SOLAR/1055-81/50
(DE81026597)

Solar Project Description

LOYOLA UNIVERSITY—BIEVER HALL MEN'S DORMITORY

New Orleans, Louisiana

July 10, 1981

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

SOLAR/1055-81/50
(DE81026597)
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
LOYOLA UNIVERSITY - BIEVER HALL
MEN'S DORMITORY - NEW ORLEANS, LOUISIANA

Department of Housing and Urban Development

Under Contract Number

H-2372

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Solar Heating and Cooling Demonstration Program Manager

By

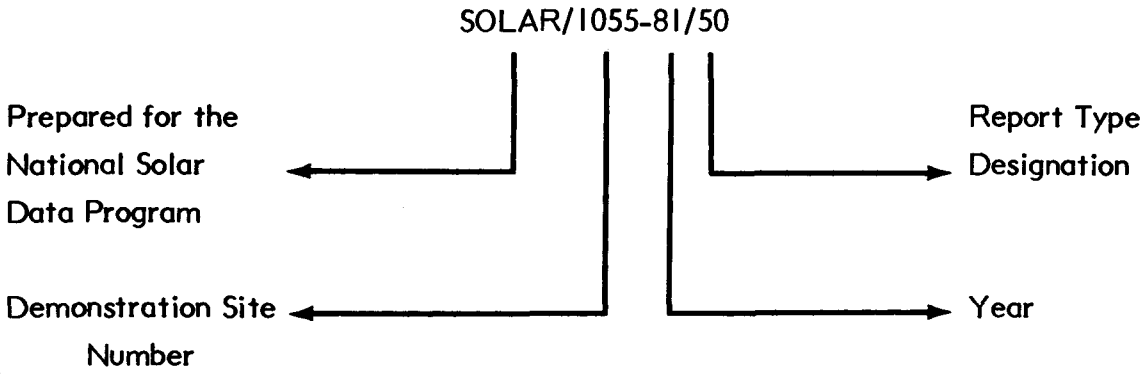
The Boeing Company
David Beers, Program Manager

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 Loyola University's project site is designated as SOLAR/1055-81/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type -- Liquid flat plate
- o Freeze Protection -- Circulation of hot storage fluid
- o Application -- Domestic hot water
- o Storage -- 5,000 gallon tank
- o New or Retrofit -- Retrofit
- o Performance Evaluation Instrumentation -- Yes
- o Site-Specific Features -- None

The Loyola University solar energy system (Grant H-8395), located in New Orleans, Louisiana, supplies energy necessary to preheat approximately 9,000 gallons of domestic hot water (DHW) each day to Biever Hall Dormitory. Biever Hall is a six-story dormitory that houses 420 students. The system is designed to supply 140° F water to bathrooms, showers, and eight washing machines.

The solar energy system was added to the existing water heating system and has 15 arrays of flat-plate collectors with a gross area of 4,590 square feet, and a net area of 4,320 square feet. The collectors face 16 degrees west of south at an angle of 38° to the horizontal. The system is an open loop system which uses potable water as both the collector fluid and storage medium. City water is preheated by flat plate collectors on the roof and stored in a 5,000 gallon tank located on the west side of the building at ground level. Upon demand the preheated water is transported to two existing 1,500 gallon hot water tanks.

When solar energy is insufficient to satisfy the hot water load, auxiliary energy is supplied by a central heating plant via a high temperature/high pressure line. The system has five modes of operation.

The dwelling has been fully instrumented for performance evqluation since September 1979 and the data is integrated into the National Solar Data Network.

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

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

The Loyola University's solar energy system supplies the necessary energy to preheat approximately 9,000 gallons of DHW each day.

- Building type - College dormitory
- Latitude - 30°
- Longitude - 90°
- Altitude - 2 ft below sea level

HEATING DESIGN REQUIREMENTS

- To supply 140° F water to bathrooms, showers and eight washing machines in a 6-story dormitory.

BUILDING

- Building faces - East
- Average stories above ground - 6
- Average stories below ground - 0
- Height above grade - 70 ft
- Roof type - Flat

DESIGN HEAT LOSS/LOAD

- Heat Loss - N/A
- Heat gain - N/A
- Shading
  - Heating season - 10%
  - Cooling season - 0

UNAVAILABLE

Figure III-1. Site Plan

- Appliance, lighting and equipment load - N/A
- Domestic hot water daily requirements - 20 gal/day/person
- Average horizontal insolation
  - January - 874 Btu/ft^2/day
  - July - 1852 Btu/ft^2/day
- Annual degree days
  - Heating - 1385
  - Data location - New Orleans, Louisiana
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration

DOMESTIC HOT WATER

- Daily water demand - 9,000 gal
- Solar - Liquid flat plate collectors
- Auxiliary - Central heating plant

GENERAL DATA

- Collector manufacturer - General Energy Devices
- Model name/number - GED Solatron Collectors 24-series
- Type of system - Liquid flat plate

SYSTEM AND COMPONENT SUMMARY

- Collector types - 1
- Circulation loops - 3
- Thermal storage units - 3
- Operational modes - 5
- Pumps - 4
- Valves - 4 types
- Sensors - 4 types (total of 14)
- Flow regulators - 16

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This residential solar demonstration project (Loyola University Grant H-8395) located at New Orleans, Louisiana is a liquid flat plate system utilized for hot water. Auxiliary heat is provided by hot water from a central heating plant.

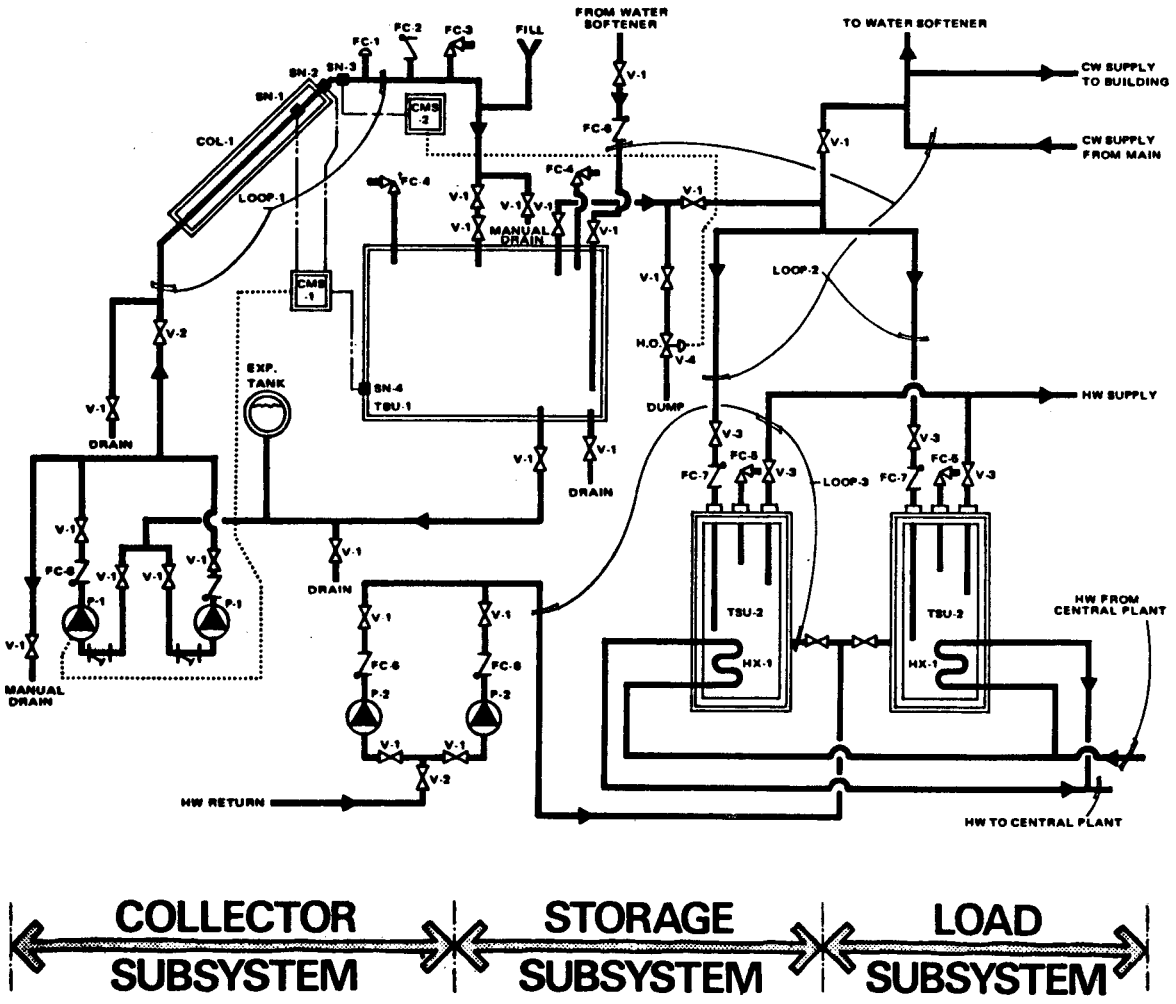


Figure IV-A-1. General Overview

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

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

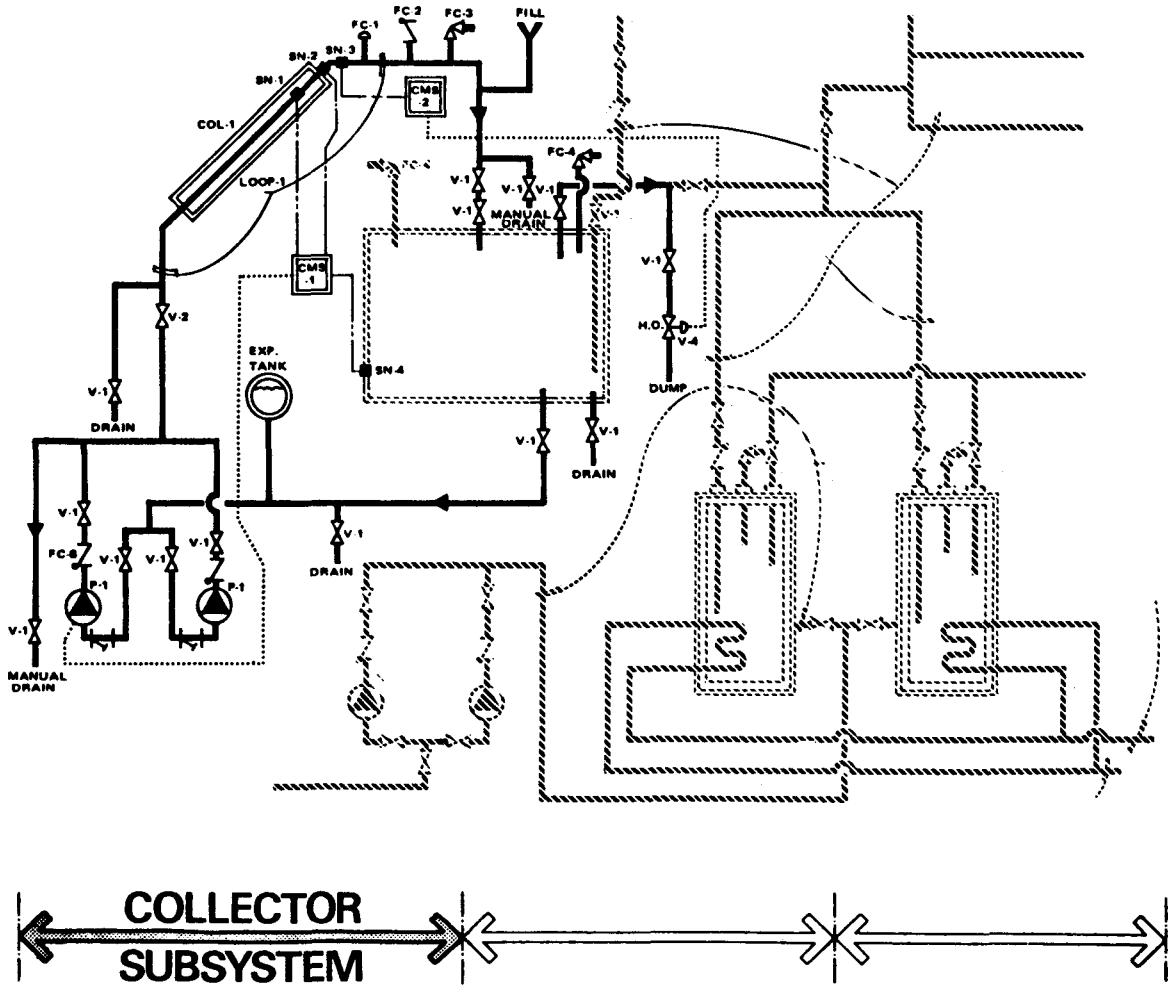
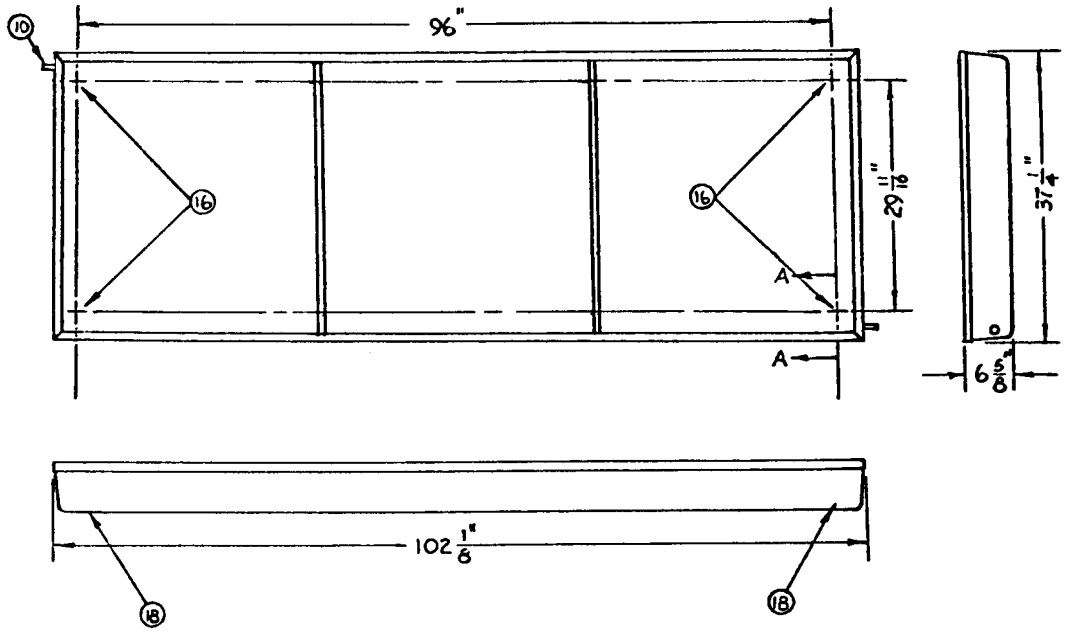


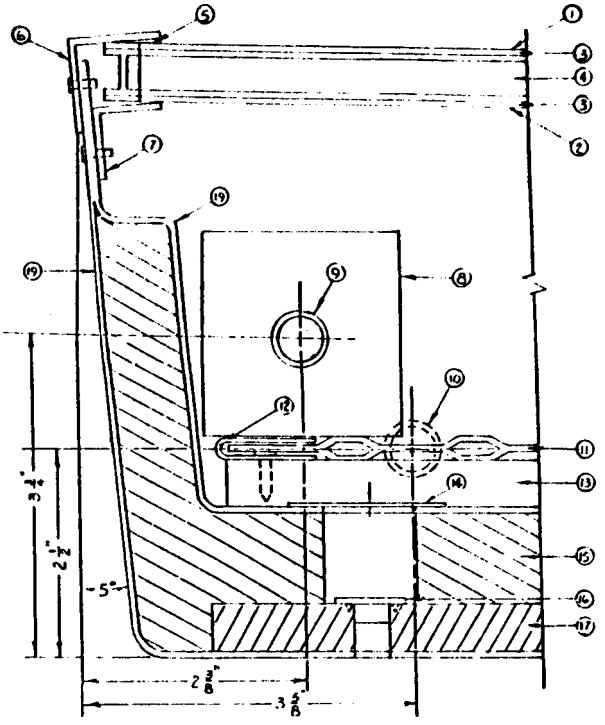
Figure IV-B-1. Collector Subsystem

Collector array system consists of 15 arrays (12 panels per array) of flat plate collector panels. Freeze protection is provided by circulation of hot storage fluid.

COLLECTOR (COL-1) (See figure IV-B-2)

- Manufacturer - General Energy Devices
- Model name/number - GED Solatron #2400-C
- Type - Liquid flat plate tube and plate
- Location - Roof
- Orientation - 16° West of South
- Tilt angle - 38° from horizontal
- Collector characteristics
  - Number of panels - 12 per array (15 arrays or 180 panels)
  - Total gross area of each array - 306 ft^2
  - Net aperture area - 291 ft^2 per array
  - Net absorber area - 280 ft^2 per array
  - Weight per panel, empty - 88 lbs
  - Weight per panel, full - Unknown
  - Weight of support structure - 54,000 lb
  - Panel length - 103.6 in.
  - Panel width - 38.6 in.
  - Frame depth - 5.0 in
  - Standoff height - 67 in
- Built-in collector - No
- Collector shading
  - Area shaded in June - 0%
  - Area shaded in December - 10%
  - Maximum shade during functional season - 10%





SECTION AA

1. OUTER GLAZING - 0.025" FIBERGLASS RE-ENFORCED POLYESTER
2. INNER GLAZING - 0.001" TEFLON FEP - (MODELS 24-41DC, 24-00DC, 24-41D AND 24-00D ONLY)
3. DOUBLE-SIDED URETHANE ADHESIVE TAPE
4. 3/8" x ½" 6063-T5 ALUMINUM "I" BEAM
5. SINGLE-SIDED URETHANE ADHESIVE TAPE
6. 1" x1" x 1/16" 6063-T5 ALUMINUM ANGLE
7. 3/4" x 3/4" x 1/16" 6063-T5 ALUMINUM ANGLE
8. 8' PREHEATER (ALUMINUM FINS ON ½" NOMINAL COPPER TUBE - 2 PER COLLECTOR)
9. INLET PIPE LOCATION (MODELS 24-41DC, 24-41D AND 24-41C)
10. OUTLET PIPE LOCATION (ALL MODELS) INLET PIPE LOCATION (MODELS 24-00DC, 24-00D, 24-00C AND 24-00)
11. COPPER ROLL-BOND ABSORBER PLATE (MODELS 24-41C, 24-00C, 24-41DC AND 24-00DC) ALUMINUM ROLL-BOND ABSORBER PLATE (MODELS 24-00, 24-41D AND 24-00D)
12. ABSORBER PLATE RETAINER CLIP
13. PLYWOOD SPACER - FIBERGLASSED TO CASE (FOUR PER CASE)
14. FIBERGLASS TEE-NUT HOLE COVER (FOUR PER CASE)
15. URETHANE INSULATION - 1½" IN BOTTOM; 3/4" IN SIDES
16. 5/16" STAINLESS STEEL TEE-NUT FOR MOUNTING (FOUR PER CASE)
17. 6" x 6" x ½" PLYWOOD BLOCKS FIBERGLASSED IN PLACE (ONE IN EACH CORNER)
18. 3/8" DRAIN HOLE - SCREENED
19. 1/16" FIBERGLASS WITH WHITE GELCOAT FINISH

Figure IV-B-2. Solar Collector

- Cover plates
  - Number of cover plates - 1
- Cover plate No. 1
  - Location - Outer layer
  - Material - Fiberglas
  - Thickness - 0.025 in.
  - Optical properties

	(solar region)	(infrared region)
- Transmittance -	NO	
- Reflectance -	INFORMATION	
- Emittance -	AVAILABLE	

  - Edge or surface treatment, other than coating - None
- Absorber
  - Manufacturer - Olin
  - Model name/number - F9171
  - Material - Copper
  - Substrate material dimension
    - Thickness - Unknown
    - Length - Unknown
    - Width - Unknown
  - Number of absorbers per collector - 1
- Coating
  - Manufacturer - Huson
  - Model name/number - 2-306
  - Coating material - Unknown

	(solar region)	(infrared region)
o Absorptance -	96%	
o Reflectance -		
o Emittance -	91%	

- Insulation
  - Layer one - sides
    - Manufacturer - Unknown
    - Product name/number - Unknown
    - Material - Urethane
    - Thermal resistance - Unknown
  - Layer one - back
    - Manufacturer - Unknown
    - Product name/number - Unknown
    - Material - Urethane
    - Thermal resistance - Unknown
- Gaskets and sealants
  - Cover - Urethane adhesive tape
- Frame
  - Manufacturer - General Energy Devices
  - Product name/number - Series 24
  - Material - Fiberglas
  - Protective coating - White gelcoat finish
  - Standoffs used - Yes
  - Number of structure attach points per module, collector to structural frame - 4
- Reflectors - None
- Desiccant - None
- Freeze protection - Circulate hot storage fluid or city water in case of power loss.
- Overheating protection - Circulate city water through collectors

- Collector performance
  - Method of evaluation - ASHRAE 93-77
  - y intercept $F_R(\tau\alpha)_\eta = 0.626$
  - Slope - $F_R U_L = -1.18$

Point Number	1	2	3	4
η = collector thermal efficiency (η %) -	0.358	.461	.581	.618
t_i or t_f = collector inlet temperature (^{o} F) -	158	133	95	77
t_a = ambient air temperature (^{o} F) -	73	77	84	77
I_t = insolation intensity Btu/hr ft^2 -	331	337	334	272
ASHRAE $(t_i-t_a)/I_t$ -	0.258	.167	.054	.002

WHERE

- η = collector thermal efficiency
- U_L = collector heat loss factor
- F_R = collector heat removal factor
- t_a = ambient air temperature, ^{o} F
- $(\tau\alpha)$ = Transmissivity-absorptivity product at normal incidence
- t_i = collector inlet temperature, ^{o} F
- t_f = average fluid temperature, ^{o} F
- I_t = radiation (insolation) intensity on collector, Btu/hr/ft^2
  - Test flow rate - 400 lb/hr
  - Heat loss coefficient - 1.018 Btu/hr x ft^2 x ^{o} F
  - Test wind speed - 11 mph average
  - Test collector area - 28.71 ft^2
  - Fluid specific heat - 1 Btu/lb x ^{o} F
  - Test fluid medium - Water

LIQUID CIRCULATION LOOP NO. 1 (COLLECTOR TO STORAGE)

- Maximum design operating temperature - 140° F
- Maximum design operating pressure - 90 psi
- Heating design liquid flow -
  - Maximum - 132 gpm
  - Minimum - 118 gpm
  - Average actual - 122 gpm
- Heat transfer medium -
  - Volume of liquid in loop - Not applicable, open loop system
  - Anticipated liquid temperatures -
    - Maximum - 160° F
    - Minimum - 80° F
  - Provisions for expansion - 100-gal expansion tank
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Recommended use temperature
    - Maximum - 160° F
    - Minimum - 80° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No

- Components within circulation loop
  - Pump - P-1
  - Thermal storage unit - TSU-1
  - Collector - COL-1
  - Valve - V-1, V-2, V-4
  - Other - FC-1 through FC-4 and FC-6
- Piping
  - Rigid - Copper Type L
  - Maximum operating
    - Temperature - 212° F
    - Pressure - 90 psi
  - Insulation Type - High density fiberglas
    - Manufacturer - Unknown
    - Characteristics - 4 lb/ft^3, 2 in thick
    - Thermal Resistance - Unknown
  - Location - Above grade
  - Exterior Finish - Corrugated aluminum jacket with stainless steel straps
  - Filters and Strainers - One at each of the two P-1 pumps
    - Manufacturer - Metra Flex
    - Product name/number - M1 (0.045 mesh)
  - Getters - None
- Circulator pump (P-1)
  - Manufacturer - Peerless
  - Model name/number - C820 AM
  - Type - Centrifugal
  - Maximum operating conditions
    - Operating head - 27.7 psi
    - Temperature - 210° F

- Material exposed to heat transfer fluid - Bronze and cast iron
- Motor size - 3.0 HP; 440 V; 3 phase; 60 Hz
- Maximum motor speed - 1750 rpm
- Drive - Belt
- Speed - Single
- Pump speed - 1750 rpm

	Low Head Mode	High Head Mode
Circulating volume -	225 gpm	75 gpm
Operating head (dynamic) -	12.12 psi	27.7 psi
Motor operation -	3 bhp	3 bhp

- Distribution Valve (V-1)
  - Manufacturer - ITT
  - Model name/number - 3010 SJ
  - Function - Isolation
  - Operation - Manual
  - Type - Gate
  - Material exposed to heat transfer fluid - Bronze
- Distribution Valve (V-2)
  - Manufacturer - ITT
  - Model name/number - 3210 SJ
  - Function - Balancing
  - Operation - Manual
  - Type - Globe
  - Materials exposed to heat transfer fluid - Bronze
- Distribution Valve (V-4)
  - Manufacturer - Dayton
  - Model name/number - 6X541

- Function - Dump
- Operation - Automatic, motorized
- Type - Solenoid

- Flow Control (FC-1)
  - Manufacturer - Hoffman
  - Model name/number - 29
  - Type - Automatic air vent
- Flow Control (FC-2)
  - Manufacturer - Watts
  - Model name/number - 36
  - Type - Vacuum relief valve
- Safety (FC-3)
  - Manufacturer - Watts
  - Model name/number - 40 XL
  - Type - Temperature relief valve
- Safety (FC-4)
  - Manufacturer - Watts
  - Model number - 3400X8
  - Type - Pressure relief valve
- Flow Check (FC-6)
  - Manufacturer - Ohio Brass
  - Product name/number - 1606
  - Type - Check valve

CONTROL MODE SELECTOR (CMS-1)

- Manufacturer - Hawthorn Industries
- Model name/number - BT-100

- Modes controlled
  - Collector to storage -
    - ON - (SN-2) > (SN-4) + 16° F
    - OFF - (SN-2) < (SN-4) + 3° F
  - Freeze control recirculation
    - ON - (SN-1) ≤ 38° F
- Sensor (SN-1)
  - Manufacturer - General Energy Devices
  - Model name/number - Frost Cycle #5-5
  - Type - Vacuum sealed Bi-metal
- Sensors (SN-2) and (SN-4)
  - Manufacturer - General Energy Devices
  - Model name/number - S-1
  - Type - Temperature, thermocouple

CONTROL MODE SELECTOR (CMS-2)

- Manufacturer - Honeywell
- Model name/number - Aquastat L6008A
- Modes controlled
  - Energy dumping
    - ON - (SN-2) ≤ 180° F (opens V-4 to drain)
- Sensors (SN-3)
  - Manufacturer - Honeywell
  - Product name/number - Aquastat L6008M
  - Type - Nitrogen filled copper bulb and tube

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

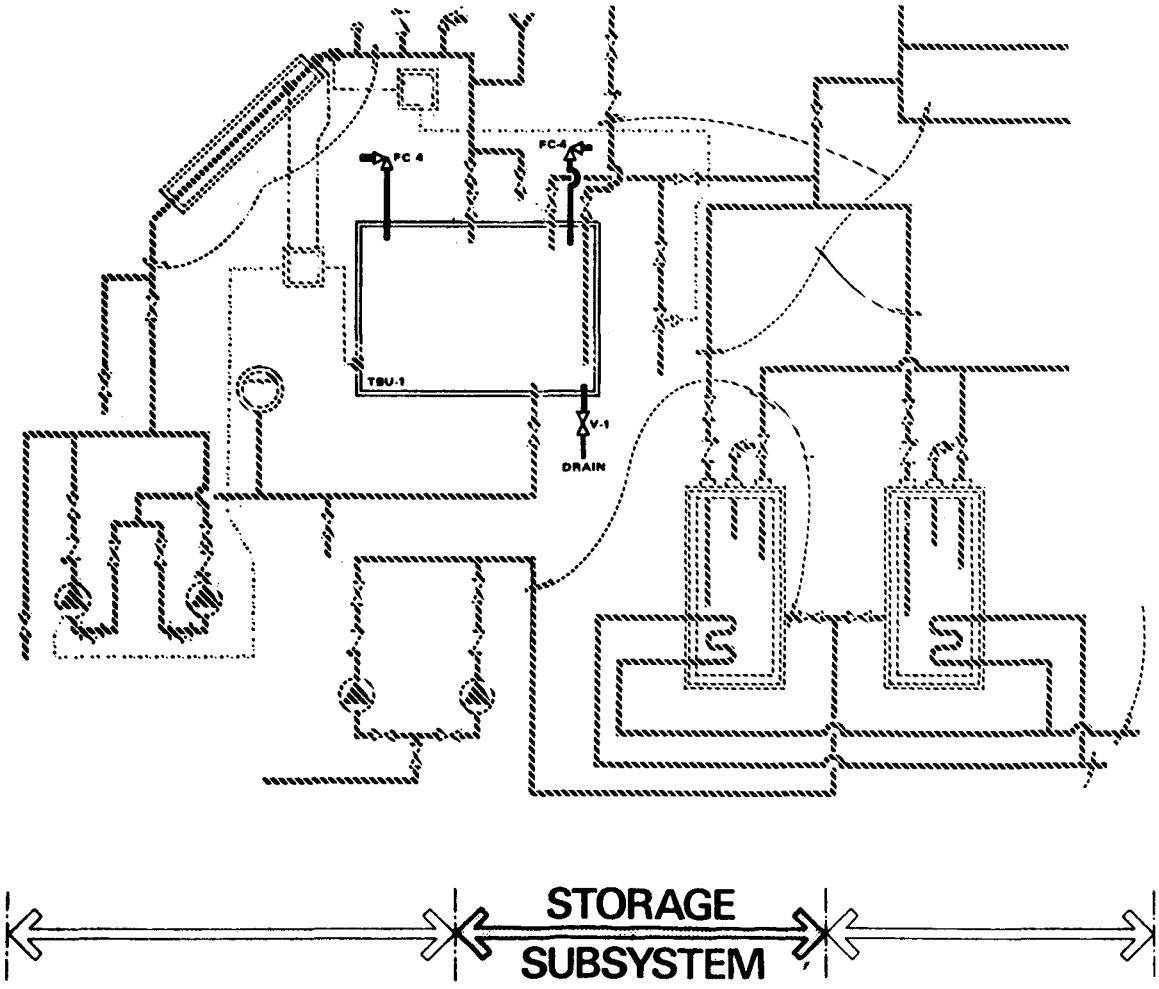


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by a 5,000 gallon storage tank. This tank is made of steel with glass interior lining. It measures 26.3 feet long by 5.8 feet diameter with fiberglas insulation. The exterior finish consists of corrugated aluminum and aluminum sheet applied in wedge shaped sectors over hemispherical ends.

The preheated water is transported to two existing 1,500 gallon DHW tanks upon demand. Both tanks are 8.3 feet high by 5.5 feet in diameter.

The containers are constructed with steel and are insulated on the outside by asbestos.

THERMAL STORAGE UNIT (TSU-1)

- Manufacturer - Pressure Vessels Inc.
- Model name/number - Glashield GH5000 AT
- Total storage container volume - 643 ft^3
- Volume of storage medium - 5,000 gal
  - Length - 26.3 ft
  - Diameter - 5.8 ft
- Maximum rated operating conditions
  - Temperature - 350° F
  - Pressure - 160 psi
- Stratification devices/measures - 4 inch strata-flo manifolds
- Storage medium
  - Design heating operating temperatures
    - Maximum - 140° F
    - Minimum - 40° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F
- Toxicity - Potable
- pH Factor - 7.0
- Inhibitor - No
- Container construction
  - Type - Steel
  - Interior lining - Plastic

- Location - Above grade, outside
- Auxiliary heaters - No
- Insulation - Fiberglas
- Exterior finish - Corrugated aluminum
- Filters - No
- Getters - No

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

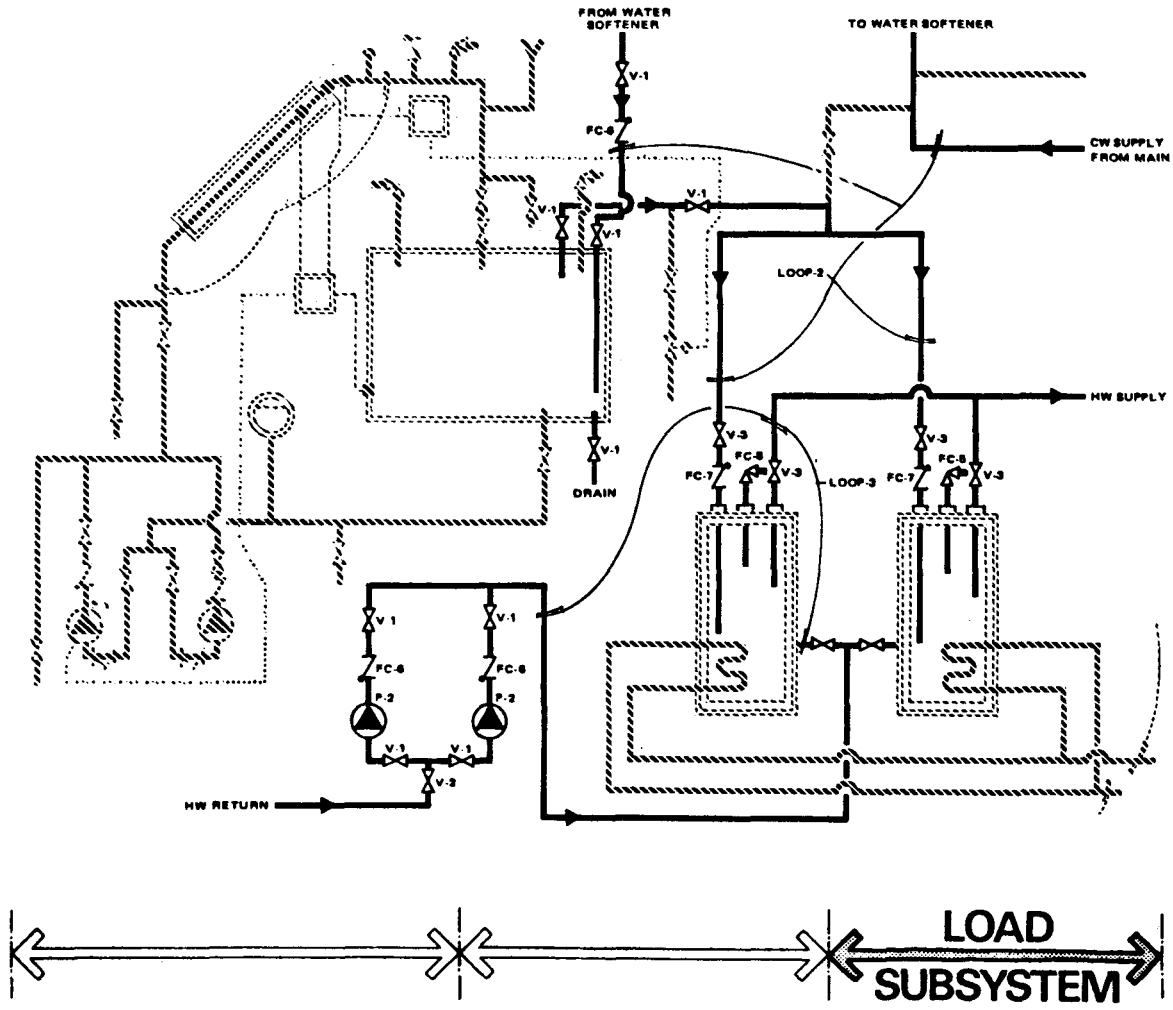


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy heated water is stored in the 5,000 gallon storage tank. This serves as a preheated water source for the two 1,500 gallon tanks which supply on demand DHW to the building. Auxiliary heat energy, augmenting this source, is provided by a central heating plant via a high temperature/pressure line.

LIQUID CIRCULATION LOOP NO. 2 (STORAGE TANKS TO DHW TANKS)

- Design maximum operation temperature - 200° F
- Design maximum operation pressure - 90 psi
- Heating
  - Design liquid flow -
    - Maximum - 100 gpm
    - Minimum - 50 gpm
- Heat transfer medium
  - Volume of liquid in loop - Not applicable, open loop system
  - Anticipated liquid temperatures
    - Maximum - 160° F
    - Minimum - 40° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4/lb/ft^3
  - Heat capacity - 62.4 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - No
- Components within circulation loop
  - DHW tanks - TSU-1, TSU-2
  - Valve(s) - V-1, V-3
  - Other - FC-6, FC-7

- Piping
  - Rigid - Copper, Type L
  - Insulation - Fiberglas
  - Location - Above grade
  - Filters - No
  - Getters - No
- Distribution Valve (V-3)
  - Manufacturer - Crane
  - Model name/number - Unknown
  - Function - Isolation
  - Operation - Manual
  - Type - Gate
  - Materials exposed to heat transfer fluid - Bronze
- Flow Check (FC-6) and (FC-7)
  - Manufacturer - Ohio Brass
  - Product name/number - 1606
  - Type - Check valve

LIQUID CIRCULATION LOOP NO. 3 (DHW TO DEMAND)

- Design maximum operation temperature - 200° F
- Design maximum operation pressure - 60 psi
- Heating
  - Design liquid flow -
    - Maximum - 100 gpm
    - Minimum - 50 gpm
  - Design pump speed - 1750 rpm
- Heat transfer medium
  - Volume of liquid in loop - Not applicable, open loop system

- Anticipated liquid temperatures
  - Maximum - 140° F
  - Minimum - 40° F
- Medium - Water (100%)
- Specific heat - 1.00 Btu/lb/° F
- Density - 62.4 lb/ft^3
- Heat capacity - 62.4 Btu/ft^3/° F
- Boiling point - 212° F
- Freezing point - 32° F
- Toxicity - Potable
- pH factor - 7.0
- Chemical feeder to maintain pH factor - No
- Inhibitor - No

- Components within circulation loop
  - Pump - P-2
  - DHW tanks - TSU-2 (2-1500 gal each)
  - Valve - V-1, V-2, V-3
  - Other - FC-5 and FC-6

- Piping
  - Rigid - Copper, Type L
  - Interior coating - None
  - Insulation - Fiberglas
  - Location - Above grade
  - Filters - No
  - Getters - No

- Circulator pump (P-2)
  - Manufacturer - Fairbanks-Morse
  - Model name/number - SR4K8
  - Type - Centrifugal
  - Maximum operating conditions
    - Dynamic pressure - 86 psi
    - Temperature - 200° F
  - Material exposed to heat transfer fluid - Unknown
  - Motor size - 0.25 HP; 115V; 1 phase; 60 Hz
  - Maximum motor speed - 1750 rpm
  - Drive - Direct
  - Speed - Single
  - Pump speed - 1750

	Low Head Mode	High Head Mode
o Circulating volume -	8 gpm	6.5 gpm
o Operating head (dynamic) -	86 psi	13 psi
o Motor operation -	0.25 bhp	0.25 bhp

- Fail Safe Control (FC-5)
  - Manufacturer - Watts
  - Product name/number - 174F
  - Type - Temperature/pressure valve

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

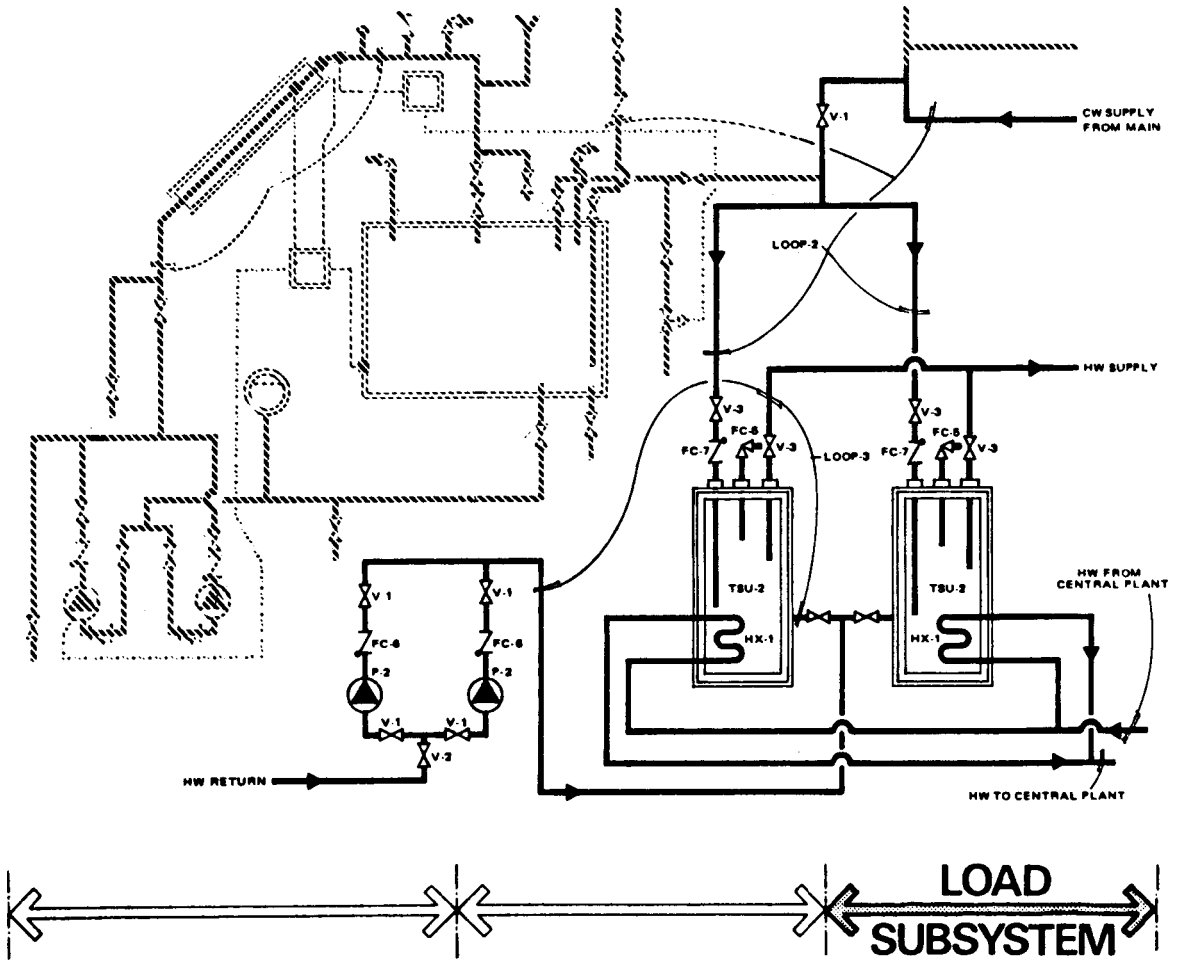


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystem provides supplemental heat energy for DHW from the central heating plant. This is an existing plant, no additional data is available.

DHW TANKS (TSU-2), TWO UNITS

- Manufacturer - Richard Mfg. Co.
- Model name/number - L-9334-TK1 and TK2
- Total storage container volume - 72 ft^3 ea
- Volume of storage medium - 1,500 gal ea
  - Height - 8.3 ft
  - Diameter - 5.5 ft
- Maximum rated operating conditions
  - Temperature - 300° F
  - Pressure - 160 psi
- Storage medium
  - Design heating operating temperatures
    - Maximum - 140° F
    - Minimum - 40° F
  - Medium - Water (100%)
  - Specific heat - 1.00 Btu/lb/° F
  - Density - 62.4 lb/ft^3
  - Heat capacity - 62.4 $Btu/ft^3/°$ F
  - Boiling point - 212° F
  - Freezing point - 32° F
- Toxicity - Potable
- pH Factor - 7.0
- Inhibitor - No
- Container construction
  - Type - Steel
  - Location - In mechanical room of building
  - Auxiliary heater(s) - No

- Insulation - Asbestos
  - Product name - Kalox
- Exterior finish - Canvas, painted
- Filter(s) - No
- Getter(s) - No

- Heat Exchanger (HX-1)
  - Manufacturer - Unknown
  - Model name/number - U933461059
  - Heat exchanger design - Unknown

	Demand Side	Energy Side
o Convection:	Forced	
o Located in:	TSU-2	TSU-2
o Part of circulation loop:	2 & 3	3

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

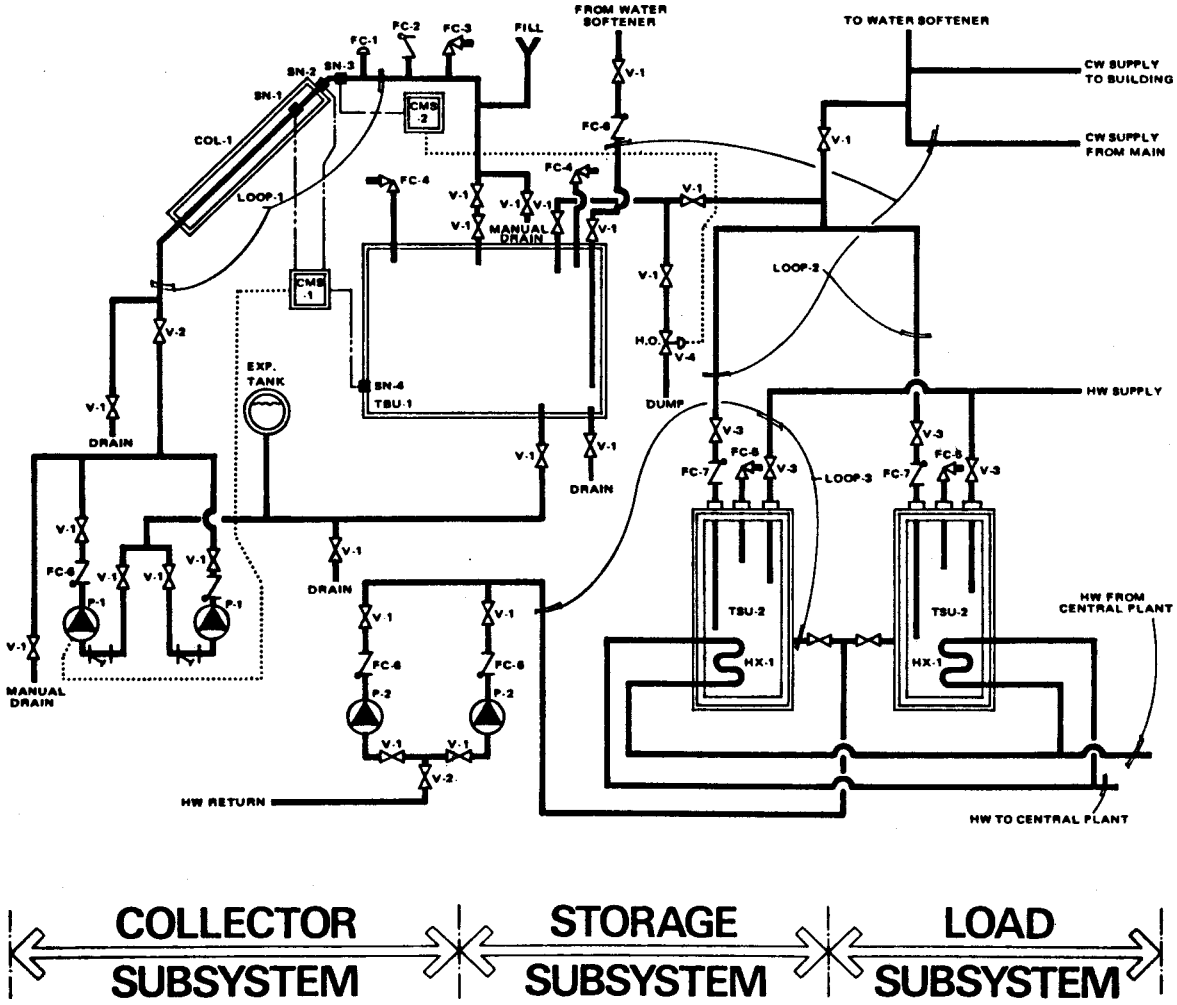


Figure IV-F-1. Controls Diagram

The Loyola University solar system is shown on Figure IV-F-1. The system consists of the following four subsystems: a) collector; b) storage; c) load (DHW); and d) auxiliary load subsystems.

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

Mode 1 - Collector to Storage

This mode activates when the temperature at the collector outlet exceeds the temperature in the bottom of the 5000 gallon storage tank by 16° F. Pump EP100, or back-up pump EP101, turns on to circulate the solar-heated water from storage to collector and back to storage. This mode terminates when the temperature difference between the collector outlet and the water in the bottom of the storage tank is less than 3° F.

Mode 2 - Storage to Load

This mode activates when there is a hot water demand. In this mode, make-up water from the cold water supply flows through a water softener system and then to the 5,000 gallon storage tank. Solar heated water is forced out of the top of the tank and transferred to two 1,500 gallon DHW tanks; where, if not hot enough, auxiliary heat is used to raise the water temperature to 140° F.

Mode 3 - Recirculation of DHW

Pumps P-2 (EP300 and, alternately, pump EP301) run continuously to circulate the DHW throughout the six-story dormitory. This makes hot water always available at the taps.

Mode 4 - Freeze Protection

When the outdoor ambient temperature is less than or equal to 38° F mode 1 is activated. This causes warm water in the 5,000 gallon tank to be pumped through the collector arrays thus preventing freezing.

Mode 5 - Temperature Control

When the temperature of the water leaving the collectors equals or exceeds 180° F, a valve is activated, the water is drained and not allowed to enter the storage tank. Cold water then flows through the collectors to cool them.

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:

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

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

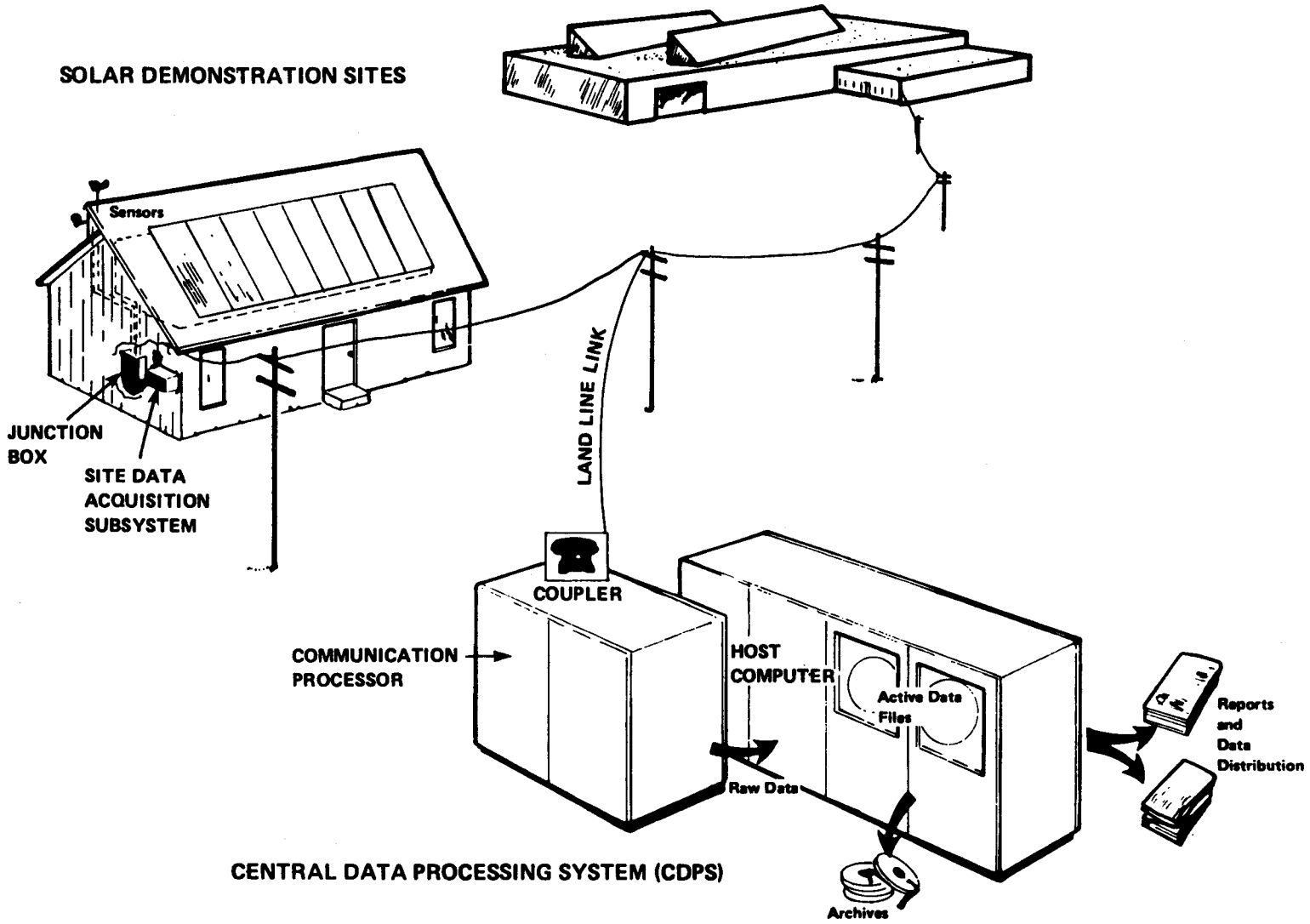


Figure V-A-1. The National Solar Data Network

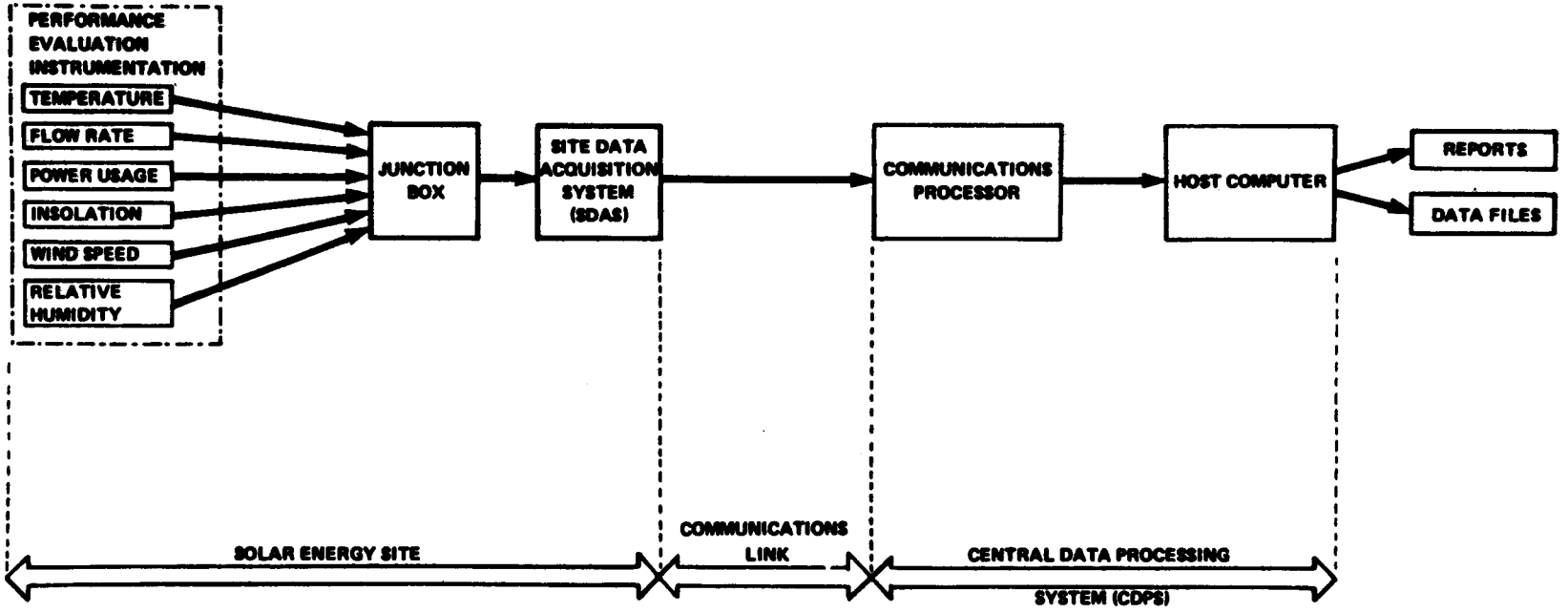


Figure V-A-2. Data Flow Path for the National Solar Data Network

The Communications Processor scans the receiving data to identify any apparent transmission errors and verifies correct site contact by checking the address code transmitted by the SDAS. Data is stored temporarily in the Communications Processor and processed by the Host Computer. The processing includes measurement checking to ensure that the data are reasonable; that is, that they are not beyond the known instrument limits and that they are not erratic. Data which appear questionable are discarded and are not used in the solar system performance 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 architectural 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	Solar Insolation	Eppley PSP
T001	Temperature, outside ambient	S53P-60
T100	Temperature, collector inlet manifold	S53P-60
T101	Temperature, main collector supply line	S53P-60
T102	Temperature, main collector return line	S53P-60
T103	Temperature, collector output manifold	S53P-60
T104	Temperature, collector/storage output line to storage tank	S53P-60
T105	Temperature, solar pump/storage tank output line from storage line	S53P-60
T101	Temperature, main collector supply line	S53P-60
EP100	Power consumed by solar pump #1	PC5-6
EP101	Power consumed by solar pump #2	PC5-6
W100	Flow rate in Pump/collector supply line	MKV-3 15-150
T200	Temperature, storage tank, medium top	S53P-140
T201	Temperature, storage tank, medium center	S53P-350
T202	Temperature, storage tank, medium bottom	S53P-583
T203	Temperature, storage tank, medium bottom	S53P-583
T204	Temperature, storage tank, medium center	S53P-350
T205	Temperature, storage tank, medium top	S53P-140
T300	Temperature, water softener/storage tank input	S53P-60
T301	Temperature, DHW/storage output line	S53P-100
T302	Temperature, coldwater supply line to building	S53P-60
T303	Temperature, DHW supply line	S53P-60
T304	Temperature, hot water supply to building	S53P-60
T305	Temperature, Recirculating hot water line	S53P-60
T306	Temperature, hotwater supply line from central boiler	S53P-60
T307	Temperature, return line to central boiler	S53P-60
T308	Temperature, surface temp of DHW tank #1	S32B
T309	Temperature, surface temp of DHW tank #2	S32B
EP300	Power consumed by recirculating pump #1	PC5-1
EP301	Power consumed by recirculating pump #2	PC5-1

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
W300	Flow rate in recirculating/DHW tank line	MKV 3/4 1-10
W301	Flow rate in return line to central boiler	MKV 3 10-100
W302	Flow totalizer, coldwater supply to building	Hersey 570

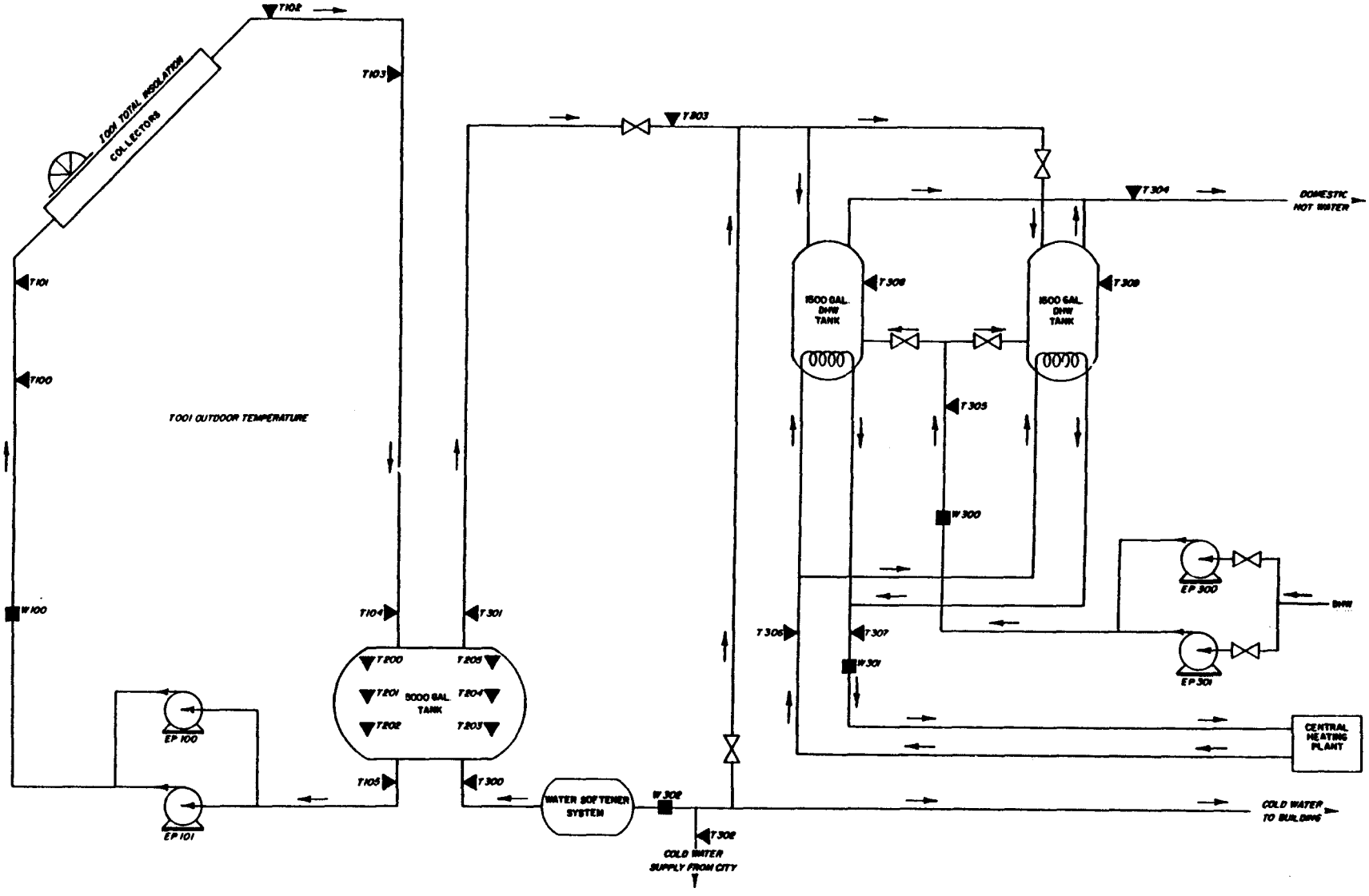


Figure V-B-1. Sensor and Control Diagram

VI. COST DATA

A. General

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

B. Construction Grant Funds

Solar Subsystem	Applicants Request	Construction Grant
Collectors	$ 74,150	$
Energy Storage	12,150	
Distribution and Controls	167,900	$210,000
Installation	included in above	
Other	-	
Total	$254,200	210,000

C. Construction Period: November 1978 through September 1979

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^{o} F to 60^{o} F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

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

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

COLLECTOR PLATE - A term used for an absorber plate.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

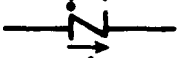
VAPOR BARRIER - A material which is used to reduce the transmission of water vapor.

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

B. Legend For Solar System Schematics

VALVES

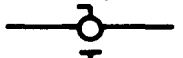

GATE VALVE


CHECK VALVE


BALANCING VALVE

GLOBE VALVE

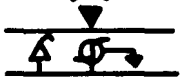

BALL VALVE


PLUG VALVE


BACKFLOW PREVENTER


VACUUM BREAKER

RELIEF OR SAFETY


PRESSURE REDUCING

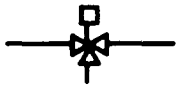

ANGLE GATE VALVE


ANGLE GLOVE VALVE


CONTROL VALVE, 2 WAY


CONTROL VALVE, 3 WAY


BUTTERFLY VALVE


4 WAY VALVE

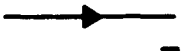
FITTINGS


DIRECTION OF FLOW

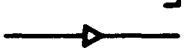

CAP


REDUCER, CONCENTRIC

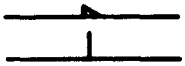

REDUCER, ECCENTRIC


TEE

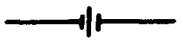

UNION

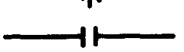

FLANGED CONNECTION

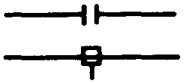
CONNECTION, BOTTOM


CONNECTION, TOP

ELBOW, TURNED UP


ELBOW, TURNED DOWN

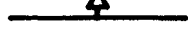

TEE, OUTLET UP

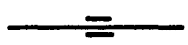

TEE, OUTLET DOWN

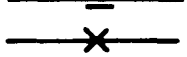
PIPING SPECIALITIES


AUTOMATIC AIR VENT


MANUAL AIR VENT


ALIGNMENT GUIDE


ANCHOR


BALL JOINT

EXPANSION JOINT


EXPANSION LOOP


FLEXIBLE CONNECTION

FLOWMETER FITTING

FLOW SWITCH

PRESSURE SWITCH

PRESSURE GAUGE

PUMP

PIPE SLOPE

STRAINER

STRAINER, W/BLOW OFF

TRAP

CONTROL SENSOR

INSTRUMENTATION SENSOR

THERMOMETER

THERMOMETER WELL ONLY

COLD WATER SUPPLY

BLOWER

AS — AIR SEPARATOR

EXP TK — EXPANSION TANK

WS — WATER SOFTENER

HED — HOSE END DRAIN

HEAT EXCHANGER

STOVE (FRANKLIN TYPE)

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