SOLAR/2036-79/50
DISTRIBUTION CATEGORY UC-59

Solar Project Description

PAGE JACKSON ELEMENTARY SCHOOL

Charles Town, West Virginia
January 19, 1979

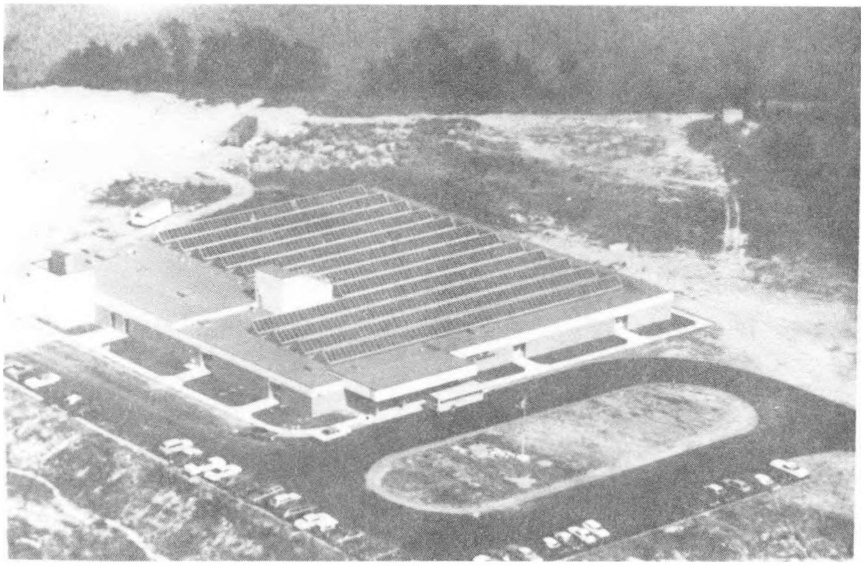
U. S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

Solar/2036-79/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION FOR PAGE JACKSON ELEMENTARY SCHOOL



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In Cooperation with
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Mueller Associates, Incorporated
The Ehrenkrantz Group

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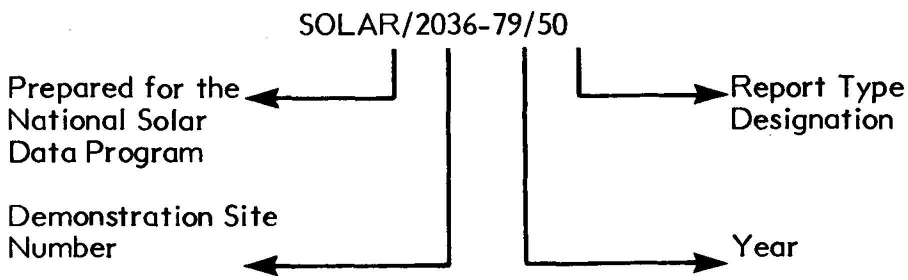
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Page Jackson project site is designated as SOLAR/2036-79/50. The elements of this designation are explained in the following illustration:



Demonstration Site Number:

Each project site 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 Report—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 as mandated by the Solar Heating and Cooling Demonstration Act of 1974. 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 the use of fossil fuel 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 such topics as:

- Solar Project Description,
- Design/Construction Contractor Final Report,
- Project Costs,
- Maintenance and Reliability,
- Operational Experience,
- System Performance Evaluation,
- Monthly Performance Reports, and
- Solar Life-Cycle Cost Reports.

The Solar Project Description is prepared for the purpose of documenting the project description in the "as-built" state. Information contained herein has been extracted from data collected during site visits and from reference documents such as the project proposal, designer specifications, contractor submittals, manufacturers' literature, photographs, "as-built" drawings, and other project documentation as available. The remaining reports in this series will rely on the Solar Project Description for specific site details.

Acknowledgements are extended to the personnel of the Page Jackson School, P. E. Poole Company, Inc., and Pickett, Seiss, and Hook, AIA, for their cooperation in the preparation of this report.

II. EXECUTIVE SUMMARY

The following is a brief summary of the Page Jackson Elementary School solar installation. Major features of this system include:

- Collector - Liquid, double glazed, flat plate
- Freeze Protection - Draindown
- Application - Heating, cooling
- Storage - Liquid, interior, on-grade
- New/Retrofit - New
- Performance Evaluation Instrumentation - Yes
- Site Specific Features - Collector/reflector sawtooth-type roof, economizer cycle

The Page Jackson Elementary School in Charles Town, West Virginia has a solar energy system for space heating and cooling for the 52,600 square foot building. The solar collectors are integrated into a sawtooth roof configuration with mirrored glass reflectors.

The 11,215 square feet of PPG double-glazed, flat-plate collectors face south at a 45° angle to the horizontal. The collectors are piped in reverse return with insulated copper branch piping. The collectors are attached to the sawtooth framing. Glass mirrors are attached to the north side of the sawtooth frame.

An extruded aluminum frame holds the collector intact. Copper absorber plates, with a black chrome selective coating, are soldered to copper tubing. The two 1/8 inch Herculite tempered glass glazings are separated from each other and the absorber plate by 3/8 inch airspaces. There is a 6 inch fiberglass insulating batt placed behind the uninsulated collectors.

Overheat protection is provided by circulating storage water. Freeze protection is provided daily by automatically draining the collectors and the exterior piping after the collector pump turns off.

Two insulated 10,000 gallon steel storage tanks are located in the mechanical equipment room and are connected in series. The atmospherically vented tanks are partially full and hold about 17,500 gallons. The additional capacity is used to store water in the drain-down mode. The tanks are insulated with 6 inches of sprayed urethane insulation which has an asbestos coating. No chilled water storage is provided.

Space heating is provided by circulating warm storage water through five air handling units. A 780,000 Btu/hr oil-fired boiler is used for additional heating.

Space cooling is provided by pumping hot storage water to a 100-ton absorption chiller. The chilled water is circulated through the five air handling units. The absorption and electric chillers operate separately.

The system has been fully instrumented for performance evaluation and integrated into the National Solar Data Network. It has been operational intermittently since April 1978.

III. SITE AND BUILDING DESCRIPTION

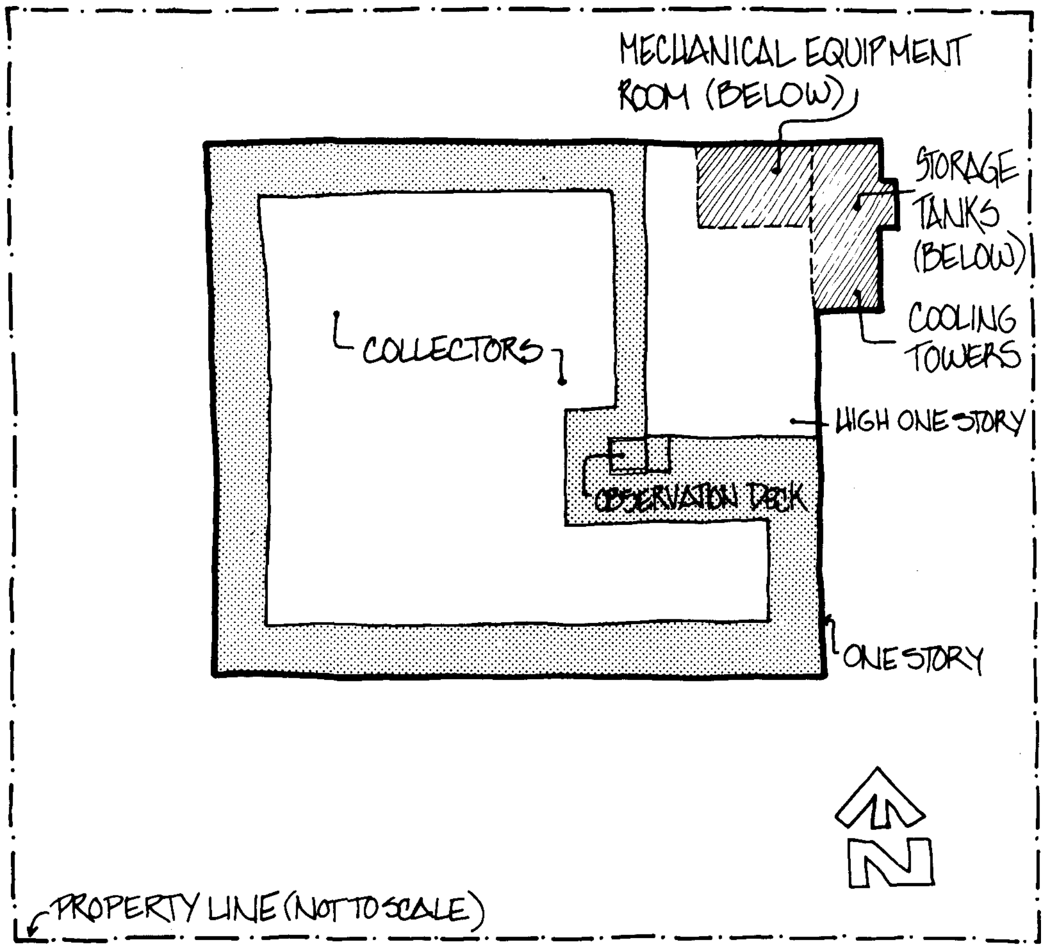


Figure III-1. Site Plan

Site Description

- Special topographic or climatic conditions-None
- Latitude - 39°N
- Annual degree days (65° F base)
  - o Heating - 5,471

- Cooling - 779
- Data location - Washington, D.C., Dulles International Airport
- Data reference - Local Climatological Data Annual Summaries for 1976, Department of Commerce, National Oceanic and Atmospheric Administration

- Average horizontal insolation
  - January - 586 Btu/ft^2/day
  - July - 1948 Btu/ft^2/day
  - Data location - Washington, D.C.
  - Data reference - Beckman, Klein, Duffie, Solar Heating Design by the F-Chart Method, Wiley-Interscience Publication, 1977.
- Site topographical description - Flat
- Shading - None

Building Description

- Occupancy - Elementary school
- Total area - 52,600 ft^2
- Solar conditioned space - 52,600 ft^2
- Height - One story
- Special features - Solar collectors, reflectors, and skylights are integrated into a collector/reflector shed design.

Structure

- Walls - Masonry cavity wall
  - Frame - Steel joist and beam
  - Exterior finish - Brick
  - Insulation - 2 inch styrofoam board in cavity (R-11)
  - Interior finish - Concrete block painted

- Windows
  - Aluminum awning, 4 Lite (one operable), no weather stripping, single glaze 1/4 inch clear plate
  - Approximately 10 percent of surface area
- Doors - Insulated hollow metal core door - no weather stripping

• Roof
  - Structural frame - Open web joist and beam
  - Exterior finish - Built up roof with slag finish
  - Insulation - 2 inch rigid board (R-12)
  - Interior finish - Suspended ceiling

• Floor material - Poured concrete floor slab

Mechanical System

• Heating
  - Solar - Individual air handling units
  - Backup - Oil fired boiler
  - Distribution - Multizone duct system

• Cooling
  - Solar - Trane absorption chiller
  - Backup - Trane centrifugal chiller
  - Distribution - Same as heating

• Domestic hot water - Not included in solar system

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

The Page Jackson solar energy demonstration project is represented in figure IV-A-1. The major components of the solar system include 11,215 ft^2 of double-glazed flat plate collectors, 9,215 ft^2 of glass mirror reflectors, two 10,000 gal hot water storage tanks, a 100-ton absorption chiller, a 120-ton electric chiller, and a 780,000 Btu/hr oil-fired boiler.

Subsequent sections describe the collector, storage, storage-to-load, auxiliary energy, and control subsystems. Figure V-B-1 shows a detailed system schematic. Appendices A and B present a glossary and a legend of symbols, respectively.

B. Collector Subsystem

General Description (see figure IV-B-1)

The collector array is arranged in 12 rows, one collector high, forming a sawtooth pattern with the reflectors on the opposite side of the array. The collectors are tilted at 45° from the horizontal and the mirrored reflectors at 38°.

For freeze protection, an automatic valve is opened to drain the collectors and exterior piping when the temperature differential of collectors and storage is below 4° F. The de-ionized water drains to the storage tank.

Collectors

- Type - Double glazed flat plate collectors
- Manufacturer/Model No. - Pittsburgh Plate and Glass/A414
- Number - 620
- Collector orientation - Due south
- Tilt angle - 45° to the horizontal

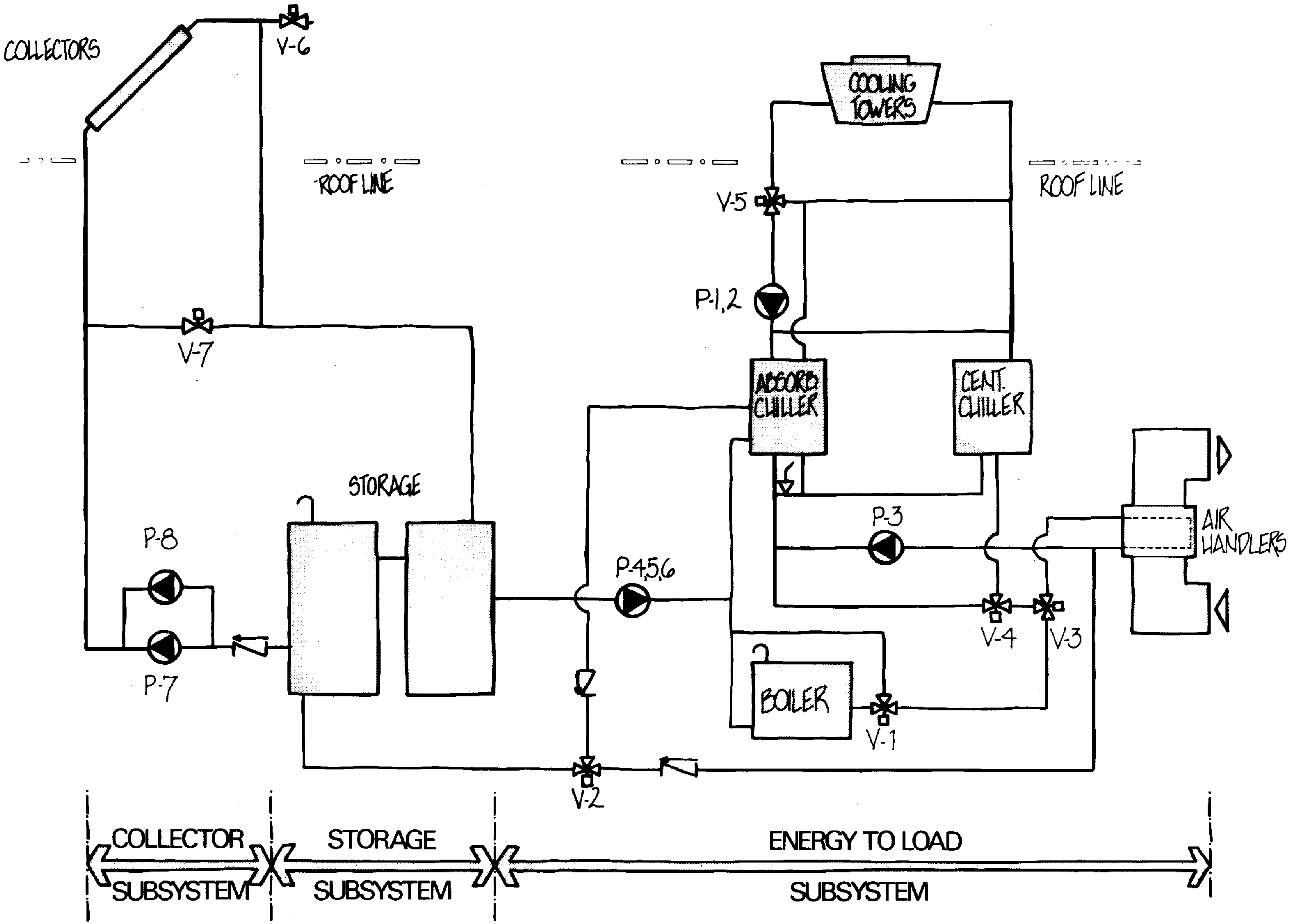


Figure IV-A-1. Overall System Schematic

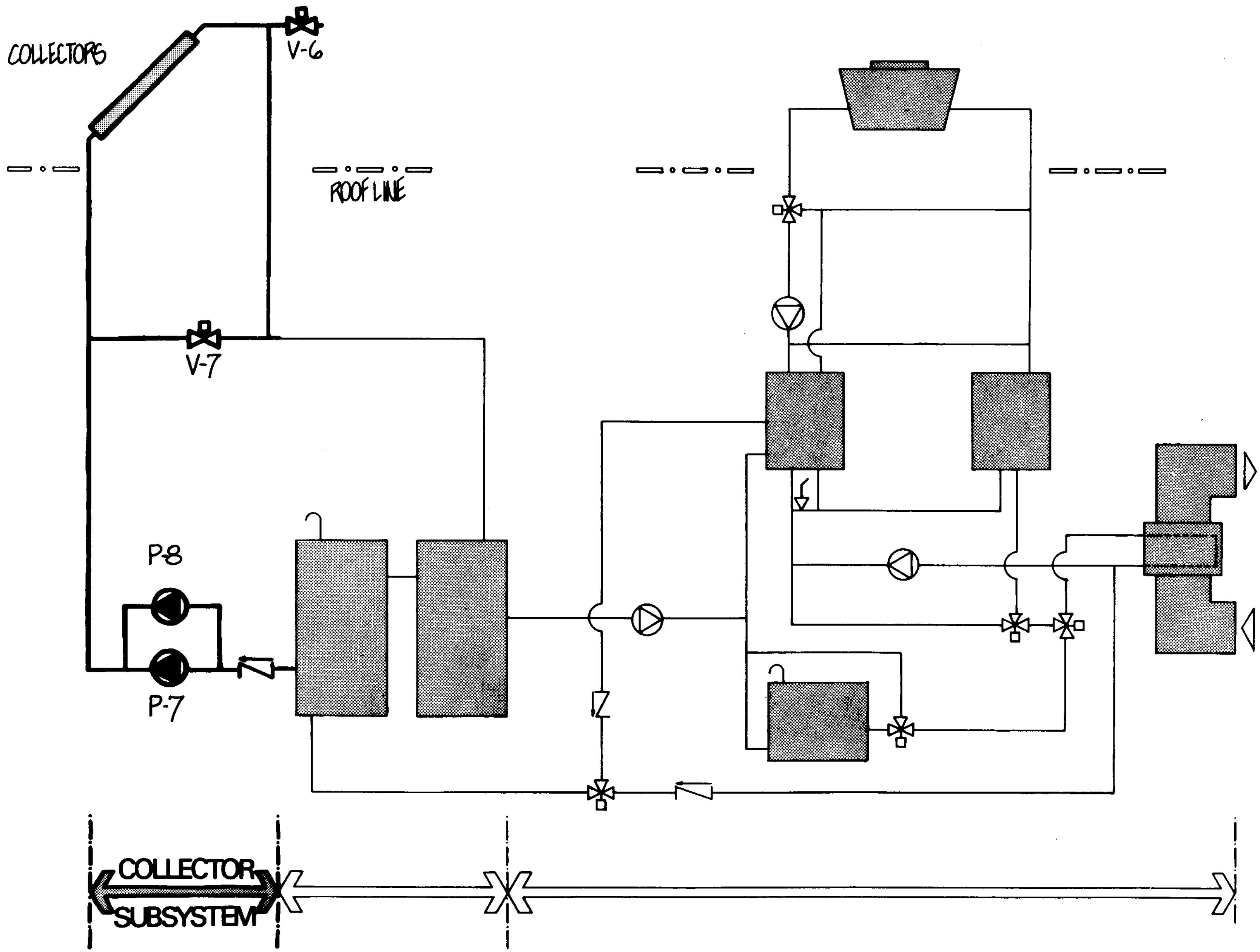


Figure IV-B-1. Collector Subsystem

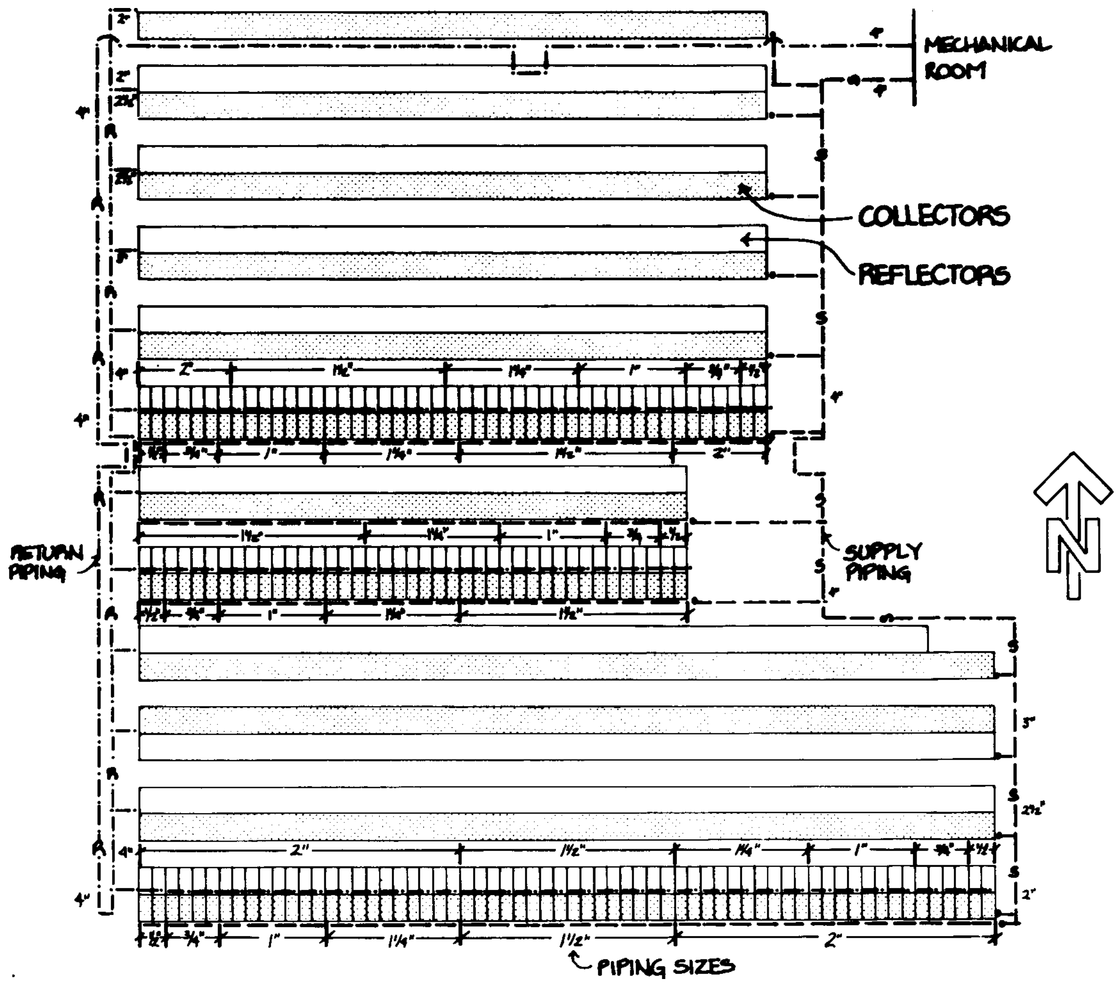


Figure IV-B-2. Solar Collector Array

- Gross area - 11,215 ft^2
- Net area - 10,943 ft^2
- Array configuration - 6 rows of 47 panels each, 2 rows of 41, and 4 rows of 64 (see figure IV-B-2)
- Collector enclosure
    - o Frame material - Aluminum
    - o Overall size - 76.2 in. long x 34.2 in. wide x 1.4 in. deep
    - o Filled weight - 105.0 lb
- Glazing
    - o Number - Double
    - o Material - Herculite tempered glass
    - o Thickness - 0.125 in.
    - o Transmittance - 85 percent
    - o Reflectance - 8 percent
- Absorber plate
    - o Type - Flat plate
    - o Material - Copper
    - o Overall plate thickness - 0.06 in.
    - o Coating - Selective black nonelectrolytic thin oxide film
    - o Absorptance - 87 percent
    - o Emittance - 12 percent
- Insulation - None. The collector panels are not insulated. Insulation is installed behind the collectors.

Collector/Reflector Support (see figure IV-B-3)
General Description

The collector panels are installed in an aluminum skylight glazing system, set similarly to a standard insulated glass panel. The plate glass reflector units are installed in a corresponding glazing system which is secured behind every collector. The number of reflector units corresponds to the number of solar collectors in the following row with the exception of 40 skylights scattered throughout the array. These two aluminum framing systems are self-supporting. Since the collector framing and the reflector framing lean against each other forming a triangular structure, a minimum amount of additional structural support is required. The top of the frames is secured by means of an extruded aluminum angle separated by a dielectric pad. The bottom of the frames rests on a continuous roof curb. The roof curb is fabricated from structural steel angles which form a curb approximately 30 inches above the roof. The angle framing is knee braced to provide lateral support for the collector/reflector framing.

Collector/Reflector Support

- Structural framing material - Aluminum glazing frames
- Framing finish - Mill finish
- Fasteners - Bolts
- Collector attachment - The collector is integral with support

Reflectors

- General - Reflectors are mounted on the north side of the collector support and are of similar construction as the collector glazing
- Size - 9,215 ft^2
- Angle - 38° above horizontal
- Material - Mirror glass
- Backup material - 6 in. batt insulation
- Support material and installation - Aluminum glazing frame with gasketing similar to collector glazing

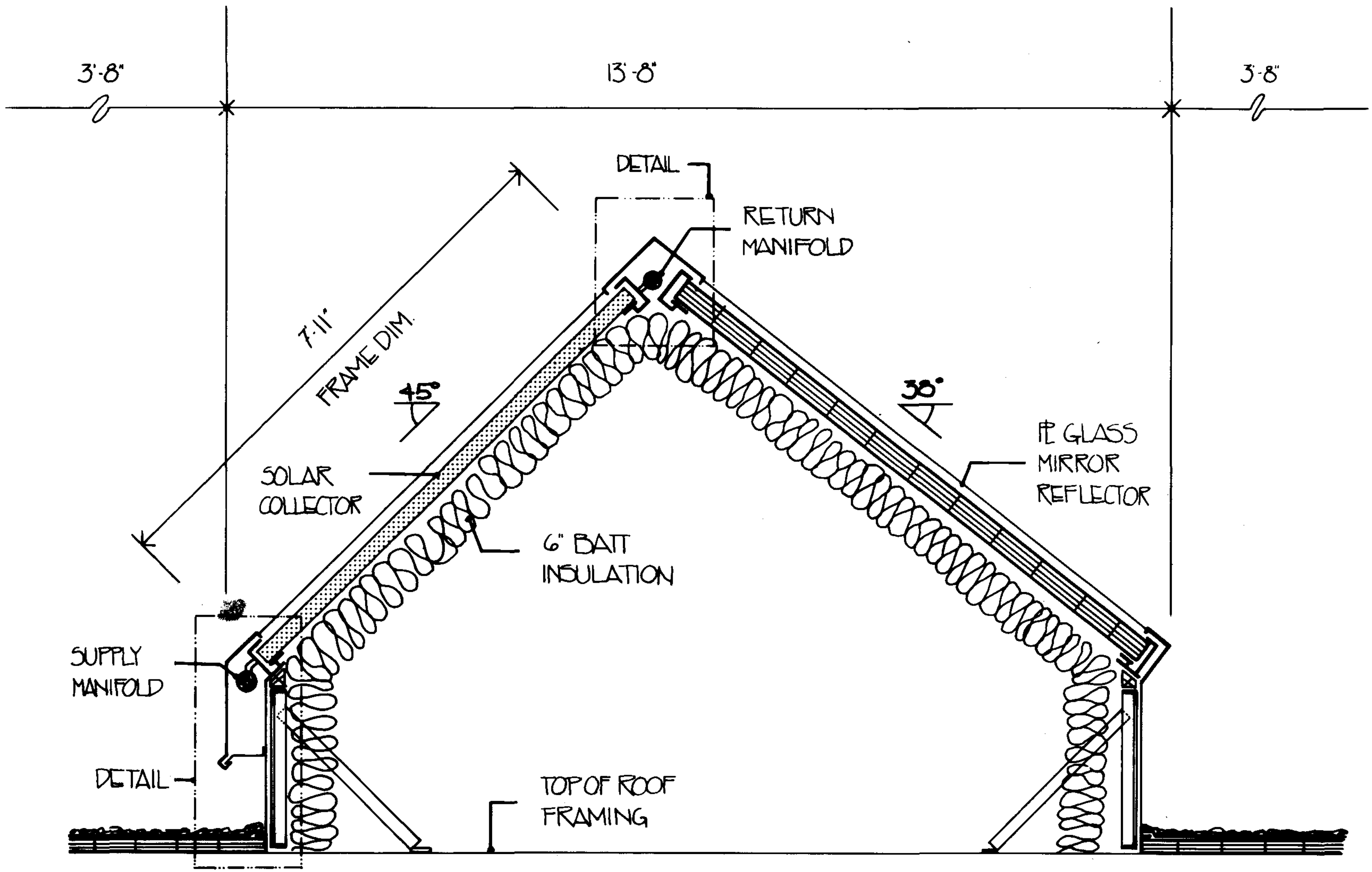


Figure IV-B-3. Cross-Section of Collector/Reflector Support

Collector Piping

- Piping between collector and manifold
  - Material - Silicone rubber with neoprene jacket
  - Manufacturer - Purosil
  - Diameter - 1/2 in. inside diameter
  - Length per collector - 1 ft
  - Installation technique - Unlined screw clamps on each end
  - Insulation - Double wrap of armorflex foam by Armstrong Mfg. Co.
- Manifold and branch piping (see figure IV-B-4)
  - Piping configuration - Reverse return
  - Material - Copper
  - Size - Varies 1/2 in. to 2 in. for collector headers
  - Total length - About 4,000 ft
  - Insulation - 1 in. fiberglass
  - Waterproofing - Collector enclosure
  - Supply piping support - Bent aluminum saddle on bracket supported by collector support (see figure IV-B-5)
  - Return piping support - Rests on top of collector panel and reflector support (see figure IV-B-6)
  - Piping roof support - None
  - Piping roof penetration - Pitch pocket
- Air venting piping
  - Material - Copper
  - Insulation - None
  - Size - 1/2 in. diameter
- Vents
  - Automatic - Barber Coleman MK 2690 Pneumatic Actuator

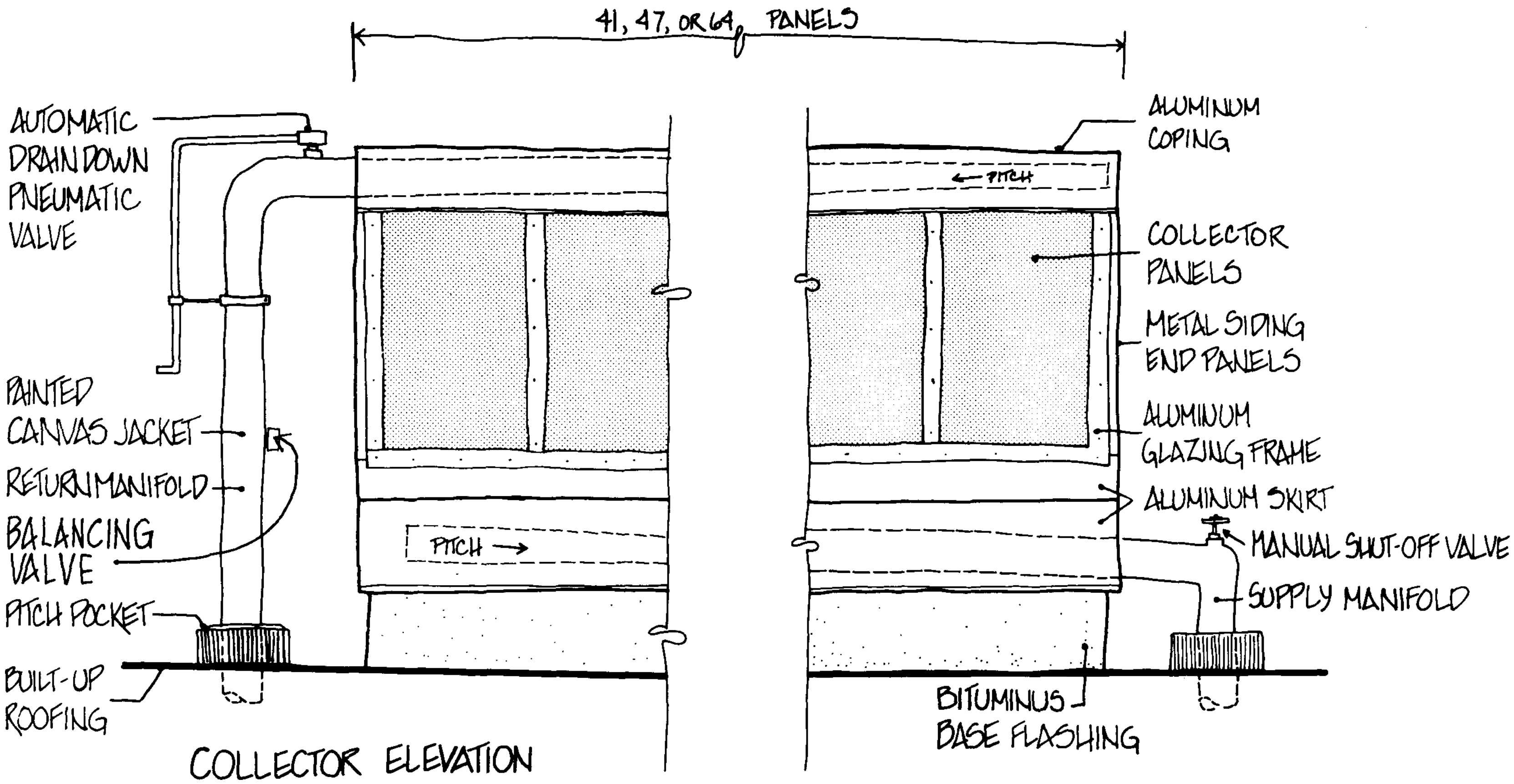


Figure IV-B-4. Collector Manifold Piping

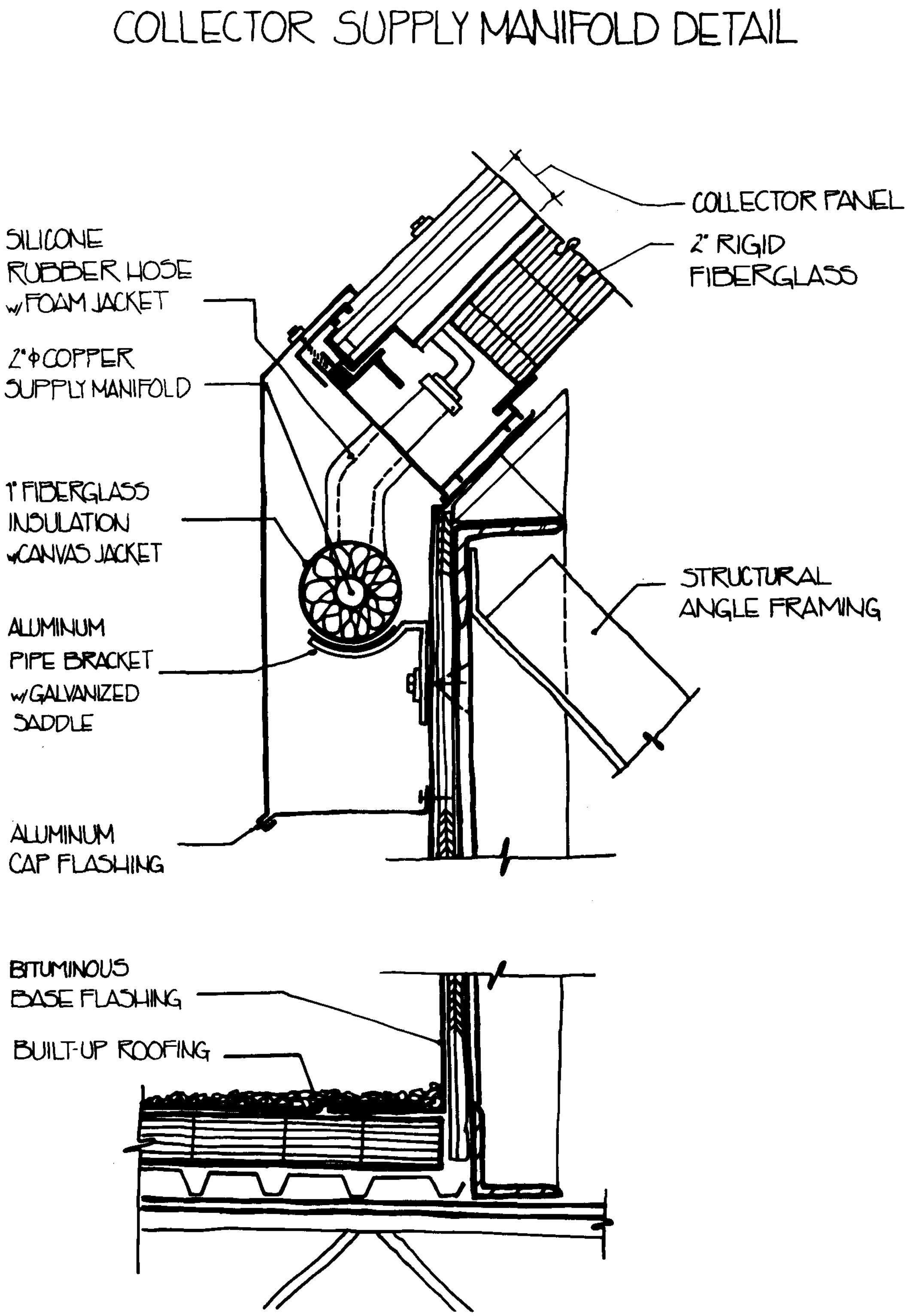
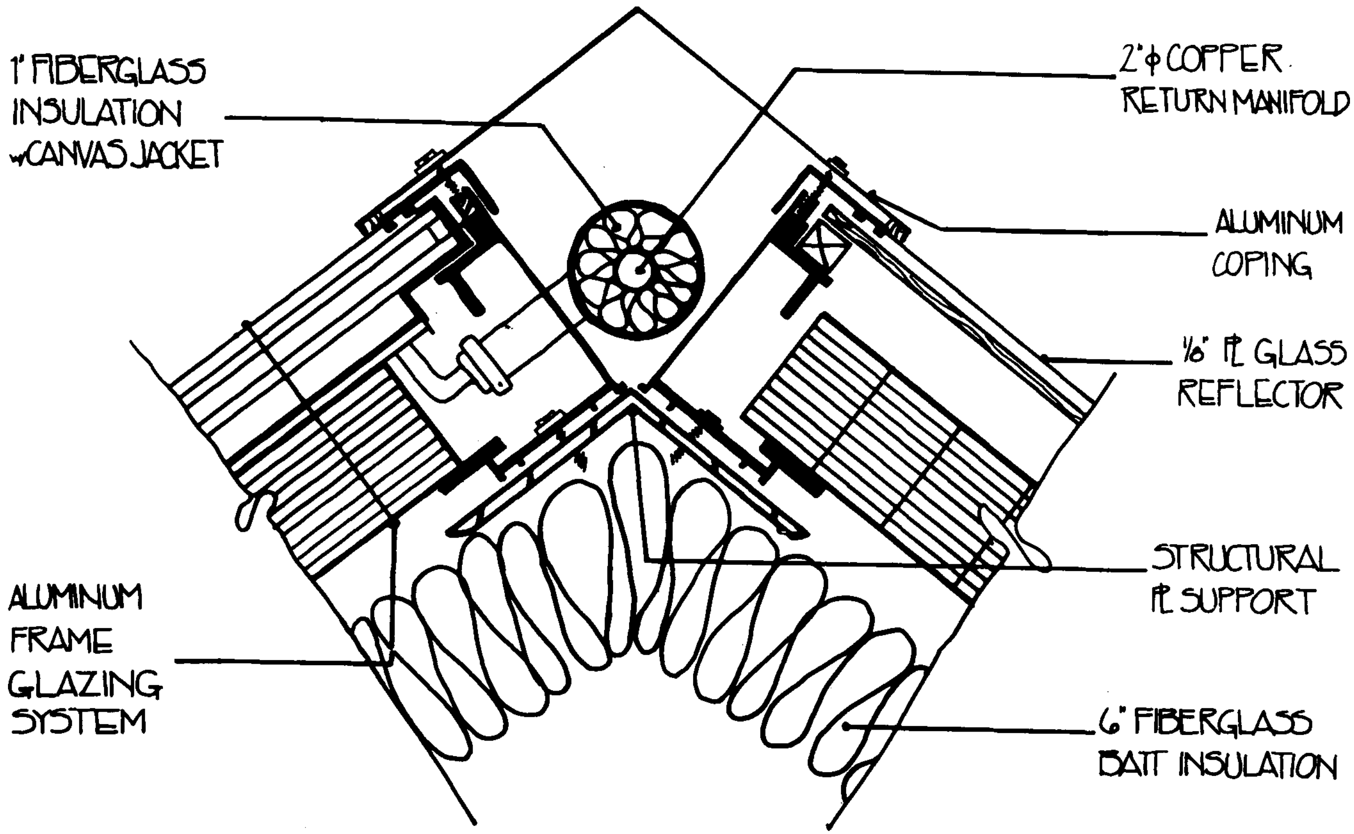


Figure IV-B-5. Collector Supply Manifold Detail



COLLECTOR RETURN MANIFOLD DETAIL

Figure IV-B-6. Collector Return Manifold Detail

- Valves
  - Balance - Located on the return manifold of each array
  - Shut off - Made by Fairbanks, Model number 0280 and are located on the supply main to each array

Heat Transfer Medium

- Type - De-ionized water

C. Storage Subsystem

General Description (see figure IV-C-1)

Two 10,000-gal hot water storage tanks are located in a room adjacent to the mechanical room. The tanks are atmospherically vented, are 13-ft long, and have a 10.5-ft diameter. Both tanks are covered with 6 in. of foamed urethane insulation and an asbestos coating. The tanks are piped in series so that the collector water is removed from the warm tank and stored in the hot tank. Both tanks are connected and are partially full for a total storage capacity of about 17,500 gal. The additional capacity is used for thermal expansion of water and for storage of collector water for draindown (see figure IV-C-2).

- Location - Inside building in a room adjacent to the mechanical room
- Capacity - 10,000 gal for each tank
- Number - Two
- Size - 10.5-ft diameter by 13.0-ft long
- Construction - 5/16 in. steel
- Operating pressure - Atmospheric
- Insulation - 6 in. of foamed urethane insulation (R-35) covered by asbestos
- Waterproofing - None required
- Installation - Resting horizontally on four steel legs on concrete floor
- Immersed coils - None

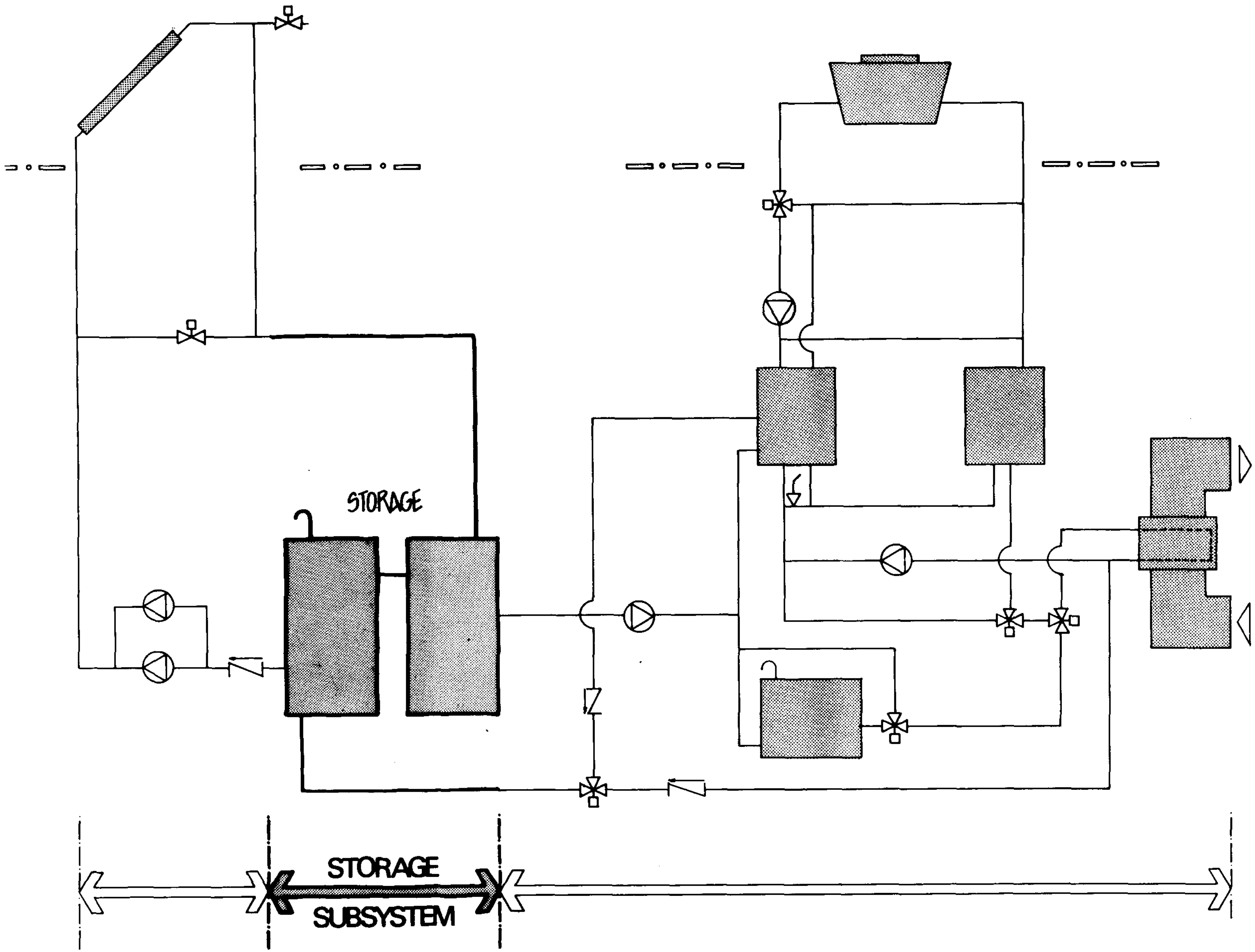
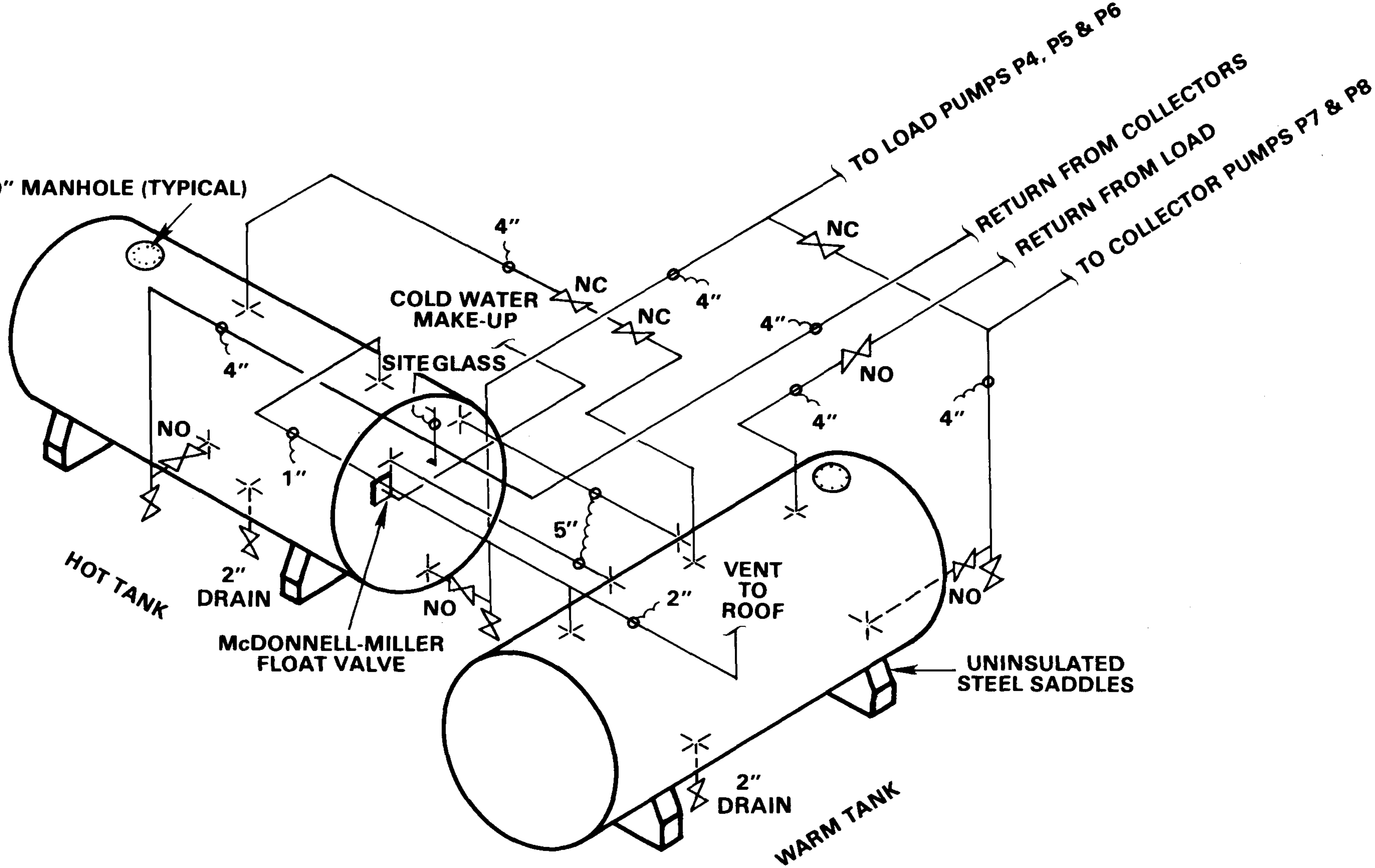


Figure IV-C-1. Storage Subsystem



NOTES
1. EACH TANK HAS 10,000 GAL CAPACITY
2. TANK DIMENSIONS ARE 10'6" DIA by 15'8" LONG
3. EACH TANK IS INSULATED WITH 6" OF FOAMED URETHANE INSULATION AND BY ASBESTOS COATING

Figure IV-C-2. Storage System Detail

- Piping connections - Welded pipe flange connections
- Sensor probe installation - Welded pipe flange connections

D. Energy-to-Load Subsystem

General Description

Space heating is provided by circulating warm water from the storage tanks to the five air handling units. Four of the air handling units are located in the mechanical room, the remaining unit is located in a hallway. An oil-fired boiler adds supplemental heating to raise the water temperature to 110° F. A mixing valve, V-1, modulates the flows from the storage tank and the boiler.

Space cooling is provided from either the absorption chiller or the centrifugal chiller; these chillers do not operate together. Storage water is circulated through the generator for the absorption chiller. Chilled water is used directly for space cooling and is not stored.

See table IV-D-1 for the pump schedule and table IV-D-2 for the air handling unit schedule.

Space Heating

- Piping - Steel
- Valves (V-1 and V-3)
  - o Type - Pneumatic activated
  - o Manufacturer - Barber Coleman
- Boiler
  - o Type - Oil-fired furnace
  - o Manufacturer/Model No. - Peerless/RL6.2-0-03
  - o Input - 8.05 gal/hr of fuel oil
  - o Output - 780,000 Btu/hr water
  - o Pressure - 30 lb water

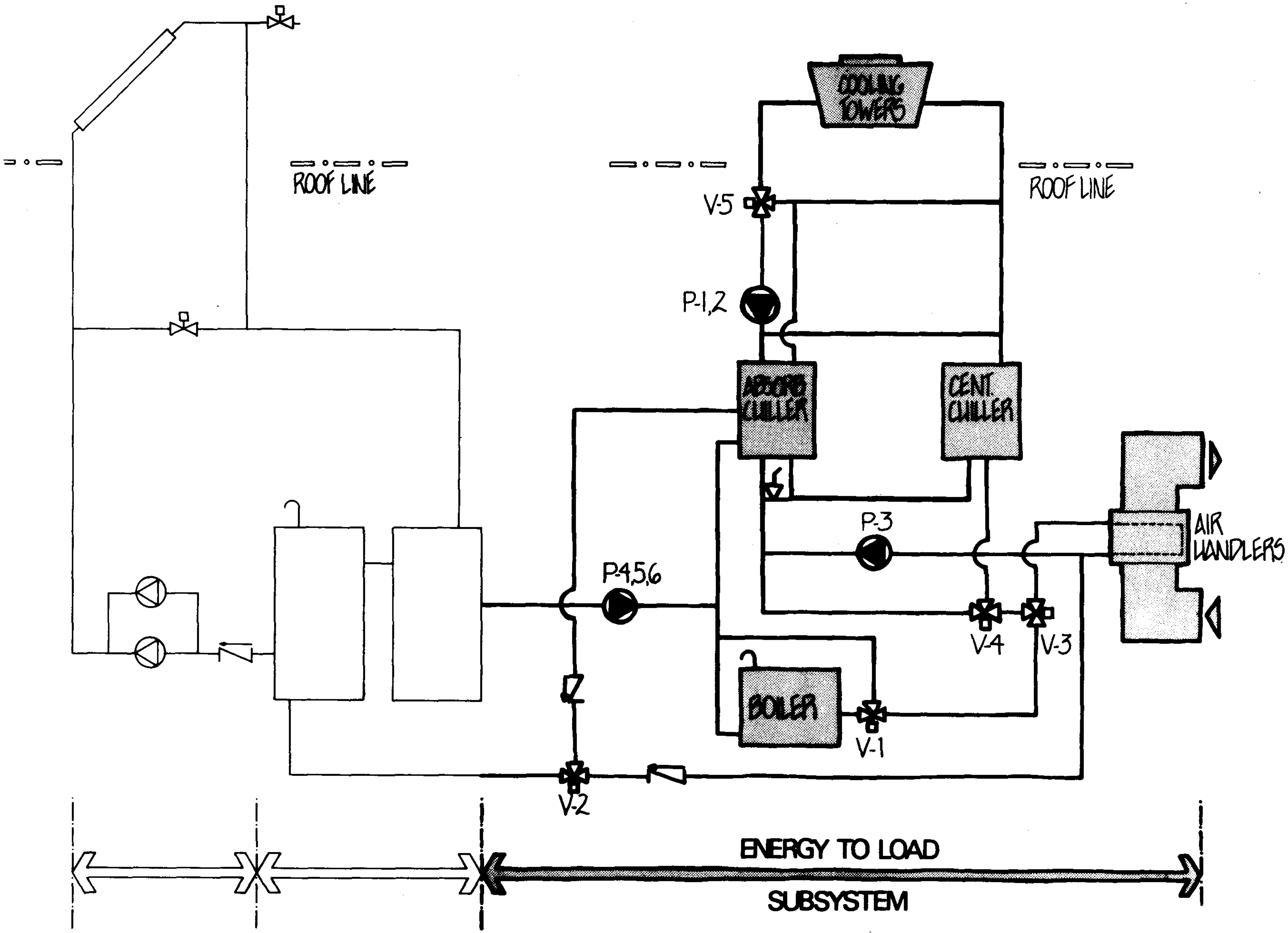


Figure IV-D-1. Energy-to-Load Subsystem

Table IV-D-1. Pump Schedule

PUMP NO	SERVICE	MANUFACTURER	MODEL NO	TYPE	FLOW RATE (GPM)	HEAD (ft)	POWER (HP)	REMARKS
P1	Cond.	Armstrong	3E 4030	Centrifugal	330	65	10	
P2	Cond.	Armstrong	3E 4030	Centrifugal	330	65	10	Standby pump
P3	CHWS	Armstrong	3E 4030	Centrifugal	330	65	10	
P4	System	Armstrong	2.5E 4030	Centrifugal	172	65	5	
P5	System	Armstrong	2.5E 4030	Centrifugal	172	65	5	
P6	System	Armstrong	2.5E 4030	Centrifugal	172	65	5	
P7	Solar	Armstrong	2.5E 4030	Centrifugal	280	49	7.5	
P8	Standby	Armstrong	2D 4030	Centrifugal	80	49	3	Emergency Pump

Table IV-D-2. Air Handling Unit Schedule

ZONE	AIR FLOW RATE (CFM)	COOLING					HEATING				WATER FLOW RATE (GPM)	FAN MOTOR (Hp)
		CAPACITY (Btu/hr)	ENTERING AIR TEMP		WATER TEMP		CAPACITY (Btu/hr)	ENTERING AIR TEMP	WATER TEMP			
			DB (°F)	WB (°F)	ENTERING (°F)	LEAVING (°F)			ENTERING (°F)	LEAVING (°F)		
1	11,200	301,000	79.8	66.5	45	55	287,500	62.4	110	100	60	5
2	19,900	567,000	80.0	66.5	45	55	276,300	61.9	110	100	110	20
3	8,000	228,000	80.5	66.9	45	55	164,500	50.7	110	100	45	3
4	12,800	374,000	79.0	66.0	45	55	160,200	65.6	110	100	75	15
5	2,280	64,600	79.5	66.2	45	55	38,600	61.8	110	100	14	1

Space Cooling (see table IV-D-3 for the chiller and cooling tower schedule)

- Piping - Steel
- Valves (V-1, V-3, V-4 and V-5)
    - o Type - Pneumatic activated
    - o Manufacturer - Barber Coleman

E. Control Subsystem

General Description

The solar energy system can operate in five modes: (1) Solar energy collection; (2) solar heating; (3) solar cooling; (4) auxiliary cooling; and (5) draindown. System operations are controlled by several temperature sensors. The onsite temperature sensors are reported in table IV-E-1. The truth table for valve and pump operations is shown in table IV-E-2.

1. Solar Energy Collection Mode

General Description—Figure IV-E-1 is the flow diagram for the Solar Energy Collection Mode. The solar collector pump P7 circulates storage water through the collectors when the temperature of the absorber plate (TS2) exceeds the temperature of the hot storage tank (TS5) by 10° F. The flow rate for this mode is 280 gal/min.

Overheat protection is provided by circulated storage water from pump P-8. The flow rate for this mode is 80 gal/min. An emergency standby propane-fired generator will operate pump P-8 in the event of a power failure.

2. Solar Heating Mode

General Description—Figure IV-E-2 is the flow diagram for the solar heating mode. Water from the storage tank is circulated through hydronic coils in the multi-zone airhandling units whenever the room temperature in a zone is less than 68° F. Two

Table IV-D-3. Chiller and Cooling Tower Schedule

UNIT	MANUFACTURER	MODEL NAME	MODEL NUMBER	CAPACITY (TONS)	LOOP				
					NAME	ENTERING WATER TEMP (°F)	LEAVING WATER TEMP (°F)	FLOW RATE (GPM)	PRESSURE DROP (in H_2O)
Absorption Chiller	Trane	Absorption Cold Generator	ABSC0IA4W68CF	80	Chilled Water	54	48	190	96
					Condenser Water	85	91	900	19
					Generator Water	185	171	190	9
Centrifugal Chiller	Trane	Centravac	CVHA-CIIC-HA-07BBIHIAB25HIA5	118	Chilled Water	54	44	320	16
					Condenser Water	85	95	360	16
Cooling Tower	Baltimore Aircoil		JST-200B	163	Condenser Water	93	85	746	

Table IV-E-1. Onsite Temperature Sensors

TEMPERATURE[1] SENSOR	SENSOR NUMBER	SENSOR MODEL NUMBER
Ambient air[2]	TS1	TS-8501
Absorber plate	TS2	SYZE-13158
Solar Collector Supply	TS3	TS-8201
Solar Collector Return	TS4	TS-8405
Storage Tank #1	TS5	TS-8201
Storage Tank #2	TS6	TS-8201
System Supply Water	TS7	TS-8201
System Return Water	TS8	TS-8201
Chilled Water Intermediate	TS9	TS-8201
Chilled Water Supply	TS10	TS-8201
Chilled Water Return	TS11	TS-8201
Boiler Water Supply	TS12	TS-8201
Hot Water Supply	TS13	TS-8201
Air Handling Unit #1, Entering Air	TS14	TS-8405
Air Handling Unit #1, Discharge Air	TS15	TS-8201
Air Handling Unit #2, Entering Air	TS16	TS-8405
Air Handling Unit #2, Discharge Air	TS17	TS-8201
Air Handling Unit #3, Entering Air	TS18	TS-8405
Air Handling Unit #3, Discharge Air	TS19	TS-8201
Air Handling Unit #4, Entering Air	TS20	TS-8405
Air Handling Unit #4, Discharge Air	TS21	TS-8201
Music Room	TS22	TS-8131
Art Room	TS23	TS-8131
Classroom B-71	TS24	TS-8131
Classroom B-7	TS25	TS-8131
Classroom B-83	TS26	TS-8131
Classroom B-82	TS27	TS-8131

[1] All temperature sensors are Solid State Electronic Sensors manufactured by Barber Coleman.

[2] Ambient air temperature sensor has a bulb clip and an AT-211 Weather Shield.

Table IV-E-2. Control Valve and Pump Legend

	OPERATING MODES				
	Solar Energy Collection	Solar Heating	Solar Cooling	Auxiliary Cooling	Draindown
VALVES					
V1	X	M	X	X	X
V2	X	H	C	X	X
V3	X	H	C	C	X
V4	X	X	M	M	X
V5	X	X	M	M	X
V6	X	X	X	X	O
V7	X	X	X	X	O
PUMPS					
P1 and P2	OFF	OFF	ON	ON	OFF
P3	OFF	OFF	ON	ON	OFF
P4, P5 and P6	OFF	ON	ON	OFF	OFF
P7 and P8	ON	OFF	OFF	OFF	OFF

LEGEND

X = Closed
O = Open
M = Modulated
H = Valve in heating position
C = Valve in cooling position

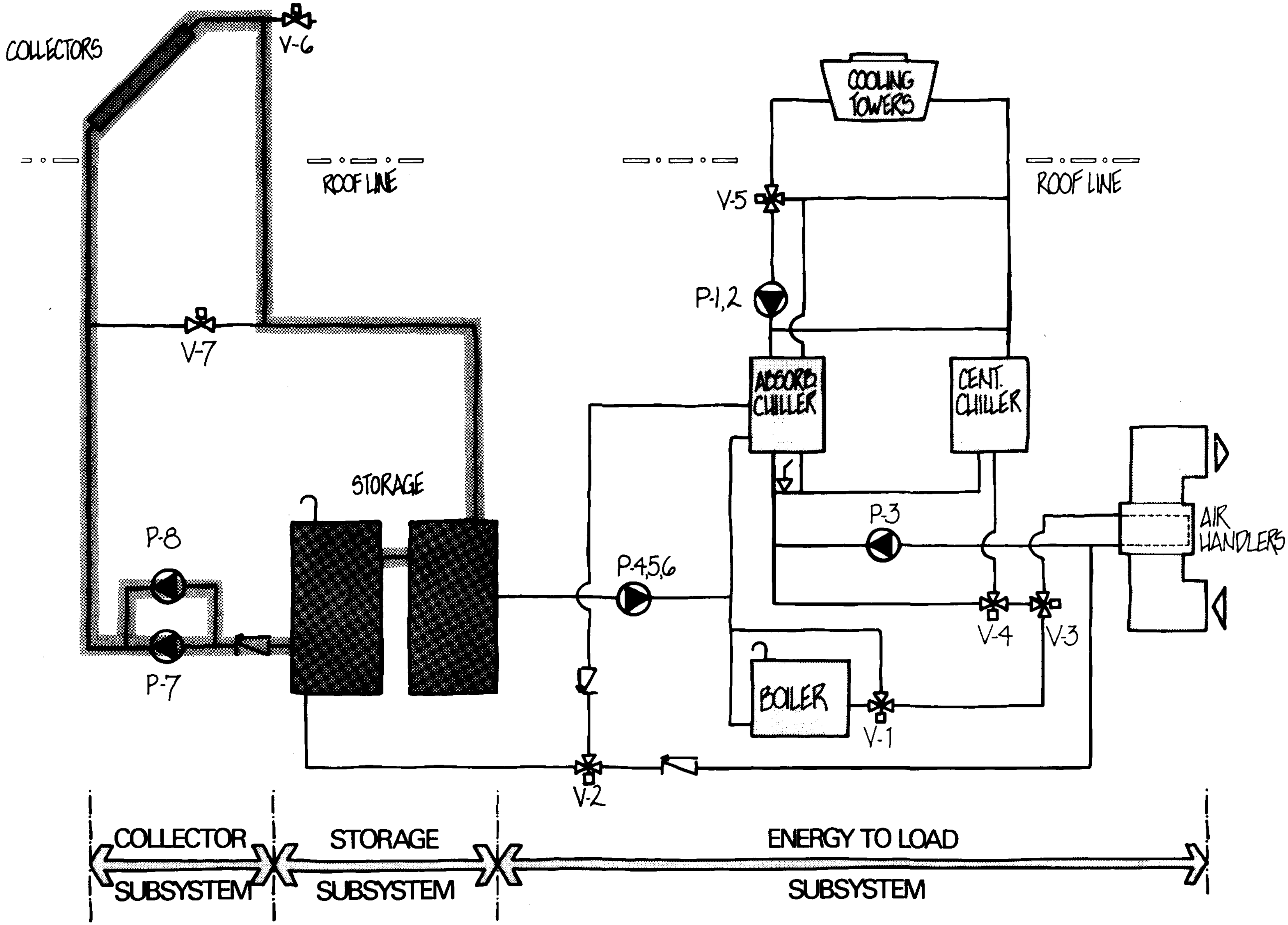


Figure IV-E-1. Solar Energy Collection Mode of three pumps (P4, P5, and P6) operate. If the storage water temperature is below the minimum temperature of 110° F, some of the water is circulated through the auxiliary boiler. Valve V-1 modulates the flow through the boiler to maintain 110° F water to the air handling units.

3. Solar Cooling Mode

General Description--Figure IV-E-3 is the flow diagram for the solar cooling mode. Storage water is circulated by pumps P4, P5, and P6 through the absorption chiller and back to the storage tanks through valves V-12, V-11, and V-2. Chilled water from the absorption chiller is automatically circulated through the electric centrifugal chiller. However, the electric chiller never operates in the solar cooling mode. Valve V-4 modulates the chilled water flow to maintain a chilled water temperature of 45° F. If the chilled water temperature rises to 48° F, the absorption chiller turns off and space cooling is provided by the auxiliary system. The solar cooling mode starts when there is a cooling demand and the storage water temperature exceeds 185° F. The absorption chiller turns off when the storage water temperature drops below 170° F.

4. Auxiliary Cooling Mode

General Description--Figure IV-E-4 is the flow diagram for the auxiliary cooling mode. The electric centrifugal chiller operates whenever the absorption chiller cannot handle the cooling load.

5. Draindown Mode

General Description--When the temperature differential between the collector outlet and the warmer storage tank reaches 3° F and the collector pump has been deactivated for 15 minutes, the draindown mode is entered. Valves V-6 and V-7 open and drains the collectors into the storage tank. Thus, the solar collectors drain every day automatically.

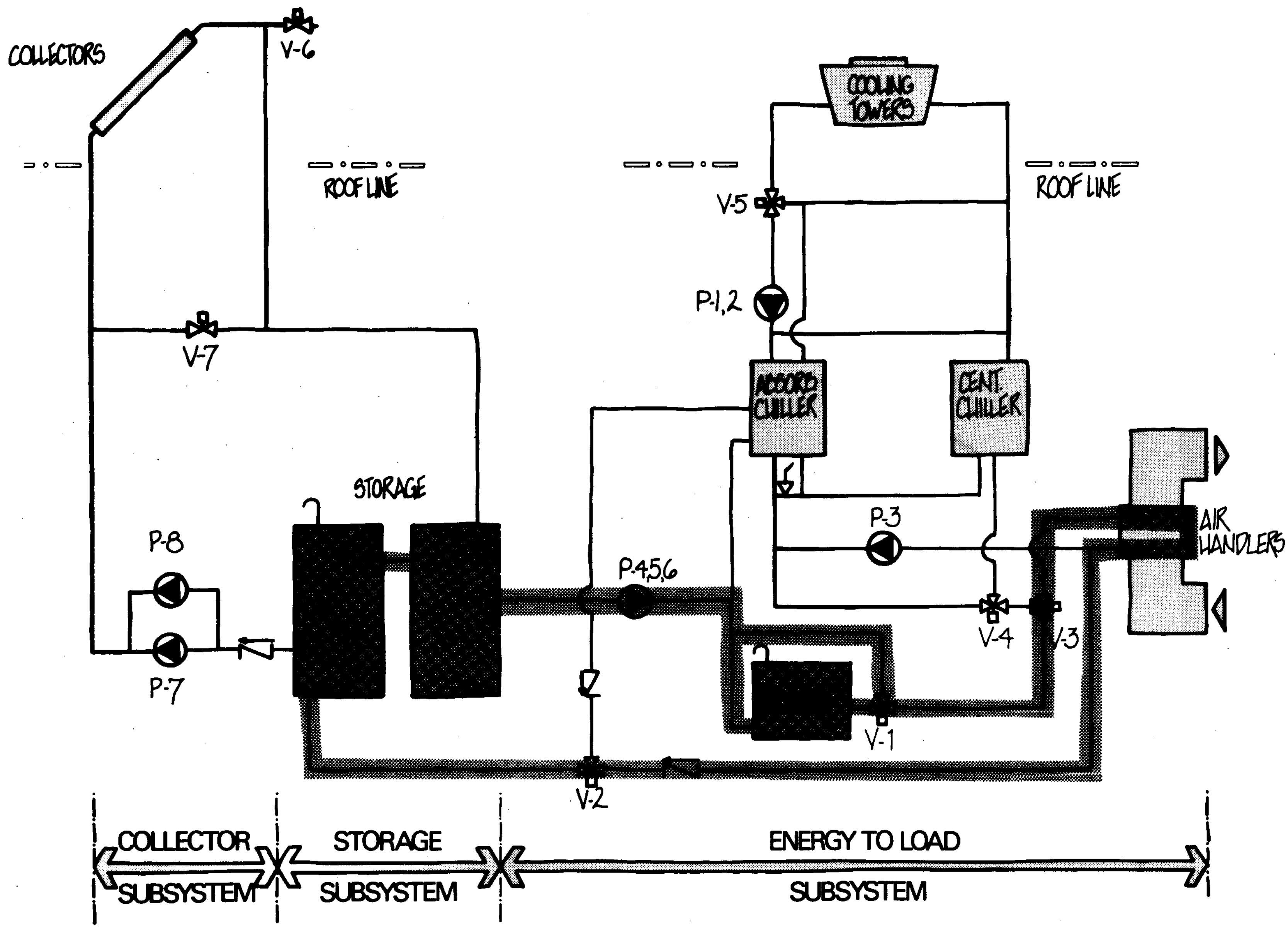


Figure IV-E-2. Solar Heating Mode

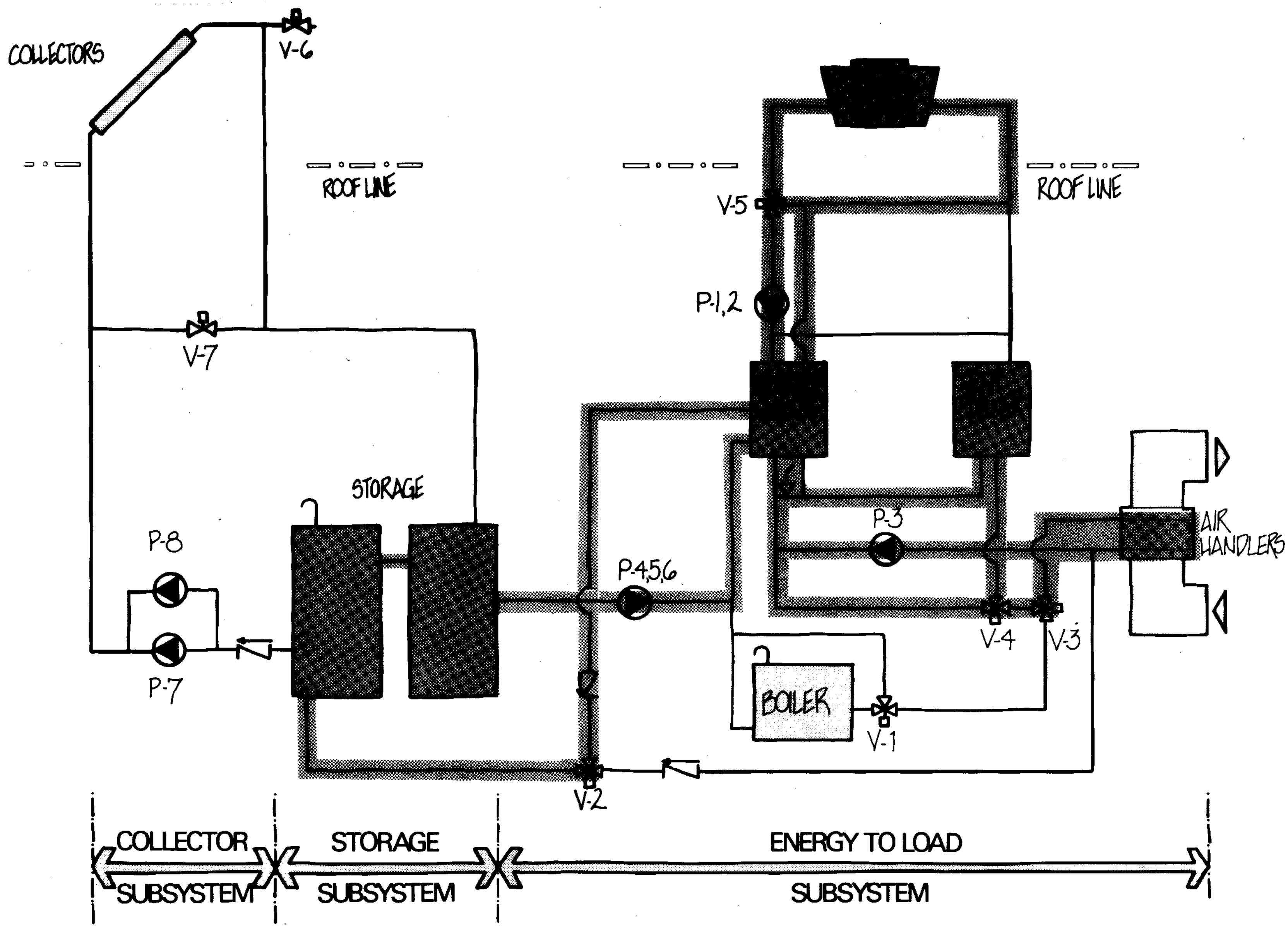


Figure IV-E-3. Solar Cooling Mode

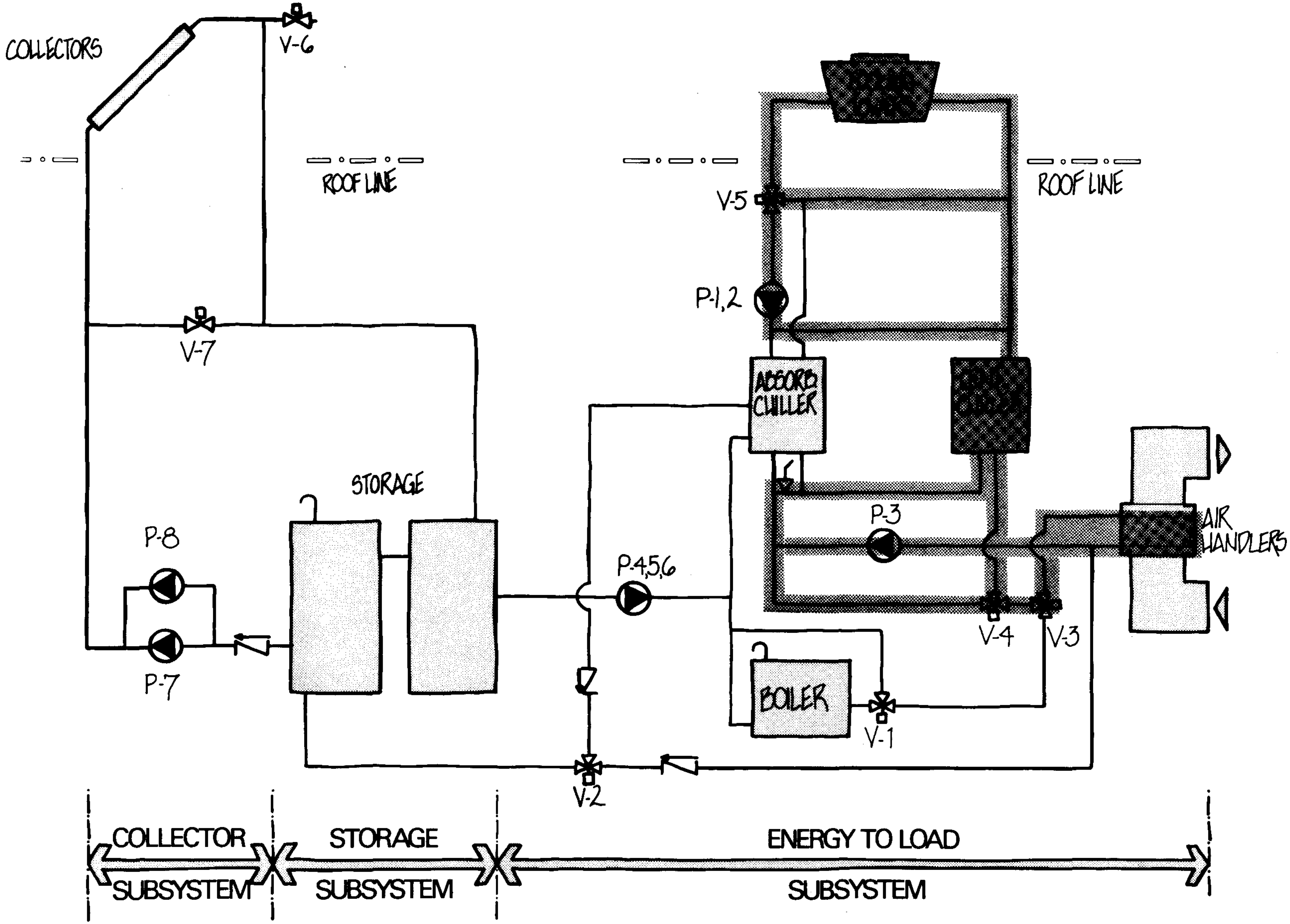


Figure IV-E-4. Auxiliary Cooling Mode

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 commercial demonstration sites which were selected for thermal performance evaluation. The data flow in the Network is shown in figure V-A-2. Products from the Network include 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.

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 are 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 date 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. Onsite Instrumentation

The onsite 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 is presented in tables V-B-1 through V-B-4, respectively. Sensor locations are shown in figure V-B-1.

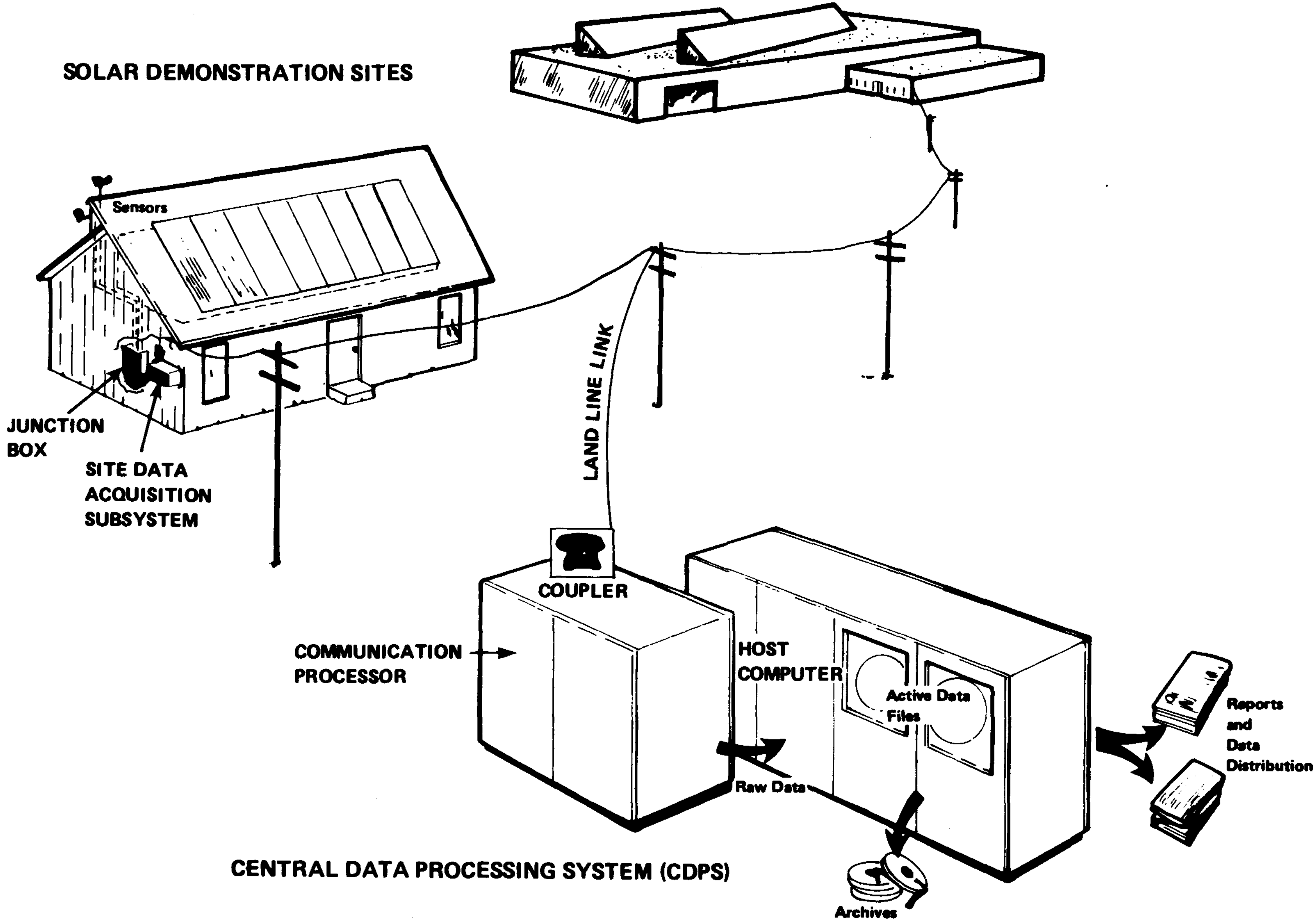


Figure V-A-1. The National Solar Data Network

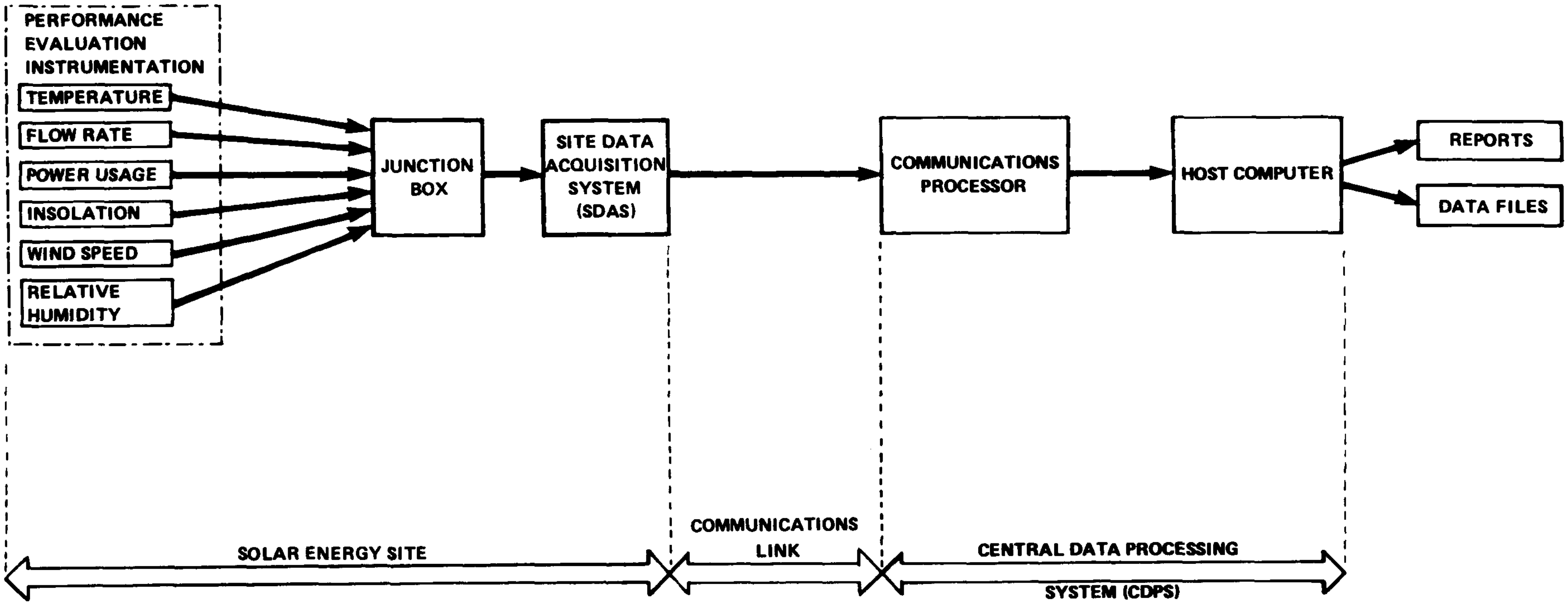


Figure V-A-2. Data Flow Path for the National Solar Data Network

Table V-B-1. Temperature Instrumentation for Page Jackson Elementary School

SENSOR	NAME	RANGE (F) Min.	RANGE (F) Max.	MFGR.	THERMOWELL PART NO.
T001	Outside Ambient Air Temperature	-20	120	Minco	IS4
T100	Collector Array Inlet Temperature	30	230	Minco	F203U15
T150	Collector Array Outlet Temperature	30	230	Minco	F203U15
T102	Storage Output Temperature	30	230	Minco	F203U15
T152	Storage Inlet Temperature	30	230	Minco	F203U15
T200	Hotter Storage Tank—Top Temperature	30	230	Minco	F203U15
T201	Hotter Storage Tank—Bottom Temperature	30	230	Minco	F203U214
T202	Cooler Storage Tank—Middle Temperature	30	230	Minco	F203U240
T400	Heating Boiler Inlet Temperature	30	230	Minco	F203U15
T450	Heating Boiler Outlet Temperature	30	230	Minco	F203U15
T401	Heating Water Return Temperature	30	230	Minco	F203U15
T451	Heating Water Supply Temperature	30	230	Minco	F203U15
T500	Absorption AC Generator Water Outlet Temperature	30	230	Minco	F203U15
T550	Absorption AC Generator Water Inlet Temperature	30	230	Minco	F203U15
T501	Absorption AC Chiller Water Outlet Temperature	-20	120	Minco	F203U15
T551	Absorption AC Chiller Water Inlet Temperature	-20	120	Minco	F203U15
T502	Centrifugal AC Chiller Outlet Temperature	-20	120	Minco	F203U15
T552	Centrifugal AC Chiller Return Water Temperature	-20	120	Minco	F203U15
T600	Inside Ambient Air Temperature	-20	120	Minco	IS4
T601	Inside Ambient Air Temperature	-20	120	Minco	IS4
T602	Inside Ambient Air Temperature	-20	120	Minco	IS4

Table V-B-2. Flow Rate Instrumentation for Page Jackson Elementary School

SENSOR	NAME	RANGE (GPM)		MFGR.	MODEL NO
		Min.	Max.		
W100	Collector Array Flow Rate (gpm)	0	280	Ramapo	MKV-4-W07
W400	Heating Water Through Boiler Flow Rate (gpm)	0	170	Ramapo	MKV-4-W07
W401	Total Heating Water Flow Rate (gpm)	0	170	Ramapo	MKV-4-W07
W500	Absorption AC Generator Water Flow Rate (gpm)	0	170	Ramapo	MKV-4-W07
W501	Absorption AC Chiller Water Outlet Flow Rate (gpm)	0	330	Ramapo	MKV-4-W07
W502	Centrifugal Chiller Water Outlet Flow Rate (gpm)	0	330	Ramapo	MKV-4-W07
F400	Boiler Fuel Rate (gal)	0	8.5	American Meter	MKV-1/2-J07

Table V-B-3. Power Instrumentation for Page Jackson Elementary School

SENSOR	NAME	PHASE	RANGE (kW) Min.	Max.	MFGR.	MODEL NO
EP100	Collector Pump Power (P-7 & P-8)		0	12	Ohio Semitronics	PC5-18
EP400	Heating Water Pump Power (P-4, P-5, P-6)		0	18	Ohio Semitronics	PC5-27
EP500	Chilled Water Pump Power (P-3)		0	12	Ohio Semitronics	PC5-18
EP501	Cooling Tower Pump Power (P-1, P-2)		0	40	Ohio Semitronics	PC5-54
EP502	Centrifugal Chiller Power	3	0	120	Ohio Semitronics	PC5-66
EP503	Absorption Air Conditioner	3	0	6	Ohio Semitronics	PC5-9
EP600	Air Handling Unit No. 1	3	0	12	Ohio Semitronics	PC5-18
EP601	Air Handling Unit No. 2	3	0	60	Ohio Semitronics	PC5-57
EP602	Air Handling Unit No. 3	3	0	6	Ohio Semitronics	PC5-9
EP603	Air Handling Unit No. 4	3	0	60	Ohio Semitronics	PC5-57
EP604	Air Handling Unit No. 5	3	0	6	Ohio Semitronics	PC5-9

Table V-B-4. Miscellaneous Instrumentation for Page Jackson Elementary School

SENSOR	NAME	RANGE (Btu/ft^2-hr) Min.	Max	MFGR.	MODEL NO.
I001	Collector Plane Total Insolation	0	396.03	Eppley Labs Inc	PSP

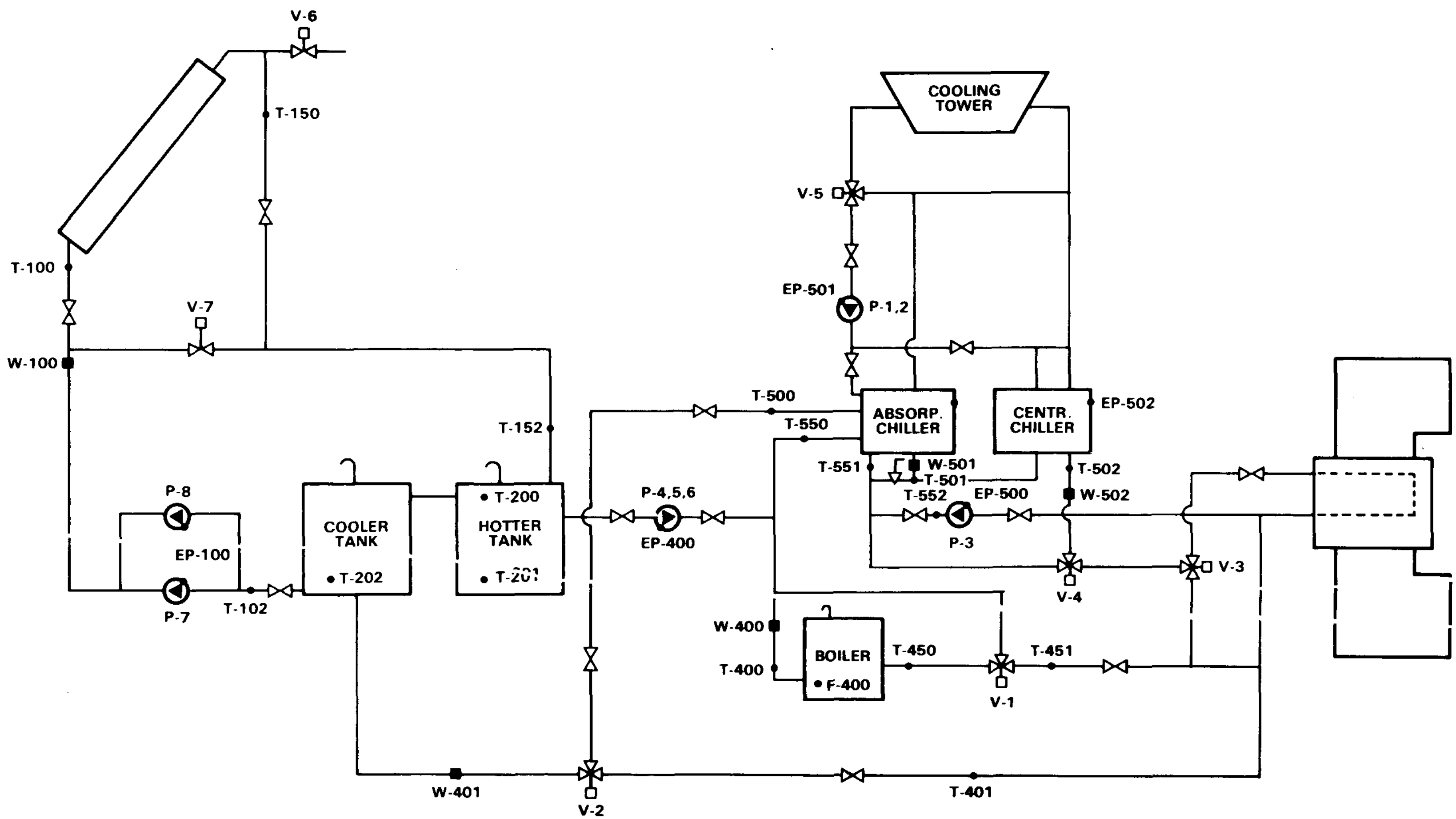


Figure V-B-1. Performance Instrumentation Schematic

VI. 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, which may be brought into a building to be conditioned or circulated.

ANTIFREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses a solution of water and glycol. This solution depresses its freezing point sufficiently to prevent possible water freeze in solar collectors and exterior piping.

AUXILIARY ENERGY SUBSYSTEM - The equipment which uses conventional energy sources to supplement the output provided by a solar energy system and to provide a full backup system when the solar system is inoperable.

BACKFLOW - The unintentional reversal of flow in a potable water distribution system by foreign or toxic substances that may contaminate the potable water.

BACKFLOW PREVENTER - 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 absorbs incident solar radiation and transfers the absorbed thermal energy to a heat transfer fluid.

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

CONCENTRATING SOLAR COLLECTOR - A solar collector which focuses beam radiation onto an absorber 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 that has the air conditioned for heating and cooling.

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

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 water droplets and cannot be focused.

DRAIN-DOWN FREEZE PROTECTION SYSTEM - A freeze protection system that prevents potential water freeze problems by automatically opening a valve to drain the solar collectors and exterior piping. Air is used for some systems, nitrogen for others.

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

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

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.

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 permanently oriented toward the sun which 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 is covered by one or more transparent covers. There are no concentrators or focusing aids in a flat-plate collector.

FOCUSING COLLECTOR - A solar collector which uses 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 at 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 shutdown or 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. Unit may also include additional components to heat the conditioned 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 use of an energy source other than the sun.

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

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.

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 a fraction of its 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—also includes 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 for use in heating or cooling air, or heating water during period of low insolation.

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

THERMOSTAT - A temperature dependent sensor which controls either the heating and cooling systems for space conditioning or the hot water heater.

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

TRACKING COLLECTOR - A solar energy collector that constantly moves to follow the path of the sun.

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

ZONE - Portions 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 GLOBE 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
- EJ — EXPANSION JOINT
- EXPANSION LOOP
- FLEXIBLE CONNECTION
- FLOWMETER FITTING
- FS — FLOW SWITCH
- PS — PRESSURE SWITCH
- PRESSURE GAUGE
- PUMP
- PIPE SLOPE
- STRAINER
- STRAINER, W/BLOW OFF
- TRAP
- C — CONTROL SENSOR
- INSTRUMENTATION SENSOR
- THERMOMETER
- THERMOMETER WELL ONLY
- CW — COLD WATER SUPPLY

AS	AIR SEPARATOR
EXP TK	EXPANSION TANK
WS	WATER SOFTENER
HED	HOSE END DRAIN

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