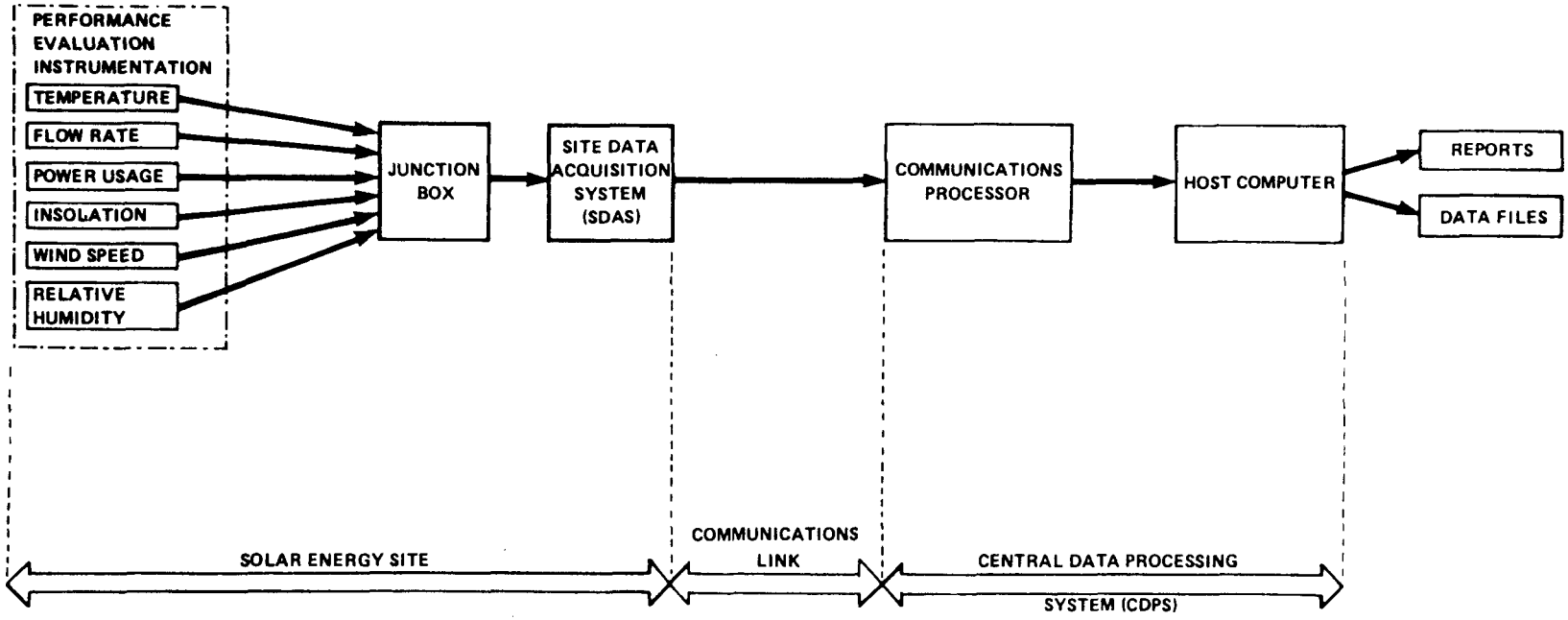


Figure V-A-2. Data Flow Path for the National Solar Data Network

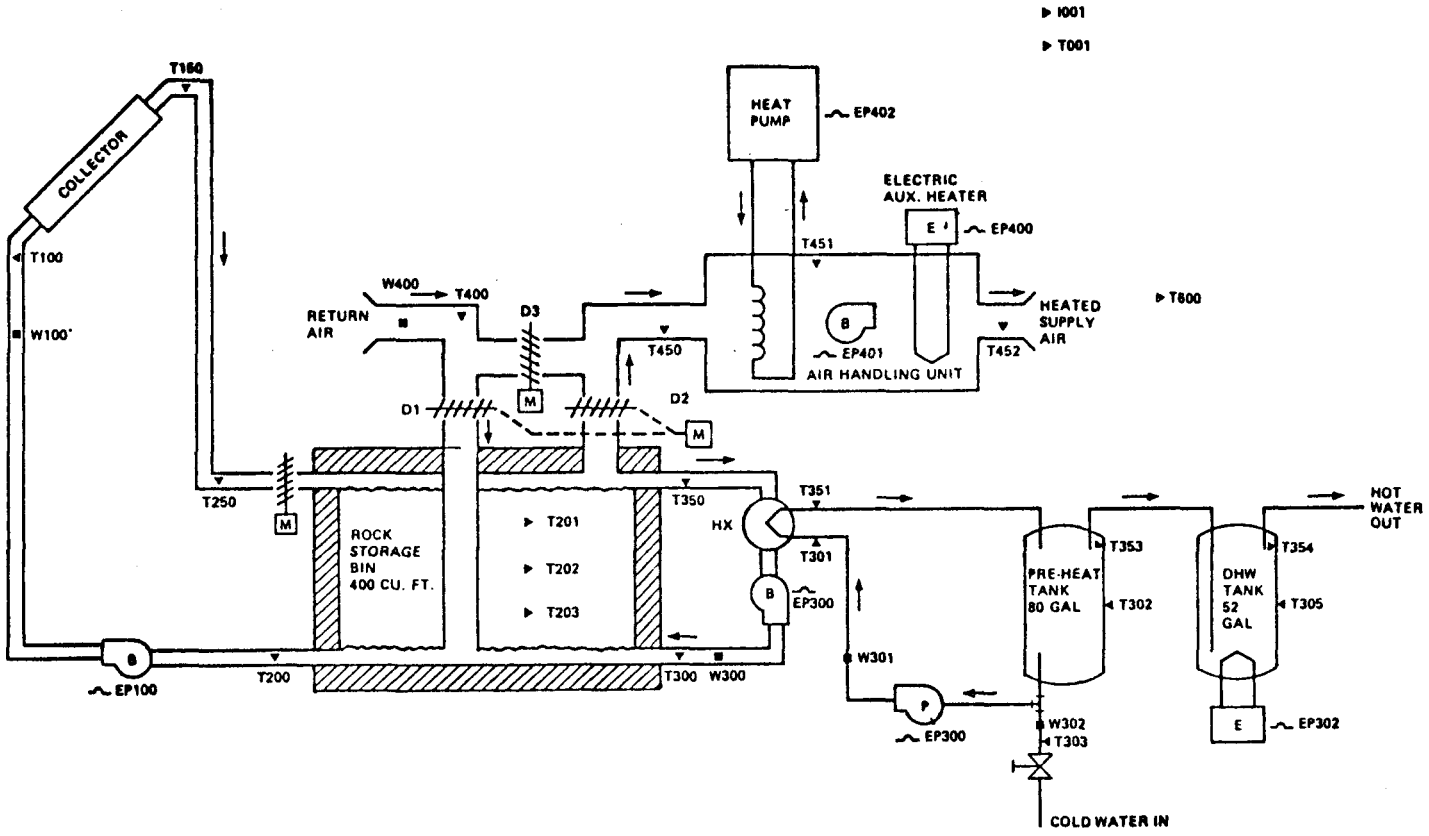


Figure V-B-1. Sensor Locations

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

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

B. On-Site Instrumentation

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

VI. COST DATA

A. General

The following cost data depicts only solar energy portion of the construction. Cost 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
Lot	# 127	# 116	# 120	# 112	
Collectors	4,397	3,737	3,737	5,276	
Storage Energy	880	860	860	1,000	
Distribution & Controls	3,655	3,545	3,545	3,905	
Installation	(Included in above items)				
Sub Total	8,932	8,142	8,142	10,181	$35,397
Additional Cost to complete-approximately 10% (based on Site Interview)					3,540
Total (Final Estimated Cost)					$38,937

C. Construction Period: June 77 through October 77

- Estimated Cost of Instrumented Houses (Lot 116)

Solar equipment	$ 6,560
Install air duct system	1,796
Install hot water converter	404
Install solar panes/storage bin	860
Install insulation on ducts & bin	340
Instrument design and administration	1,200
Instrument install	2,143
TOTAL	$11,445

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