13
2/31/79

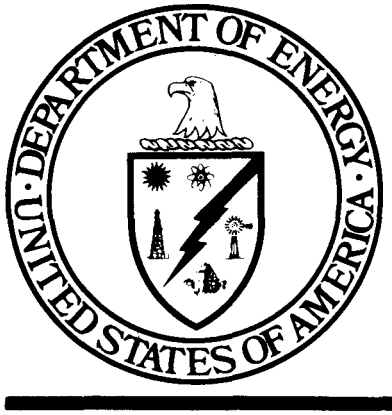
HD. 6017

MASTER

SOLAR/1014/79/50

Solar Project Description

HEI WAI WONG MULTI-DWELLING BUILDING
Honolulu, Hawaii
October 3, 1979



U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

Solar/1014-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
HEI WAI WONG
MULTI-DWELLING BUILDING - HONOLULU, HAWAII

Department of Housing and Urban Development

Under Contract Number

H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

The Boeing Company
David Beers, Program Manager

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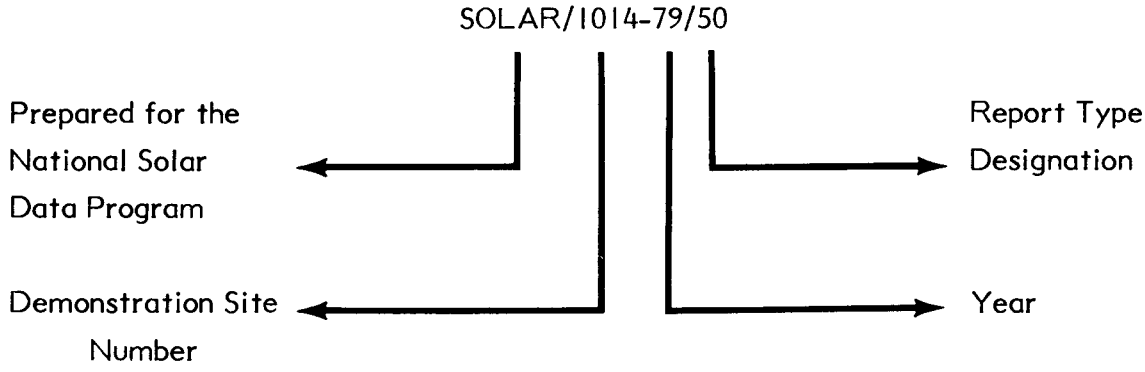
LIST OF FIGURES

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 Hei Wai Wong mulit-dwelling building project site is designated as SOLAR/1014-79/50. The elements of this designation are explained in the following illustration:



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

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

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

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

I. FOREWORD

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

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

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

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type - Liquid
- o Freeze Protection - None required
- o Application - Domestic hot water
- o Storage - Water, 1230 gallon tank
- o New or Retrofit - New
- o Performance Evaluation Instrumentation - Yes
- o Site-Specific Features - Gas-fired boiler auxiliary heating in laundry, electrical auxiliary heating in apartments.

The Hei Wai Wong site, (HUD Grant H-2797) is a 4 story, 55 unit apartment building in Honolulu, Hawaii..

Three solar systems are installed at this project to supplement the domestic hot water (DHW) requirements, include preheating the laundry hot water for average usage rate.

The solar energy system collector-to-storage results from thermosyphoning. The flat plate collector array has a gross area of 3,002 sq ft of which 807.4 square feet is instrumented. The collectors are facing south with a collector tilt of 24^{o}. Collected energy is accumulated in the 1230 gallon water tank that is roof top mounted. Such preheated water can be gravity fed to the laundry and apartment units. Auxiliary heating of the hot water in each apartment is provided by 30 gallon tanks using electric resistance heat elements. Auxiliary heating of the hot water in the laundry is provided by an 85 gallon tank fired by natural gas.

The dwelling has been fully instrumented for performance evaluation since November 1977 and the data is integrated into the National Solar Data Network.

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

III. SITE AND BUILDING DESCRIPTION

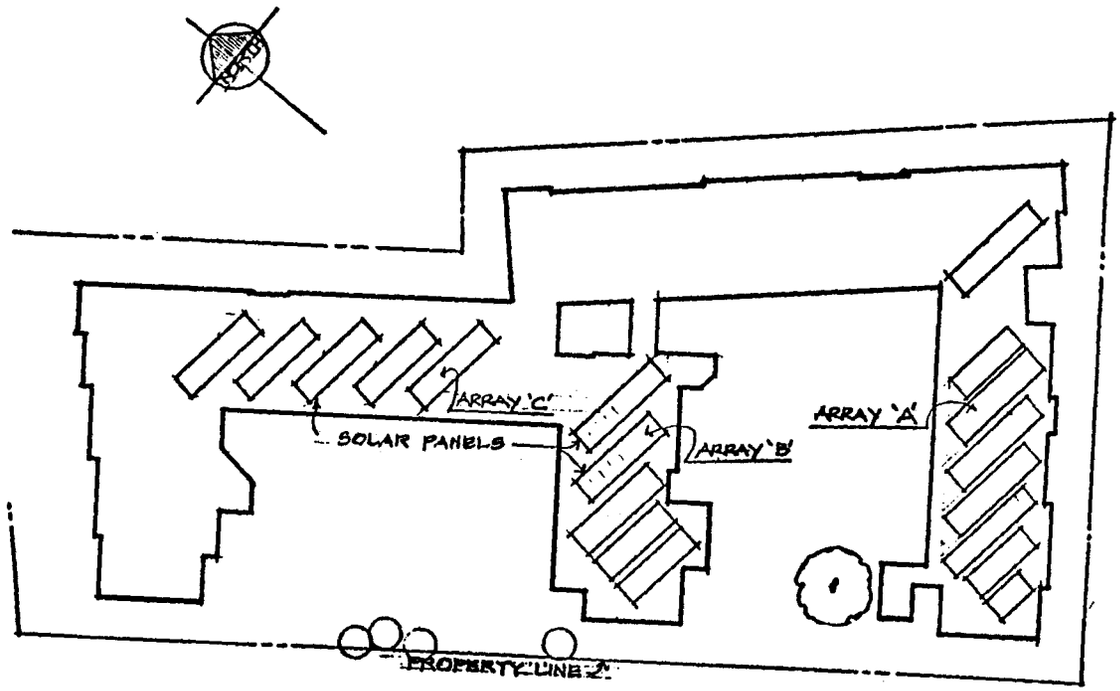


Figure III-1. Site Plan

Site Description (See Figure III-1)

- Latitude - 21°
- Longitude - 158°
- Elevation - 60 ft.
- Annual degree days
  - Heating -
  - Data location - Honolulu, Hawaii
  - Data reference - Local Climatological Data Annual Summaries, Department of Commerce, National Oceanographic and Atmospheric Administration
- Average horizontal insolation
  - January - 1918 Btu/ft^2/day
  - July - 1963 Btu/ft^2/day

Building Description

- Occupancy
  - Multi-dwelling - 55 units, 6 units are instrumented
- Roof slope at collector - Flat
- Special features - Gas-fired hot water heater

Mechanical System

- Heating
  - Solar - Hot water
  - Auxiliary - Gas-fired hot water tank for laundry

Domestic Hot Water

- Daily water demand - 1110 gal. per day
- Solar - Preheat water for laundry and DHW
- Auxiliary - Electric resistance elements and a gas-fired boiler in the laundry

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

This multi-residential solar demonstration project (Hei Wai Wong, Grant H-2797) located at Honolulu, Hawaii is a liquid passive system utilized for domestic hot water. Auxiliary units are provided for additional heating of domestic water.

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

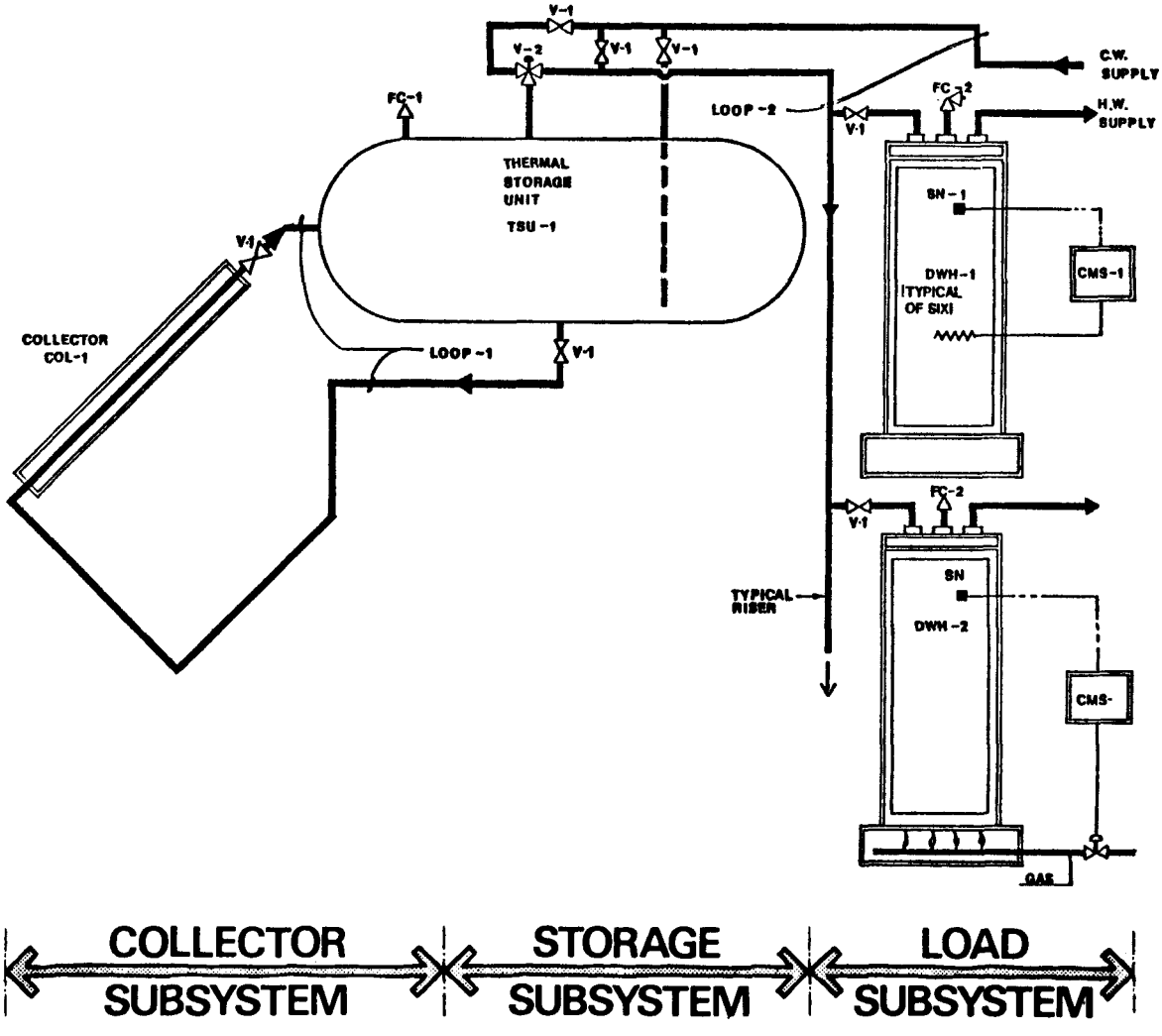


Figure IV-A-1. General Overview

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

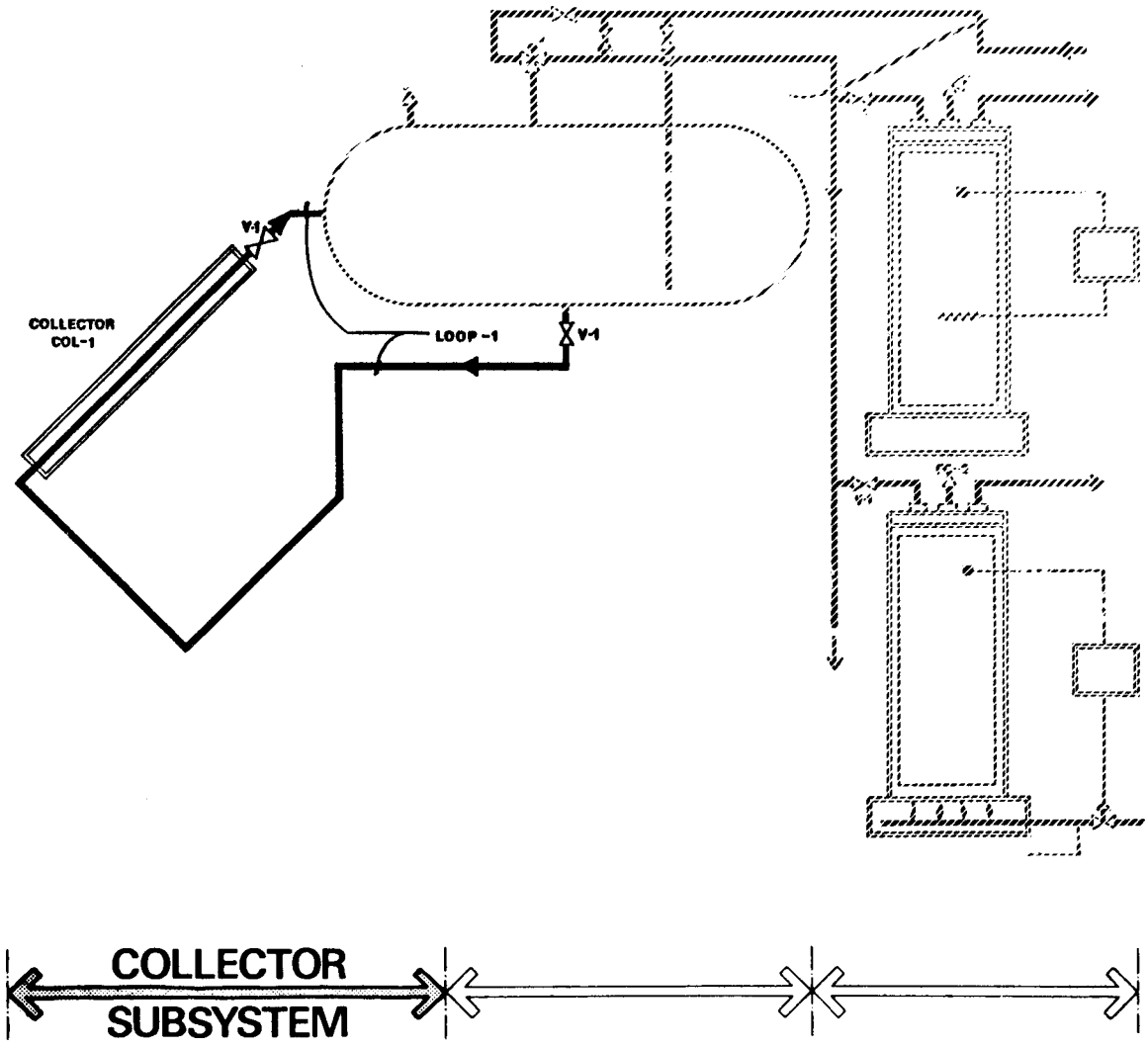


Figure IV-B-1. Collector Subsystem

Collector array system consists of 9 single glazed selective surface, flat plate collector panels. Freeze protection is unnecessary due to climatic conditions the year round.

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

- Manufacturer - Raypak
- Model name/number - SG-18P
- Type - Liquid flat plate
- Location - Roof
- Orientation - Due South
- Tilt angle - 24^{o}
- Number of collector panels - 39 (instrumented)
- Array configuration - Three clusters, 145 collectors in three arrays of (A) 61, (B) 39 and (C) 45
- Collector
  - Total gross area of array - 3002 sq. ft.
  - Net aperture area - 807 sq. ft. (instrumented)
  - Weight per panel, empty - 110 lbs
  - Weight per panel, full - 112 lbs
  - Panel length - 76.5 inches
  - Panel width - 37.5 inches
  - Frame depth - 4 inches
  - Standoff height - 0
- Glazing (cover plate)
  - Number of cover plates - One, with selective absorber
- Cover plate No. 1
  - Product name/number - 700138-1U
  - Material - Glass, tempered, double strength
  - Thickness - 0.125 inch
  - Coating - None

Figure IV-B-2. Solar Collector

- Optical properties (solar region) (infrared region)
  - Transmittance 91% 91%
  - Reflectance 8% 8%
  - Emittance - 93°
- Edge or surface treatment, other than coating - Non-reflective surface
- Coating on cover plate material - None

- Absorber
  - Manufacturer - Raypak
  - Model name/number - 053858/6
  - Material - Aluminum, Napco APL-2036
  - Substrate material dimension
    - Thickness - 0.020 inch
    - Length - 76.0 inch
    - Width - 34.0 inches
- Coating
  - Manufacturer - NAPCO
  - Model name/number - NAPCO-APL-32
  - Application method - Anodized eletrostatically
  - Absorptance, Solar region - 96%; Infrared - 75%
  - Reflectance, Solar region - 4%; Infrared - 25%
  - Emittance - 98%
- Heat transfer fluid passages
  - Location - In absorber
  - Pattern - Parallel
  - Materials - Copper, Type M, Tube 3003 H 14
  - Wall thickness - 0.025 inch

- Internal diameter - 0.035 inch
- Maximum operating conditions
  - Temperature - 350° F
  - Pressure - 200 psi

- Insulation
  - Layer one - sides
    - Manufacturer - Owens Corning
    - Product name/number - Fiberglass
    - Material - Glass fiber
    - Thermal resistance - R-7
  - Layer one - back
    - Product name/number - Owens Corning
    - Manufacturer - Fiberglass
    - Material - Glass fiber
    - Thermal resistance - R-10

- Gaskets and sealants
  - Inner cover - EPDM (Action Mfg. Co.) Plastic
  - Outer cover - Same as inner cover
  - Penetrations - Neoprene (LA Rubber) and rubber

- Frame
  - Manufacturer - Raypak
  - Product name/number - PR18 Solar-Pak
  - Material - Galvanized cold rolled mild steel
  - Protective coating - Baked enamel
  - Number of structure attach points per module to building - 4
  - Desiccant - Yes, under Fiberglass

- Freeze protection - None
- Overheating protection - None

- Collector performance
  - Method of evaluation - ASHRAE $(t_i-t_a)/I_t$
  - y intercept - 79° F/hr/ft^2
  - Slope - $R_R U_L$ (1.31)

Point Number	1	2	3	4
n = Collector thermal efficiency (%) -	31.8	55.4	69.8	78.7
t_i = collector inlet temperature ($^{\circ}$F) -	188	135	101	80
t_a = ambient air temperature ($^{\circ}$F) -	81	80	80	78
I_t = insolation intensity Btu/hr ft^2 -	300	308	310	311
ASHRAE $(t_i-t_a)/I_t$ -	0.36	0.18	0.07	0.00

  - Test flow rate - 336.6 lb/hr
  - Total heat loss Coefficient - 1.44 Btu/hr/ft^2/$^{\circ}$ F
  - Test collector area
    - Gross - 20.7 sq ft each
    - Net - 18.72 sq ft each
  - Fluid specific heat - 1.00 Btu/lb/$^{\circ}$ F
  - Test fluid medium - 100% water

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

- Maximum design operating temperature - 190° F
- Maximum design operating pressure - 60 psi
- Heating design liquid flow - Thermosyphon (4.6 gpm minimum)
- Heat transfer medium - Water
  - Specific heat - 1.00 Btu/lb/$^{\circ}$F
  - Density - 63 lb/ft^3
  - Boiling point - 212° F

- Freezing point - 32° F
- Maximum recommended use temperature - 150° F
- Toxicity - Potable
- pH factor - 7.4
- Chemical feeder to maintain pH factor - No
- Inhibitor - No

- Piping
  - Rigid - Copper, type K
  - Piping insulation - Cellular rubber (Armstrong)
  - Location - Above grade
  - Exterior finish - Hypalon rubber paint
  - Finish/Insulation - Joint type - Armaflex glue
- Distribution Valve (V-1)
  - Function - ON-OFF, flow adjusting
  - Operation - Manual
  - Type - Gate

- Freeze protection - None
- Overheating protection - None

- Collector performance
  - Method of evaluation - ASHRAE $(t_i-t_a)/I_t$

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

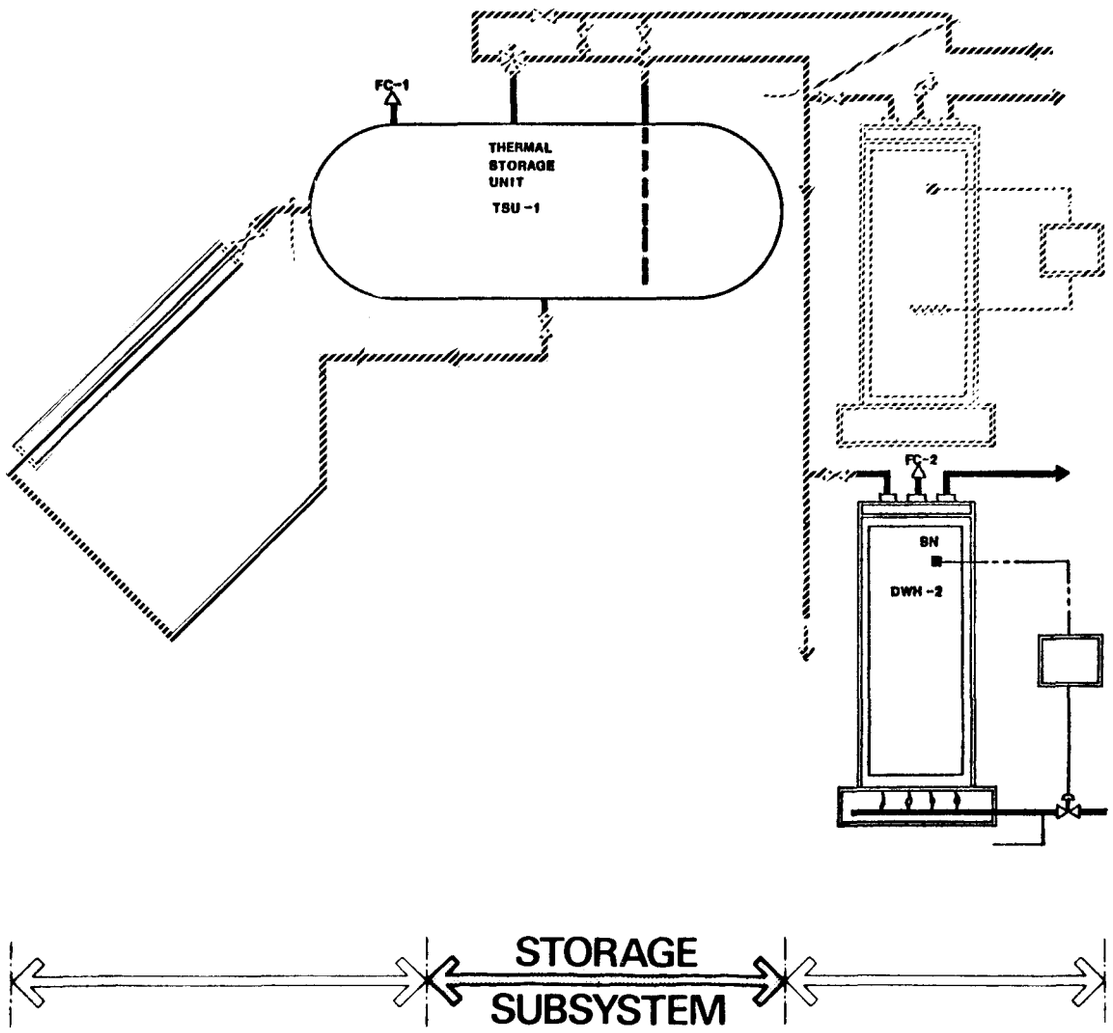


Figure IV-C-1. Storage Subsystem

Solar energy storage is provided by three storage tanks of 4,358 gallons (A-1825 gal., B-1230 gal., and C-1330 gal). This tank is made of steel with a glass liner and measures 5 feet in diameter, 9.8 feet in length. The stored preheated water is gravity fed and supplied to each apartment on demand. There are 54, 30 gallon tanks with electric elements for heating. Auxiliary heating for the laundry is provided by one 85 gallon tank fired by natural gas.

Thermal Storage Unit (TSU-1)

- Container
  - Total storage volume - 164 cubic feet (1230 gallons), instrumented
    - Length - 9.8 ft
    - Diameter - 5 ft
- Storage medium
  - Design operating temperature - 150° F
  - Medium - Water
  - Specific heat - 1.0 Btu/lb/° F
  - Density - 63 lb/ft^3
  - Boiling point - 212° F
  - Freezing point - 32°F
  - Recommended medium temperature - 150° F
  - Toxicity - Potable
  - pH Factor - 7
  - Inhibitor - No
- Container construction
  - Type - Steel
  - Location - Roof
  - Auxiliary heaters - None
  - Insulation - Glass lining
  - Exterior finish - Urethane
  - Filters - None

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

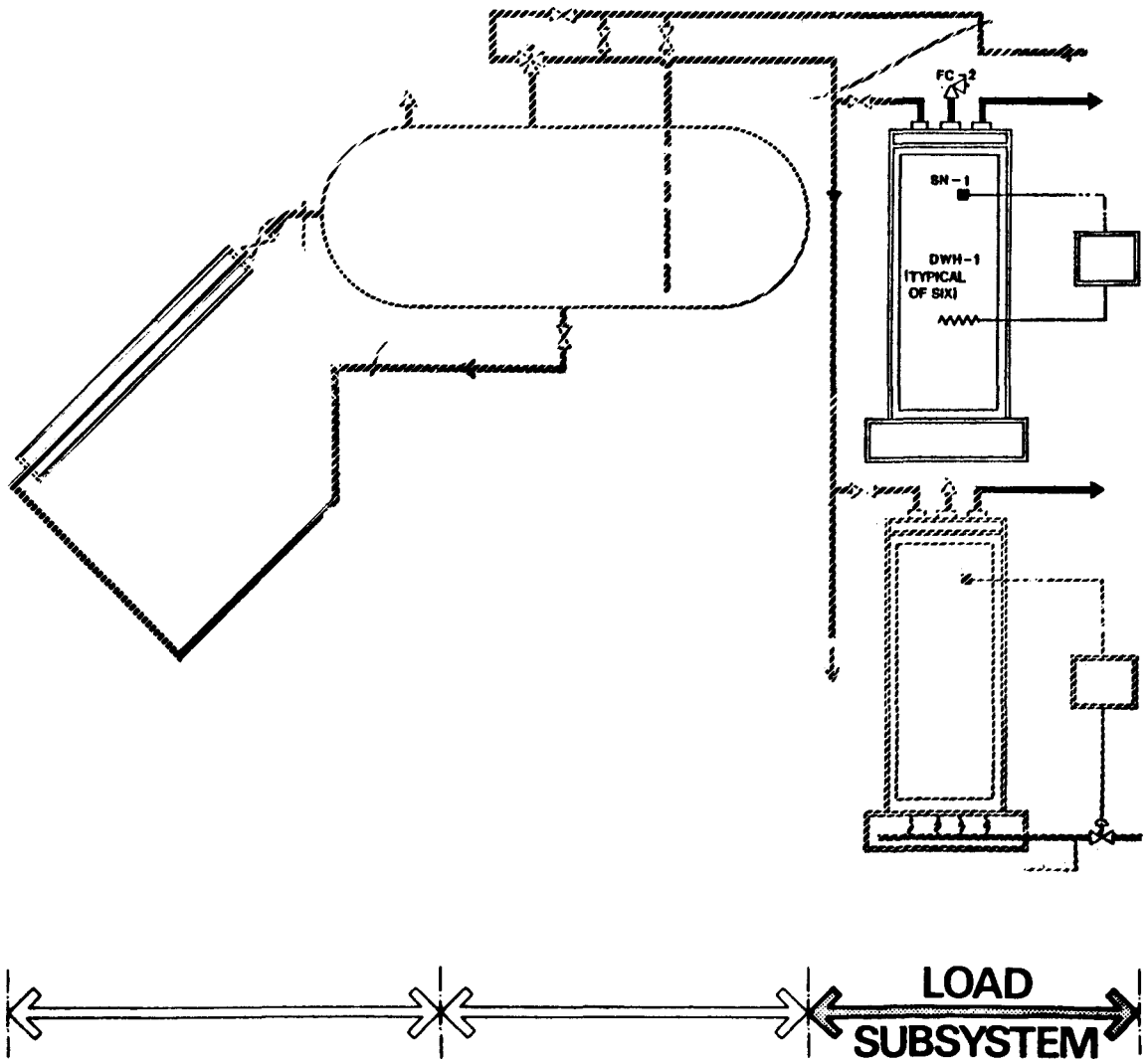


Figure IV-D-1. Energy-to-Load Subsystem

Solar energy stored in the 1230 gallon tank is used partially to meet domestic hot water heating. Auxiliary DHW heating, supplementing this source, is provided at each apartment by electric resistance stripping. The laundry hot water source is supplemented by a natural gas-fired heater.

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

- Maximum design operation temperature - 190° F
- Pressure - 60 psi
- Heating design liquid flow - On demand, 1110 gal per day
- Heat transfer medium
  - Medium - Water
  - Specific heat - 1.0 Btu/lb/° F
  - Density - 63 lb/ft^3
  - Heat capacity - 63.0 Btu/ft^3/° F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 150° F
  - Toxicity - Potable
  - pH factor - 7.4
  - Chemical feeder to maintain pH factor - No
  - Inhibitor - None
- Piping
  - Rigid - Copper, type K
  - Location - Above grade
  - Exterior finish - Hypalon Rubber, painted
  - Insulation - Cellular rubber
  - Finish/insulation joint type - Armaflex glue
- Distribution Valve (V-2)
  - Manufacturer - Watts (rated at 180° F
  - Model name/number - N-170
  - Function - 3 way mixing

- Operation - Automatic
- Type - Tempering
- Materials exposed to heat transfer fluid - Bronze - Rubber

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

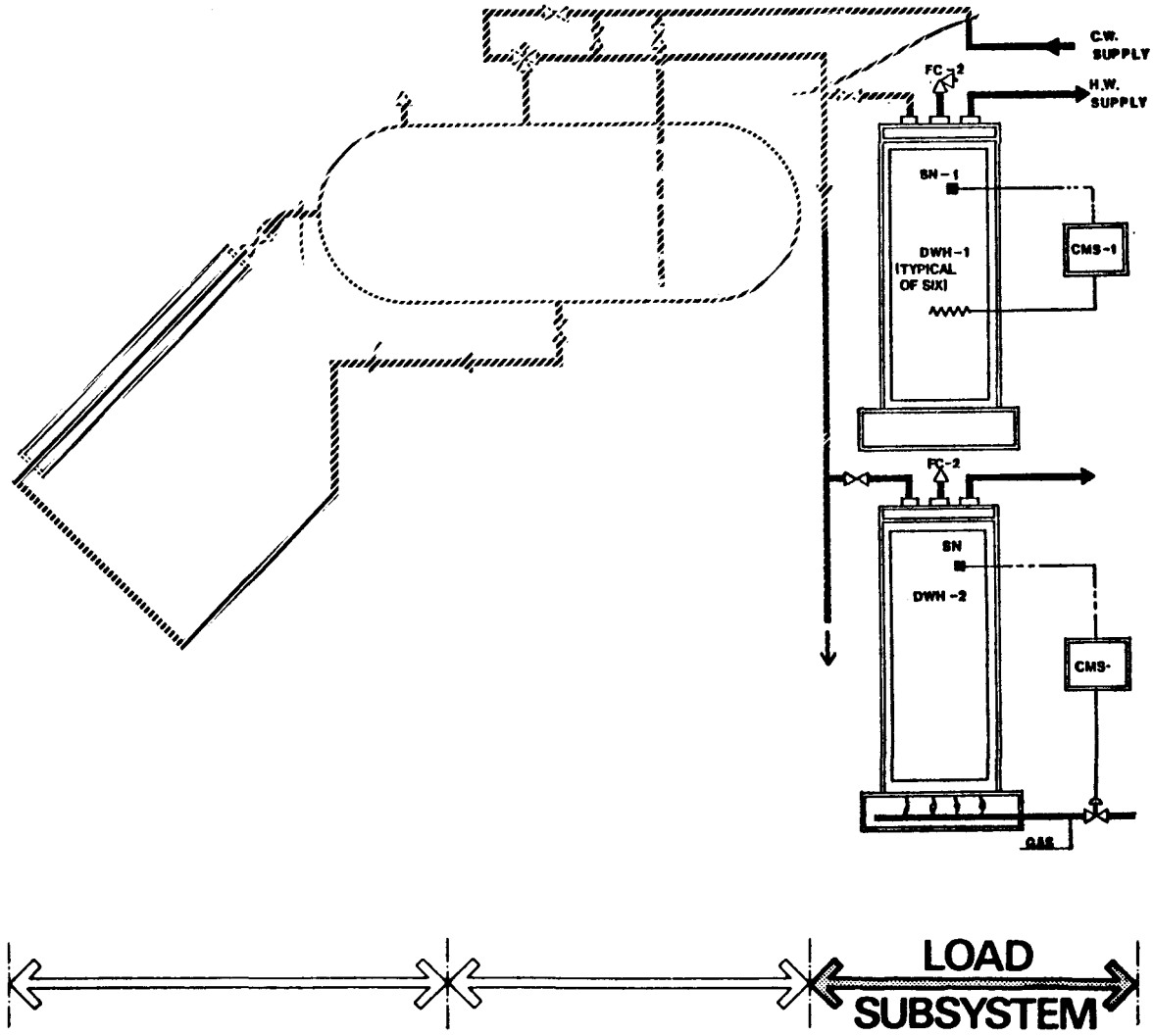


Figure IV-E-1. Auxiliary-to-Load Subsystem

The auxiliary subsystem consists of six domestic hot water tanks with electrical elements, one for each of the six apartments. The laundry utilizes a gas fired heater for the hot water. Each tank and the gas fired heater are individually controlled by the independently control sensors. Specific data are given in the following section.

Auxiliary Loads (DWH-1)

- Domestic Water Heater (DHW-1)
  - Manufacturer - Continental
  - Model - CRG-30, Solar
  - Energy source - Electric
  - Tank size - 30 gal
    - Diameter - 20½ inch
    - Height - 33 inch
  - Energy input - 15,363 Btu/hr
  - Energy output - 15,363 Btu/hr
  - Design operating pressure - 140° F
  - Heating - Electric resistance stripping
  - Maximum recovery rate - 26 gal/hr
  - Yearly average inlet temperature - 70° F
  - Design output temperature - 140° F
  - Burner ignition method - Electric
  - Flue vent - No
- Boiler (DWH-2), for laundry
  - Manufacturer - Jet glass
  - Model name/number - M-85-168 JSB
  - Tank volume - 85 gal
  - Energy source - Natural gas
  - Energy input - 199,999 Btu/hr
  - Energy output - 140,000 Btu/hr
  - Burner ignition method - Pilot
  - Flue vent - No
  - Maximum pressure - 150 psi

- Maximum temperature - 180° F
- Design operating pressure - 60 psi
- Heating stages - Single
- Maximum recovery rate - 240 gal/hr
- Yearly average inlet temperature - 70° F
- Design water output temperature - 140° F
- External exposed area - 46.5 sq ft
- Corrosion protection anodes - Magnesium

- Control Mode Selector (CMS-1)
  - Manufacturer - Continental
  - Model name/number - CRG-30 Solar
  - Auxiliary power to DHW supply - ON-OFF
    - ON - (SN-01) less than 140° F
    - OFF - (SN-01) more than 140° F
  - Auxiliary heating - SN-02
  - Sensor (SN-02)
    - Type - Thermostat
- Fail Safe Control (FC-02)
  - Manufacturer - Watts
  - Model name/number - 100 X2
  - Control Modes - Pressure/temperature relief

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

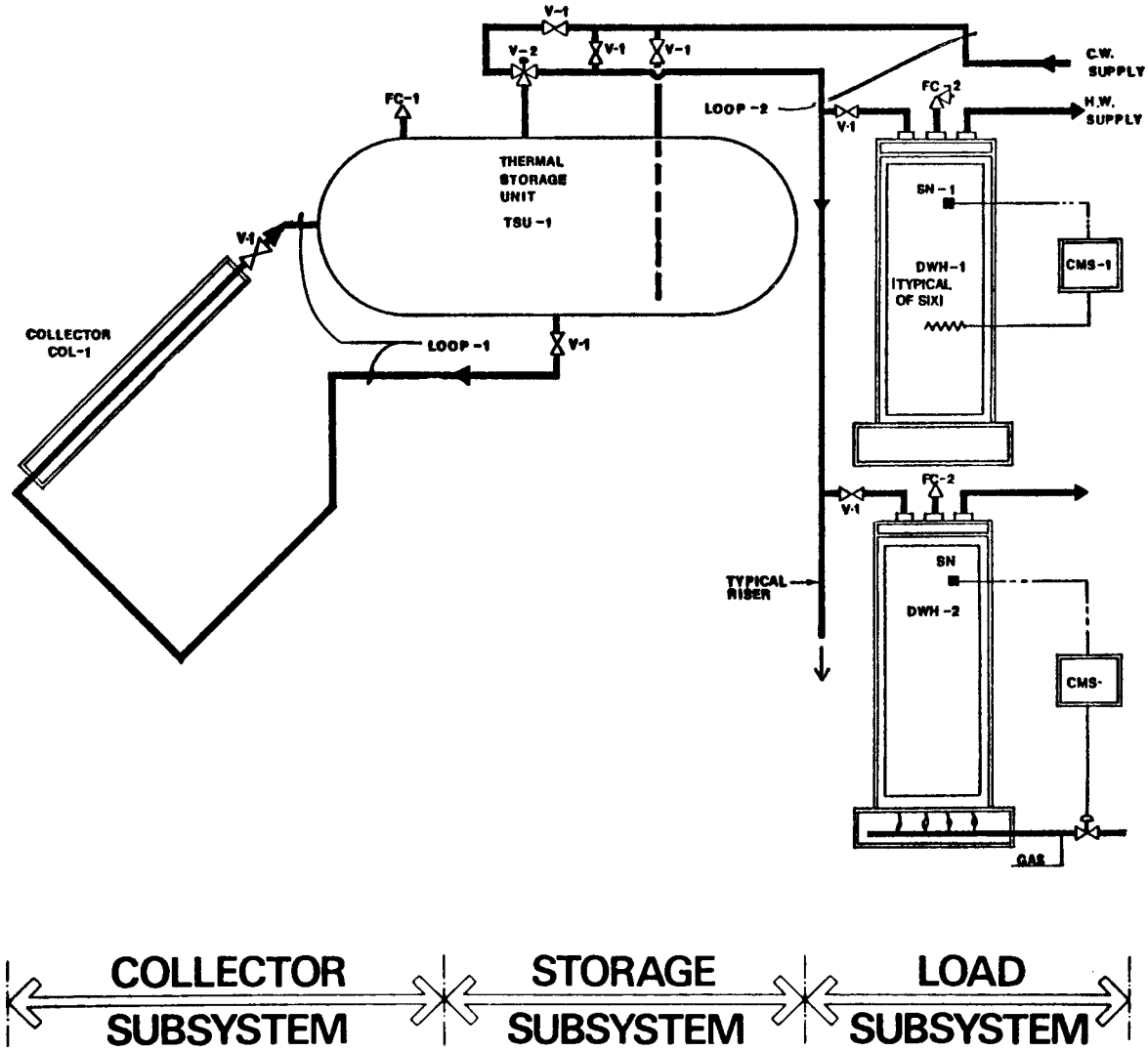


Figure IV-F-1. Controls Diagram

The Hei Wai Wong project's solar system is shown in figure IV-F-1. This system consists of the following four subsystems: a) Collector, b) Storage, c) Load and d) Auxiliary loads. Among the auxiliary subsystems is a gas-fired hot water heater for the 85 gallon laundry storage tank and electric resistance strips to heat the individual 30 gallon hot water heaters in the apartments.

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

Mode 1 - Collector-to-Storage:

This mode is initiated whenever sufficient temperature difference exists between the collector surface temperature and the bottom of storage to activate the thermosyphon effect causing water to circulate through the collector array.

Mode 2 Storage-to-Load

Solar heated water from the storage tank is supplied to either the individual domestic hot water tanks or the laundry hot water heater tank on demand. The system is pressurized by the city water system.

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.

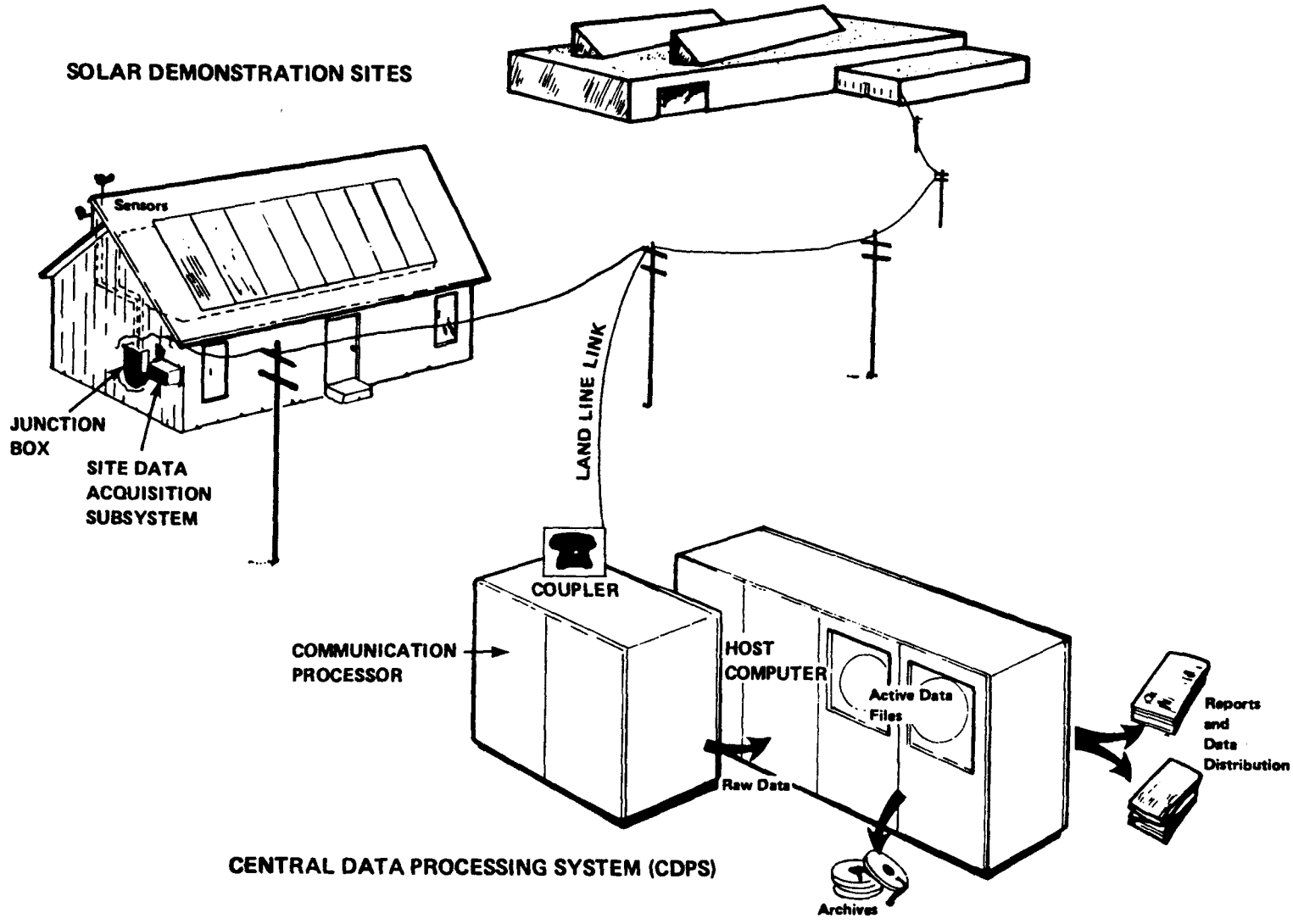


Figure V-A-1. The National Solar Data Network

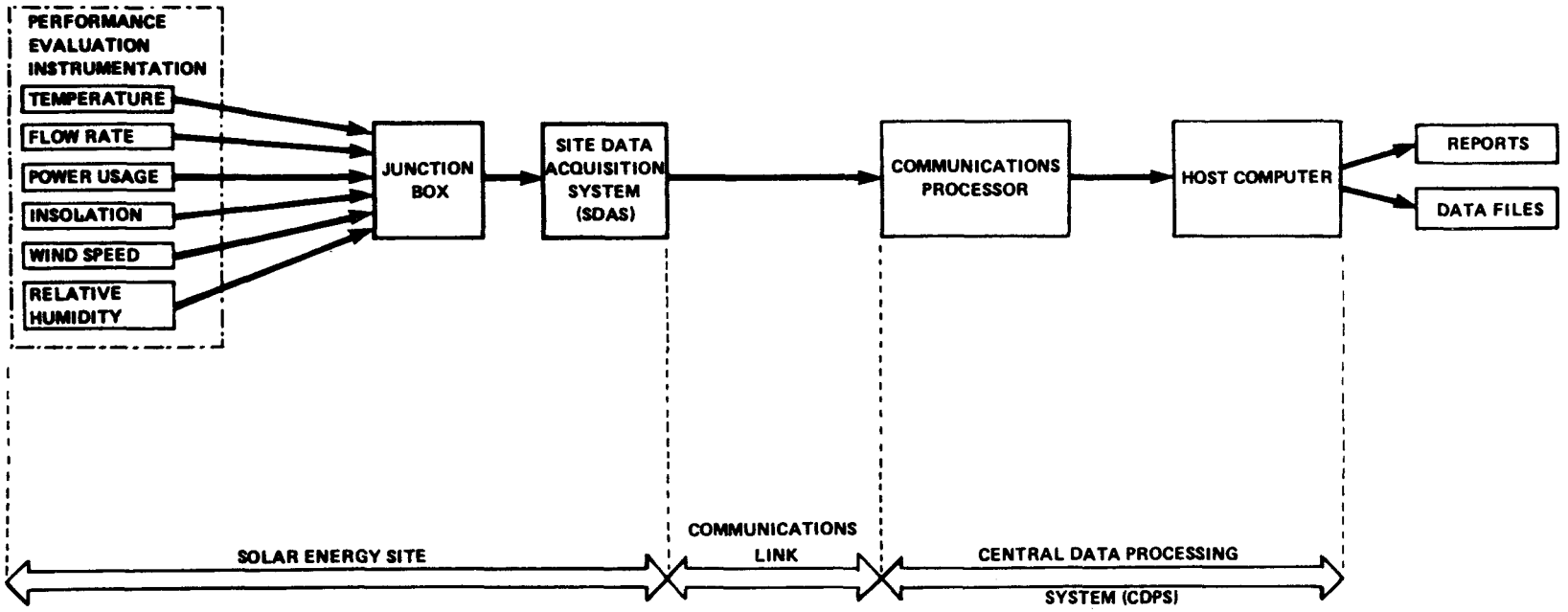


Figure V-A-2. Data Flow Path for the National Solar Data Network

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

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

B. On-Site Instrumentation

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

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Insolation, total	Eppley PSP
T001	Temperature, outside ambient	S53P-60
W100	Flow, collector loop	240-2CU"W"
T100	Temperature, collector inlet	S57P-60
T150	Temperature, collector bank	S53P-60
T101	Temperature, collector inlet	S57P-60
T151	Temperature, collector bank	S53P-60
T102	Temperature, collector bank inlet	S57P-60
T152	Temperature, collector bank	S53P-60
T103	Temperature, collector bank inlet	S57P-60
T153	Temperature, collector bank	S53P-60
T200	Temperature, storage tank, upper	S53P-180
T201	Temperature, storage tank, middle	S53P-360
T202	Temperature, storage tank, bottom	S53P-560
W300	Total Flow, cold water make-up	Hersey 560
EP300	Power, preheat loop pump and controls	PC5-1
T300	Temperature, DHW supply, incle	S57P-60
T350	Temperature, DHW supply	S53P-60
W301	Totalizer - laundry tank	Niagra 1 in
T301	Temperature, laundry tank inlet	S57P-60
T351	Temperature, laundry tank	S53P-60
F301	Contact closure, burner ON/OFF 199,000 Btu/hr	Dwyer 1996-20
W320	Flow rate, DHW tank A	MKV-3/4-.7-7GPM
T302	Temperature, DHW tank A	S53P-60
T312	Temperature, DHW tank A	S53P-60
EP302	Power, DHW tank A	OS PC5-29
W303	Flow rate, DHW tank B	MKV-3/4-.7-7GPM
T303	Temperature, DHW tank B inlet	S53P-60
T313	Temperature, DHW tank B	S53P-60
EP303	Power, DHW tank B	OS PC5-29
W304	Flow rate, DHW tank C	MKV-3/4-.7-7GPM
T304	Temperature, DHW tank C	S53P-60
T314	Temperature, DHW tank C	S53P-60
EQ304	Power, DHW tank C	OS PC5-29

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
W305	Flow Rate, DHW Tank D	MKV-3/4-.7-7GPM
T305	Temperature, DHW tank D inlet	S53P-60
T315	Temperature, DHW tank D	S53P-60
EP305	Power, DHW tank D	OS PC5-29
W306	Totalizer DHW tank E	Niagra I in
T306	Temperature, DHW tank E inlet	S53P-100
T316	Temperature, DHW tank E	S53P-60
EP306	Power, DHW tank E	OS PC5-29
W307	Flow rate, DHW tank F	MKV-3/4.7-7GPM
T307	Temperature, DHW tank F	S53P-60
T317	Temperature, DHW tank F	S53P-60
EP307	Power, DHW tank F	OS PC5-29
D001	Direction, wind	S-102-P/DC
V001	Velocity, wind	Part of above

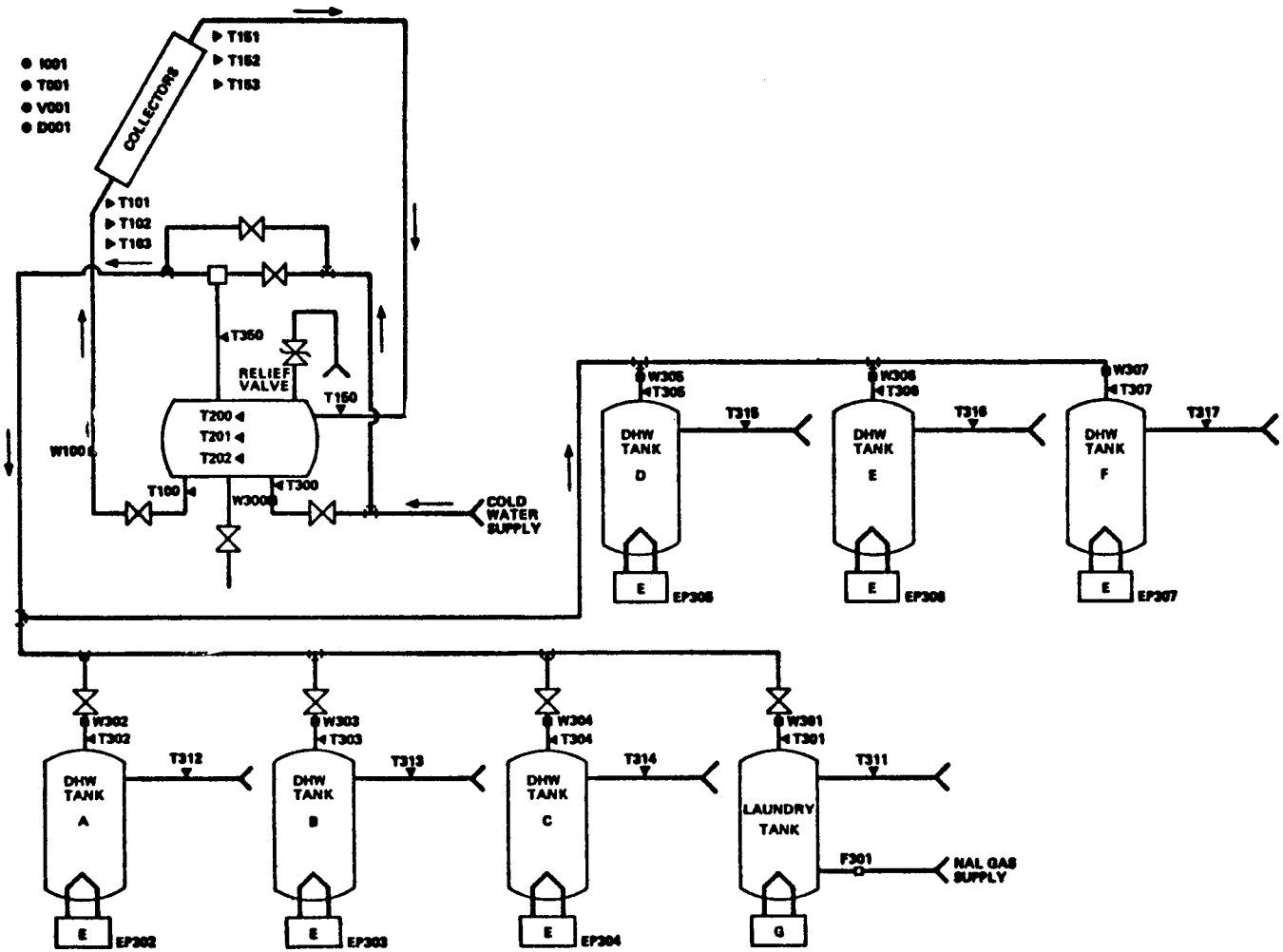


Figure V-B-1. Sensor and Control Diagram

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
Solar System No.	#1	#2	#3	Total	
Collectors	$20,696	$21,400	$12,579	$45,675	
Energy Storage	1,314	787	799	2,900	
Distribution and Controls	1,970	1,181	1,198	4,350	
Installation	8,870	5,314	5,391	19,575	
Total	$32,850	$19,683	$19,968	$72,500	$ 69,324

C. Construction Period: October 15, 1976 through June 30, 1977

VII. APPENDIX

A. Glossary

ABSORBER PLATE - The surface in a flat plate collector that absorbs incident solar radiation and transfers the absorbed energy to a heat transfer fluid.
ABSORPTANCE - The ratio of absorbed radiation by a surface to the total incident radiation on that surface.
ABSORPTION SUBSYSTEM - The mechanical equipment that conditions indoor air by an absorption process.
ACTIVE SOLAR SYSTEM - An integrated solar energy system, consisting of collector, storage, solar energy-to-load subsystems, that can condition indoor air or preheat domestic hot water in a controlled manner.
AIR-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which air is the heat transfer fluid.
AIR CONDITIONING - The process of treating indoor air by controlling the temperature, humidity, and distribution to specified comfort settings as set by the occupants in the conditioned space.
AMBIENT AIR - A term for outdoor air, and may be brought into a building to be conditioned or circulated.
ANTI-FREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses additives or solutions to the heat transfer medium, which depresses its freezing point sufficiently to prevent possible water freeze in the solar collectors and the exterior piping.
AUXILIARY ENERGY SUBSYSTEM - The equipment, utilizing conventional energy sources, used to supplement the output provided by a solar energy system and used to provide a full backup system when the solar system is inoperable.
BACKFLOW - The reversal of flow in a distribution system.
BACKFLOW PREVENTOR - A device or means to stop backflow.
BEAM RADIATION - Solar radiation which is not scattered and may be concentrated.
BRITISH THERMAL UNIT (Btu) - A unit of energy that is required to heat one pound of water from 59° F to 60° F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

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

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

COLLECTOR PLATE - A term used for an absorber plate.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

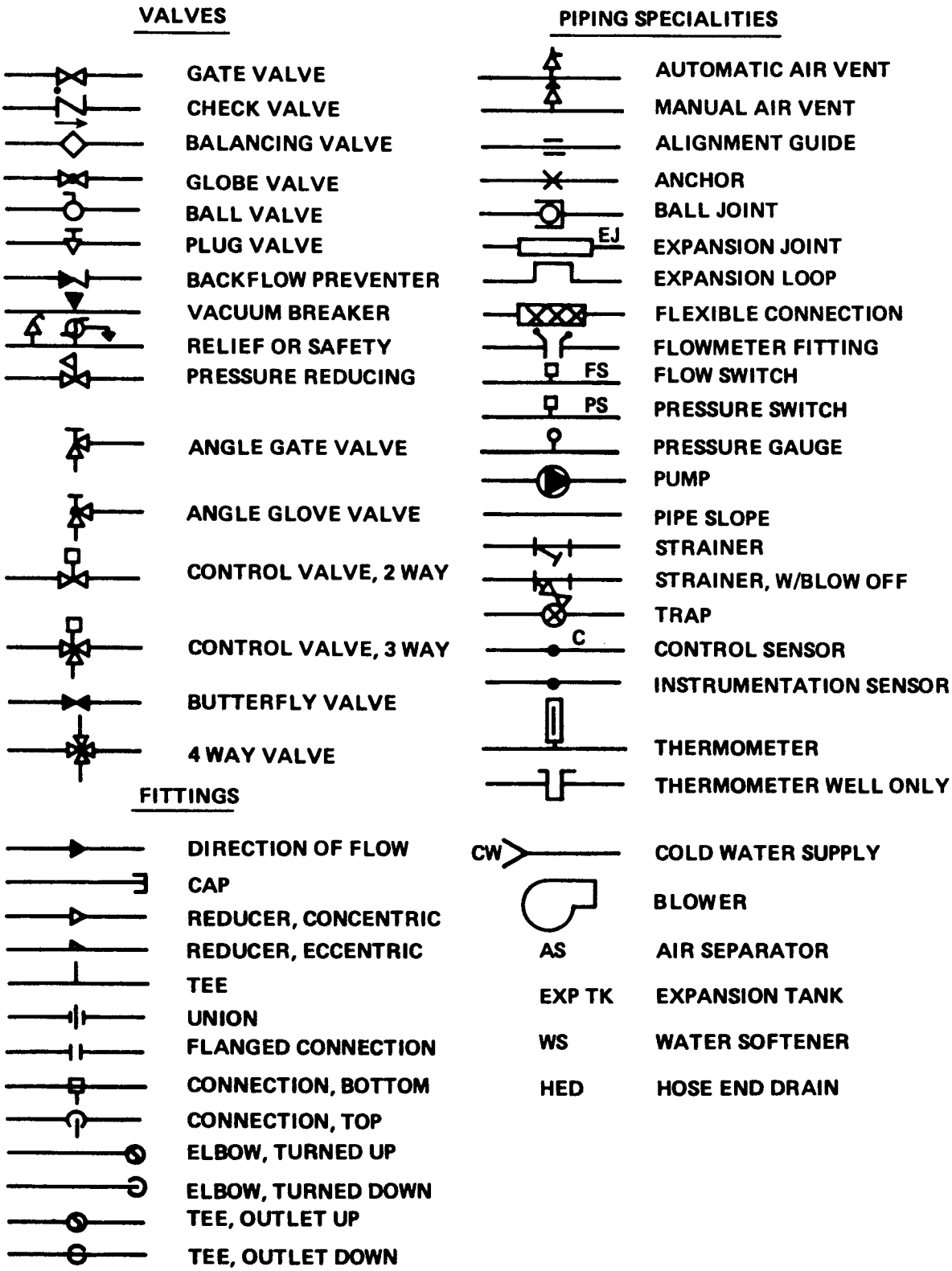
TON OF REFRIGERATION - A unit of refrigeration which is equivalent to 12,000 Btu/hr.

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

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

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

B. Legend For Solar System Schematics



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