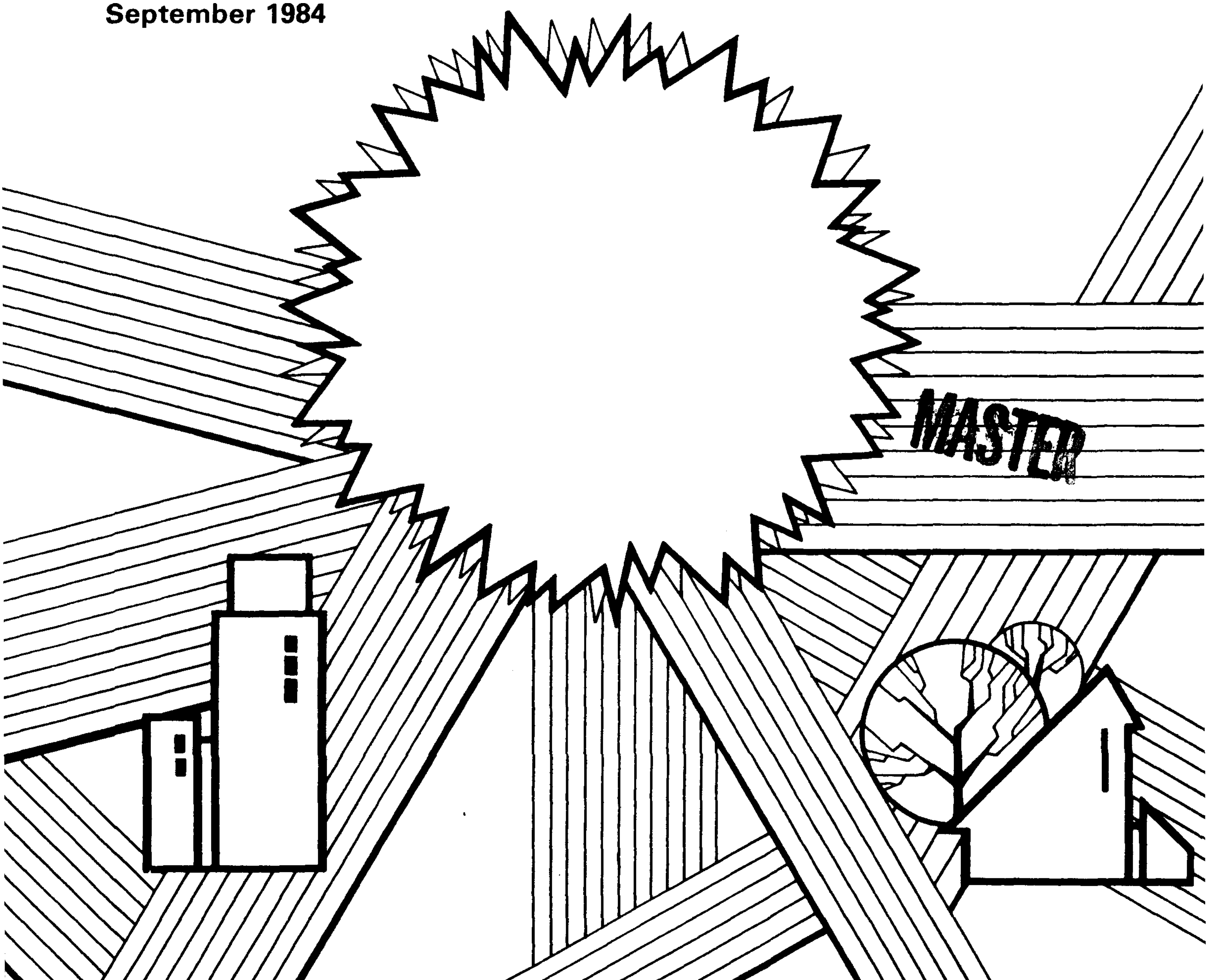
SOLAR/0011-84/02

SOLAR ENERGY SYSTEM CASE STUDY: OAKMEAD INDUSTRIES
Santa Clara, California

September 1984



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U.S. DEPARTMENT OF ENERGY
NATIONAL SOLAR DATA PROGRAM

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SOLAR ENERGY SYSTEM CASE STUDY

OAKMEAD INDUSTRIES

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The National Solar Data Network
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EXECUTIVE SUMMARY

A study is made of a solar energy system for space heating and domestic hot water loads. The Renault and Handley Building, referred to do Oakmead Industries site, is a commercial office and manufacturing facility located in Santa Clara, California. The building has approximately 60,000 square feet of floor area. The solar system has 2,622 square feet of liquid flat-plate collectors with a 6,500-gallon storage tank. The solar energy system installation is a retrofit which did not achieve its design solar fraction. The system, however, operated well and required minimal maintenance.

Performance data of the solar system was collected by the National Solar Data Network for two heating seasons, from 1980 to 1982. Highlights of the performance of the solar system during the two heating seasons are:

- The collector array exhibited good collector array efficiency. The storage tank is oversized which provided low collector inlet temperatures. The overall operational collector efficiency was 45%. The overall collector efficiency was 38%.

- The solar system had low operating energies which provided for good energy savings. The system averaged over $2,000 savings each year.

- The solar system provided 54% of the space heating load and 43% of the DHW load.

- The DHW load was larger than expected. As a result pump P4 was undersized and if larger, the solar contribution could have been greater, realizing higher effective savings.

- Weather conditions were well below the long-term average for Santa Clara, California. The average insolation was 1,483 BTU/ft^2-day compared to the long-term average of 1,599 BTU/ft^2-day.

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SECTION 1

INTRODUCTION

Several of the solar systems monitored by the National Solar Data Network (NSDN) have been selected for "case studies," an in-depth history and analysis. This report is a study of the solar system at Oakmead Industries, a space heating and domestic hot water (DHW) system for a 60,000-square-foot office and manufacturing building in Santa Clara, California. The solar system was designed by Western Energy, Inc. of Palo Alto, with technical supervision from Pacific Sun, Inc of Menlo Park, California.

The building is of single-story, slab-on-grade construction with 5 inch thick tilt-up concrete walls. North, east and west facing glazing systems are bronzed, thermopane glass. The northern section of each building is bermed to the glazing level. The roof structure is insulated to an equivalent of R-19.

The building utilizes approximately 2,600 ft^2 of high-performance, flat-plate collectors, mounted at 45° on the north overhang. Additionally, the building uses 1,400 ft^2 of vertical air-collectors affixed to the south wall. The liquid collectors supply heated water for perimeter space heating and service hot water generation. Storage is provided by 6,500-gallon atmospheric pressure water tank. The mechanical system is capable of accommodating the future absorption cooling equipment.

The south wall air-collector system is designed to augment the south perimeter heating systems. During the heating season, return air from the perimeter ducting is drawn through the air collector. The air collectors are operated during the daylight hours only, and utilize the energy as it is available. A southern overhang protects the array from overheating in the summer. The solar system operated well and was one of the better performers monitored by the NSDN.

SECTION 2

BUILDING DESCRIPTION

2.1 LOCATION

The Renault and Handley Building, referred to as Oakmead Industries, is one of two nearly identical solar heated buildings located at the Oakmead Industrial Park in Santa Clara, California. This commercial building contains approximately 60,000 square feet of floor area and is normally occupied six days a week, not including Sunday. The solar energy system installation is a retrofit and was originally designed to provide 85% of the annual heating requirements and 90% of the annual hot water demand. However, a significant new hot water load was added after the design projections. North, east, and west facing glazing systems are of bronzed, thermopane glass. The northern section of each building is bermed to the glazing level. The roof structure is insulated to an equivalent of R-19.

2.2 SYSTEM DESCRIPTION

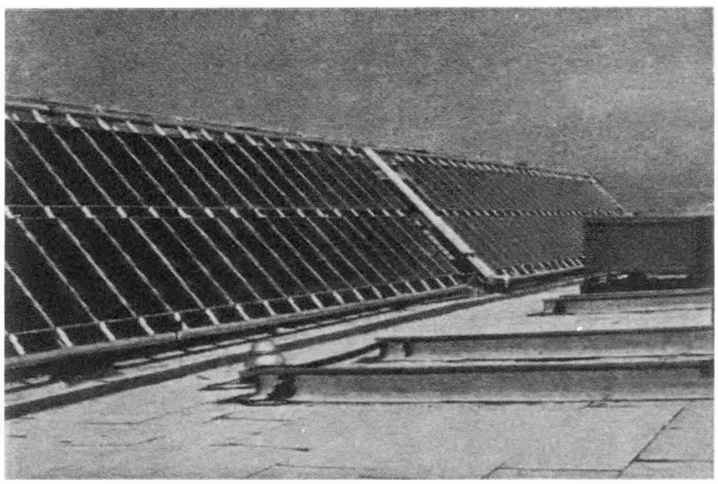
The building has two central heating zones, one for the north zone of the building and the other for the south zone. The north zone heating system provides space heating for the central electronics area and for several offices. The north zone is heated by a combination of solar energy from a liquid-based flat-plate collector array and an auxiliary gas-fired furnace. The south zone is heated by a hybrid passive/active solar energy system installed on the south wall, solar energy from the liquid flat-plate collectors, and by an auxiliary gas-fired furnace. Refer to Figure 1.

Liquid-Based Solar Subsystem - The liquid-based solar collectors utilize a 10% by weight solution of propylene-glycol in water as the heat transfer medium for collecting solar energy. The flat-plate collector array faces due south at a tilt of 45 degrees from the horizontal on the north overhang. The array is 2,622 square feet in area. The collector surface is enhanced with a black chrome selective surface and a single layer of water-white crystal glass.

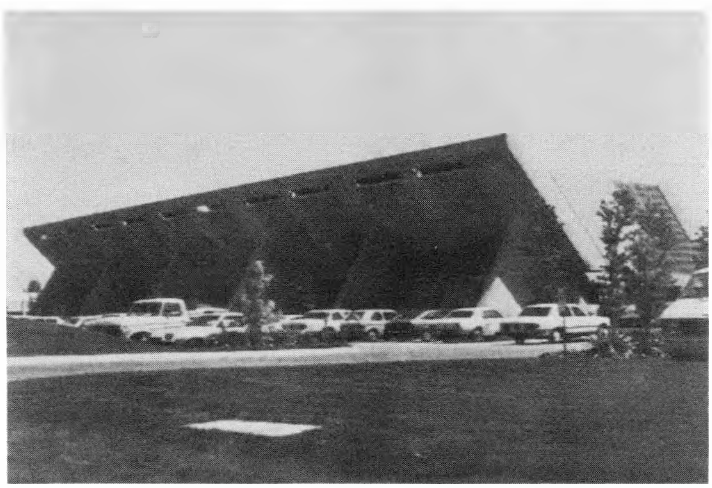
The collector array is connected with storage and loads through the primary heat exchanger. The heat exchange step has been included so that positive, chemically-based freeze protection methods can be employed.

Energy removal from the heat exchanger is accomplished by means of a recirculation loop on the storage side. This loop, designated as a Thermal Control Loop (TCL), provides a connection between the heat exchanger, the 6,500-gallon storage tank, and north and south zones space heating subsystems. The Thermal Control Loop strives to maintain a temperature between 120°F-125°F. Pump P3 maintains a constant flow of 45 gpm at the Thermal Control Loop, while valve AV2 modulates flow in and out of the Thermal Control Loop.

Air Collectors on South Wall



Liquid Collector Array on North Facia



Oakmead Industries Solar Site

OAKMEAD INDUSTRIES

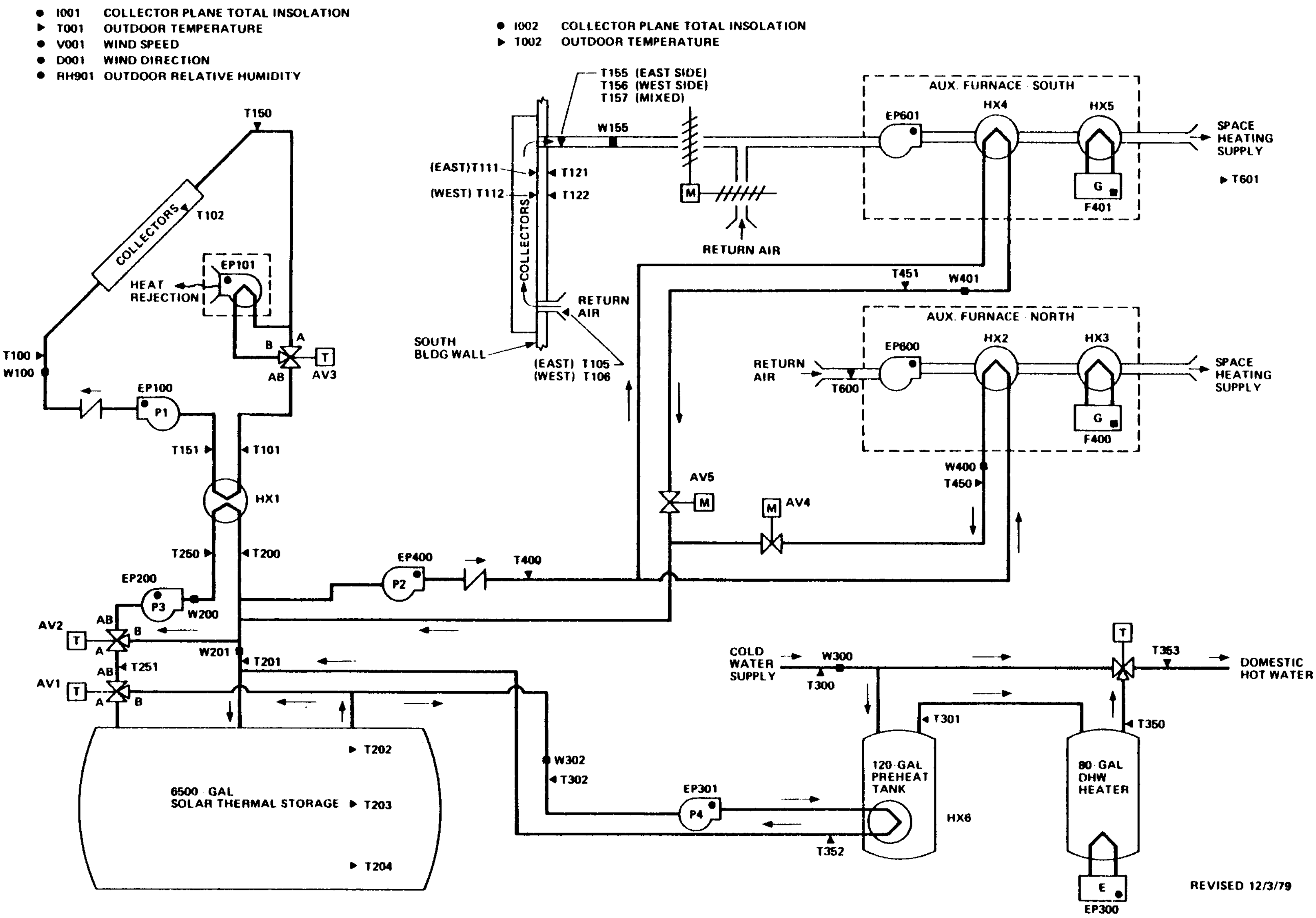


Figure 1. Oakmead Industries Solar Energy System Schematic

Valve AV2 acts in two modes. In the charge mode, when collected energy exceeds that of the building demand, valve AV2 modulates flow to and from the storage tank. When flow occurs to and from storage, valve AV1 provides makeup water by modulating flow from either the top or bottom of the tank to maintain 120°F in the TCL loop. This strategy maintains 120°F in the TCL and delivers solar energy to storage.

In the discharge mode, valve AV2 controls the rate of energy removal from the storage tank. The Thermal Control Loop is maintained at the set point by appropriate additions of warm water from the top of the storage tank by valve AV1. Energy additions to the loop are in response to the building heating loads as seen through HX2 and HX4 hot water coils. Pump P2 circulates water to these coils upon demand from the temperature control system. The thermal control loop logic provides a constant operating temperature for the hot water coils, while at the same time preventing unnecessary full flow conditions through the storage tank.

Other major components of the liquid-based subsystem include a storage tank, a heat rejection unit, and the domestic hot water system. The heat rejector unit dissipates excess solar energy when temperatures exceed the control set point. The storage tank stores the available energy in a 6,500-gallon insulated steel tank. A two-tank domestic hot water system will draw energy from the main storage system as necessary. A heat exchanger, HX6 located in a 120-gallon preheat tank, separates the potable water from the main storage tank.

Air-Based South Wall Solar Subsystem - During final design of the building, it was decided to incorporate a novel, relatively low cost solar subsystem in the south wall. The south wall incorporates 1,400 square feet of vertical air collectors. A major design objective was to arrive at a configuration adaptable to a Trombe-type collection system with little interference with the wall-casting procedure. The southern walls were modified to include inlet and outlet ports for air flow. The ports are spaced laterally on nine-foot centers and have a vertical spacing of nine feet.

The thickness of the concrete wall, 5.5 inches, is identical to that of the east and west walls. Because daytime heating is stressed at this site, the system deemphasizes the storage effects of the wall mass. (By way of comparison, a residential-based Trombe wall would be on the order of 18-inches thick.) The absorptivity of the wall surface has been enhanced with a field-applied black paint. Other design details include horizontal, perforated sheet-metal strips to control lateral air flow, and a field-installed glazing system. The glazing system consists of a double layer of low-iron, tempered glass attached with standard concrete fasteners, and flashing details. A six-foot overhang shades the vertical collector system, protecting the array from overheating during the summer seasons.

During operation, return air is drawn into the south wall system via the lower registers. The air rises within the two-inch gap formed between the wall and glazing. Flow is induced, in part, by natural thermosiphon effects, and, in part, by a slight vacuum created in the perimeter duct distribution system. The heated air returns to the building interior via the upper ports and then enters a collection plenum. The collection plenum is, in turn, connected to the south perimeter distribution system. Discharge air from the south wall can be further conditioned by a hot water coil, HX4, supplied by the liquid-based solar subsystem. An auxiliary duct-mounted gas heater serves to meet demand in the event that the combined efforts of the solar subsystems are insufficient to meet the load.

During the summer months, the perimeter air-distribution system is rendered inoperative. The collector array is protected from overheating by an architectural overhang.

The manufacturers of the major solar system equipment and components are listed below.

Equipment/Components	Manufacturer	Model Number
Collectors	Revere	Sun-Aid
Heat Rejector Unit	American Standard	Fanex 224
Heat Exchanger	Bell & Gossett	Shell + Tube WU-128-44
Preheat Tank	Buffalo	-
DHW Tank	National	-
Storage Tank	Saracco Mfg.	Custom-made
Valves (AV1 & AV2)	Stafa Control System AG	-
Controls	Stafa Control System AG	-
Pump P1	Bell & Gossett	1522-1½ AAB
Pump P2	Bell & Gossett	60-1½ AA
Pump P3	Bell & Gossett	60-1½ AA
Pump P4	Grundfos	UP-25-42SF

2.3 OPERATIONAL MODES

The system, shown schematically in Figure 2-1, has eight modes of solar operation.

Mode 1 - Liquid Collector Subsystem-to-Thermal Control Loop - In this mode, collector loop pump P1 starts if the collector plate stagnation temperature is greater than 120°F. An adjustable time delay relay provides an off delay for pump P1 (normally five minutes). At the end of the delay period, pump P1 will continue to operate if the collector plate temperature is 5°F greater than the Thermal Control Loop (TCL) temperature. Pump P3 is interlocked with pump P1 to provide constant operation of collector to TCL. Pumps P1 and P3 are deactivated when the differential temperature between the collector plate and the TCL falls below 5°F.

Mode 2 - Liquid Collector Subsystem Protection - If the collector plate temperature exceeds 240°F or the top of the storage tank is greater than 200°F, valve AV3 connects the solar loop to the heat rejector, energizes the heat rejector fan, deenergizes pump P3, and energizes pump P1. This provides collector protection from extremely high temperatures. This mode is deactivated when the plate temperature falls below 240°F or the storage tank falls below 200°F.

Mode 3 - Thermal Control Loop to Storage (Liquid Subsystem) - In this mode, solar energy is transferred to storage when the TCL temperature exceeds 120°F. Valve AV2 modulates flow to and from storage while valve AV1 provides makeup water from the top or bottom of the storage tank. This mode is completely controlled by the operation of valves AV1 and AV2.

Mode 4 - Thermal Control Loop-to-Space Heating (Liquid Subsystem) - This mode is energized when there is a demand for space heating. Pump P2 is interlocked to operate with pump P3 if the TCL temperature is greater than 80°F or the storage tank top temperature is greater than 80°F. Solar energy is provided to the north and south space heating zones until there is no demand for space heating or the temperature in the TCL and storage tank falls below 80°F.

Mode 5 - Storage-to-DHW Subsystem (Liquid Subsystem) - In this mode, solar energy is transferred from the storage tank to the DHW preheat tank if the DHW preheat tank is less than 160°F, storage tank is greater than 100°F, and the storage tank temperature is 10°F greater than the DHW preheat tank. Pump P4 is activated to deliver energy to the DHW subsystem and deactivates when the difference between the storage tank temperature and the DHW preheat tank falls below 5°F.

Mode 6 - Auxiliary Space Heating (Liquid and Air Subsystems) - This mode activates when there is a need for space heating and solar energy is insufficient to meet the demand. The auxiliary gas-fired furnace will provide the remaining building space heating demand. (There are two gas-fired furnaces for the north and south heating zones.)

Mode 7 - Auxiliary Hot Water Heating (Liquid Subsystem) - In this mode, auxiliary hot water is provided by an electric heater. If solar energy is insufficient, then the electric hot water heater provides auxiliary energy upon demand. The DHW tank is maintained at a control set point of approximately 140°F.

Mode 8 - Air Collector Subsystem-to-Space Heating - This mode activates when there is a need for space heating in the south zone only. If the temperature in the air collectors is greater than 85°F, then the fan in the auxiliary furnace will activate to deliver heated air to the south zone. This mode is deactivated when the temperature in the air collectors falls below 85°F or there is no space heating demand in the south zone. (The return plenum damper is closed during the summer months.)

SECTION 3

SYSTEM PRELIMINARY DESIGN

3.1 REQUIREMENTS

The Oakmead Industries office and manufacturing facility in Santa Clara, California was designed to be the nation's first industrial plant complex heated by solar energy. Oakmead Industries is part of a $3 million complex, which will include three buildings on a 15 acre site. With the projection that natural gas supplies were going to be severely depleted, Raymond Handley, President of the developing firm decided to erect such a project. The project was meant to prove that solar energy can heat the complex efficiently and economically.

The following describe the preliminary design as presented to Energy Research and Development Administration on November 1, 1976.

3.2 DESCRIPTION

The solar energy system will consist of both hydronic and forced air types. The hydronic system will consist of 110 three inches by eight inches copper flat plate solar collectors in two rows across the 45 foot concrete Fascia in the front part of the building. During collecting hours, water circulates through these collectors and heat collected is stored in a 12,000 gallon, lined, insulated steel storage tanks. When space heat is called for, water is pumped through a heat exchanger in the storage tank before being circulated to a fan-coil unit in the area requiring heat. If the temperature of the space is maintained near required levels, no back-up heat is required. If the temperature in the space drops below the required temperature, a back-up boiler is activated to supply the required heat. If the return water temperature of the fan-coil distribution line is above the temperature of the water in the storage tank, a solenoid valve is activated to bypass the solar storage tank.

Hot water used in the bathrooms is preheated in a heat exchanger placed in the storage tank on its way to the hot water heater. If the water entering the heater is warm enough, no back-up heat is required. Otherwise the solar pre-heat will provide a percentage of the requirement.

The forced air solar energy system will be located on the south facing vertical walls of the two buildings. It will consist of tilt-up concrete walls painted black with Kalwall plastic glazing framed in about six inches out from the wall surface. Air will be ducted in at the bottom of the wall and during solar collecting hours in the heating season, a blower will blow air across the black wall surface. This solar preheated air from the exterior will serve as a higher air temperature fresh air source rather than the ambient outside air.

The industrial building consists of 60,120 square feet. Construction of the building is of tilt-up concrete panels, concrete floor slabs, and flat built-up roofs. Surrounding the building will be courtyards, outdoor dining areas, seating areas, landscaped walkways and parking. The industrial building will be built on sepculation by Renault & Handley, and the mechanical and electrical systems will be determined later.

The following details were submitted by Renault & Handley to the U.S. Energy Research and Development Administration, November 1, 1976.

SYSTEM AND SUBSYSTEM PERFORMANCE/TECHNICAL DATA

A. CLIMATOLOGICAL DATA

For the proposed project site provide the following information:

1. Latitude: 37° N
2. Heating Degree Days

   Yearly: 2566

   January: 508
3. Peak Daily Insolation: 2280 BTU/ft^2 on horizontal surface
4. Yearly Sunshine: 85%*

B. COLLECTOR Commercial/Brand Name: Solera *3492

1. Type of Collector

   a. Flate Plate: Copper absorber, copper tube
2. Transparent Cover

   a. Materials

      (1) Type: $\frac{3''}{16''}$ clear tempered glass

   b. Commercial Identification: Clear tempered glass

   c. Solar Spectrum Transmissivity: Available in standard references

*Actual number not available - This number calculated by dividing yearly measured solar radiation by computer calculated yearly possible solar radiation.

d. Solar Spectrum Reflectivity: Available in standard references

e. Infrared Transmisivity: Available in standard references

f. Infrared Reflectivity: Available in standard references

g. Number of Covers: 1

h. Combustibility: Not combustible

i. Edge Treatment: Standard tempered glass edge treatment

j. Physical Properties

(1) Density: Available in standard references

(2) Linear Coefficient of Expansion: Available in standard references

(3) Thermal Conductivity: Available in standard references

(4) Specific Heat: Available in standard references

(5) Tensile Strength: Available in standard references

(6) Compressive Strength: Available in standard references

(7) Weight: Available in standard references

3. Absorber Plate

a. Absorptive Coating

(1) Materials

(a) Type: Flat black enamel

(b) Commercial Identification: Flat black engine enamel

(2) Solar Spectrum Absorptivity: 95%

(3) Infrared Emissivity: 95%

b. Base Plate

(1) Materials

(a) Type: Copper

(b) Commercial Identification: .010 soft copper sheet

(2) Thermal Properties

(a) Thermal Conductivity: Available in standard references

(b) Specific Heat: Available in standard references

(3) Physical Properties

(a) Linear Coefficient of Expansion: Available in standard references

(b) Density: Available in standard references

(c) Tensile Strength: Available in standard references

(d) Compressive Strength: Available in standard references

(4) Bonding Materials

(a) Type (Brazed, Soldered, etc.): Soldered

(b) Composition: 50% tin, 50% lead

(c) Commercial Identification: 50/50 solder

4. Insulation

a. Materials

(1) Type: Urethane foam

(2) Composition: Rigid foam

(3) Commercial Identification: Trymer CPR 9545,

b. Outgassing Characteristics

(1) Outgassing Temperature: Not available

(2) Gas Given Off: Not available

(3) Any Condensation: Not available

c. Physical Properties

(1) Linear Coefficient of expansion: Available in in standard references

(2) Density: Available in standard references

(3) Thermal Conductivity: Available in standard references

(4) Specific Heat: Available in standard references

(5) Coefficient of Cubical Expansion: Available in standard references

(6) Dimensions: 1" Thick below absorber, 3/4" thick on sides

5. Outer Base Enclosure

a. Materials

(1) Type: Aluminum

(2) Commercial Identification: Extruded aluminum

(3) Combustibility: None

b. Physical Properties (As Applicable)

(1) Linear Coefficient of Expansion: Available in standard references

(2) Density: Available in standard references

(3) Thermal Conductivity: Available in standard references

(4) Specific Heat: Available in standard references

(5) Coefficient of Cubical Expansion: Available in standard references

(6) Dimensions: 35" x 93"

c. Thermal Conductivity: Available in standard references

6. Composite Collector

a. Cooling/Transport Fluid

(1) Fluid

(a) Commercial Identification: Water

(2) Quantities of Fluid in Collector:

(a) Fluid: 2 Quarts

(3) pH: Variable, depending on local water supply

(4) Ion Content: Variable, depending on local water supply

(5) Mineral Content: Variable, depending on local water supply

(6) Durability (Service Life): Variable, depending on local water supply

(7) Properties

(a) Thermal Conductivity: Available in standard references

(b) Specific Heat: Available in standard references

(c) Density: Available in standard references

(d) Viscosity: Available in standard references

(e) Coefficient of Cubical Expansion: Available in standard references

b. Performance Data: Provide test or Performance Analysis Data along with information detailing the conditions under which the data were generated. Active systems require that test results be submitted rating the solar collector in accordance with the NBS "Method of Testing for Rating Solar Collectors Based on Thermal Performance," Document NBSIR 74-365, or through other procedures which will provide similar performance information, as determined by ERDA.

(1) Collection Period (Time of Day):

1:00 p.m. to 3:30 p.m.

(2) Maximum expected temperature under no flow conditions: 260°F

(3) Discuss provisions for protecting collector under no flow conditions. No materials are used in the collector that cannot withstand at least 310°F.

(4) Collector Array Characteristics

(a) Total Area: 23 ft^2/collector x 110 project collectors = 2530 ft^2

(b) Solar Window Area: 22 ft^2/collector x 110 project collectors = 2420 ft^2

(c) Weights of Collector and Framing: 4 lbs/ft^2

3.3 THERMAL CALCULATIONS

The following was obtained from the proposal submitted on November 1, 1976 to the U.S. Energy Research and Development Administration by Renault & Handley.

SOLAR ENERGY CALCULATION METHOD

The following method of calculating the solar radiation available to a tilted collector when only the radiation data for a horizontal surface is available was taken from articles by B. Y. H. Liu and R. C. Jordan, published by ASHRAE. The method involves breaking the available data into its direct and diffuse components, and then recombining them after taking into account factors for collector geometry.

BUILDING SUMMARY

	TOTAL ENERGY REQUIREMENTS 10^8 BTU/YR	SOLAR ENERGY UTILIZATION WATER SYSTEM	SOLAR ENERGY UTILIZATION AIR SYSTEM	TOTAL SOLAR CONTRIBUTION
Space Heating	11.9	37%*	24%	61%
Water Heating	2.5	50%*	-	

*See Note A

ENERGY UTILIZATION

	INSOLATION AVAILABLE BTU/FT^2 - H.S.*		COLLECTOR EFFICIENCY %	UNIT ENERGY COLLECTED BTU/FT^2- H.S.*	COLLECTOR AREA FT^2	ENERGY COLLECTED 10^8 BTU/H.S.*	TOTAL ENERGY COLLECTED 10^8 BTU/H.S.*
	45° TILT	90° TILT					
Water System	346,110	-	50	173,055	2,500	4.38	7.19
Air System		266,340	65	173,121	1,600	2.81	

*See Note B

*Note A

Since the collected solar heat applied towards heating domestic hot water will vary with the fluctuating storage tank temperatures during the heating season, it is difficult to calculate an exact percentage of solar contribution towards each heat demand. We have therefore assumed that all heat collected during the heating season will be applied to space heating. There are however, six months out of the year when excess heat is collected and the storage tank will maintain its maximum operating temperature. During these months 100 percent of all domestic hot water needs will be solar heated resulting in an at least 50 percent year round solar contribution towards water heating.

*Note B

Units are BTU/SqFt/Heating Season or BTU/Heating Season. Since the space heating season does not extend year round, we felt it was misleading to include energy collected during the summer months which cannot be utilized.

SOLAR RADIATION AVAILABLE

Total monthly average solar and sky radiation on horizontal surface (San Jose State University 1963-1973)

JAN	685.7 BTU/FT^2-DAY	JUL	2280.6
FEB	1039.6	AUG	2194.3
MAR	1389.1	SEP	1745.3
APR	1866.9	OCT	1183.4
MAY	2125.7	NOV	783.1
JUN	2209.8	DEC	632.6

Total monthly average solar radiation on horizontal surface at air mass = 0

$= 24/\pi \times Io \times (\cos(lat) \cos(s.d.) \sin(w_s + w_s\ rad \sin(lat) \sin(s.d.))$

Where: I_o = Solar Constant = 426.7 BTU/FT^2-H

lat = Latitude = 37.5° for Palo Alto

s.d. = Aug. Solar Declination of Month

W_s = Sunrise/Sunset Hour Angle

$\cos W_s = -(\tan(lat))(\tan(s.d.))$

JAN	1392.44 BTU/FT^2-DAY	JUL	3645.18
FEB	1918.56	AUG	3210.46
MAR	2453.50	SEP	2762.70
APR	3070.25	OCT	2140.20
MAY	3531.28	NOV	1554.87
JUN	3734.01	DEC	1277.60

For JAN:

$\frac{\text{Daily Total Rad. Measured}}{\text{Daily Total at A.M.} = 0} = .492$*

$\frac{\text{Daily Diffuse Rad.}}{\text{Daily Total Measured}} = .375$

Therefore:

Diffuse Radiation = .375 x 685.7 - 257.1 BTU/FT^2-DAY
Direct Radiation = .685.7 - 257.1 = 428.6 BTU/FT^2-DAY

*From graph by Liu and Jordan

	DIFFUSE TOTAL	DIFFUSE RAD (BTU/FT^2-DAY)	DIRECT RAD (BTU/FT^2-DAY)
JAN	.375	257.1	428.6
FEB	.330	343.1	696.5
MAR	.310	430.6	958.5
APR	.290	541.4	1325.5
MAY	.295	627.1	1498.6
JUN	.300	662.9	1546.9
JUL	.275	627.2	1653.4
AUG	.225	493.7	1700.6
SEP	.270	471.2	1274.1
OCT	.325	384.6	798.8
NOV	.375	293.7	489.4
DEC	.380	240.4	392.2

Total Radiation Available = Diffuse Rad x Percent of Sky Seen by Collector + Direct Rad. x Tilt Angle Factor

Collector Tilt = 45.0° to the South

Amount of Sky Seen = $\frac{180° - 45°}{180°}$ = 75%

Tilt Angle Factor:*

JAN	2.189	JUL	.764
FEB	1.762	AUG	.916
MAR	1.332	SEP	1.196
APR	1.001	OCT	1.609
MAY	.806	NOV	2.073
JUN	.728	DEC	2.349

Total Average Daily Radiation Available on Proposed Solar Collectors:

JAN	1131.0 BTU/FT^2-DAY	JUL	1733.6
FEB	1484.6	AUG	1928.0
MAR	1599.7	SEP	1877.2
APR	1732.9	OCT	1573.7
MAY	1678.2	NOV	1234.8
JUN	1623.3	DEC	1101.6

The following was obtained from Pacific Sun, Inc., in a letter to Western Energy, Inc.

* From tables published by U.C. Berkeley, Engineering Dept.

Our heat-loss calculations are based on the building surface areas, tabulated below. The appropriate R- and U-values are also shown.

	Bldg. #2	R-Value	U-Value
Glazing (Double Pane)	4,100 ft^2	R-1.7	0.58
Roof Area	60,000	R-19	0.053
Wall Area	12,500	R-11	0.091
Steel Doors	620	∿R-1	∿1.0
Floor Area	60,000	-	-

The floor losses were taken to be 1.5 Btu/ft^2-hr, based on a year-round groundwater temperature of 55°F. This figure is based on experimental measurements[1] by the National Bureau of Standards, as reported in the ASHRAE Handbook of Fundamentals. Edge losses are included. Aside from the floor calculations, our areas and U-values are in good agreement with your preliminary figures.

It was assumed that heat loads attributable to air exchange were dominated by the ventilation requirements. We feel this is a reasonable approach considering the use of modular, weathertight construction and fixed windows. We are, of course, discounting any gross infiltration due to openings of the steel delivery doors. This factor can only be determined when the tenant has been determined.

A recent ASHRAE summary[2] of office building ventilation requirements indicates an acceptable range of 10-15 cfm/person. If one assumes an occupation density of 1 person/100 ft^2 and 12.5 cfm/person, we arrive at total ventilation requirement of 7500 cfm. This value should be on the high side, since a density of 1 person/100 ft^2 is considered an upper limit for most office buildings. The production area will probably experience a much lower occupation rate. Then, too, special tenant-specified ventilation requirements (perhaps process-related) would require reassessment.

The assumed ventilation requirements can be expressed in equivalent "volume changes," based on a 16' ceiling height and the appropriate building areas. The 7500 cfm yields the same result. We will further assume that the ventilation system is operated only 12 hrs/day.

The heat loss calculations for both buildings are summarized in the following table.

---

1 NBS Report BMS-103.

2 J. Kern and H. Spoormaker, "Fresh Air Supply." ASHRAE Journal, July 1976.

DEGREE-DAYS PER MONTH		HEAT LOSS (BTU/MONTH)
JUL	14	---
AUG	17	---
SEP	21	---
OCT	107	9.3×10^7
NOV	303	14.7×10^7
DEC	481	19.6×10^7
JAN	508	20.3×10^7
FEB	367	16.5×10^7
MAR	335	15.6×10^7
APR	231	12.8×10^7
MAY	127	10.0×10^7
JUN	55	---

These figures might be reduced significantly by a "night setback" scheme applied to the thermostatic controls. The method should be particularly effective in the Santa Clara region, where degree-days accrue primarily during the late evening and early morning. Studies[3] have shown that an 8°F setback routine can result in yearly residential fuel savings of about 15% in regions accruing about 3000 degree-days/year. Commercial savings should be comparable.

Water Heating Energy - The active system can supply all of the hot water demands from mid-May to mid-October - 5 months.

$$1200 \text{ gal/day} = 104 \times 10^6 \text{ BTU/summer season}$$

[3] D. Quentzel, "Night-Time Thermostat Setback," ASHRAE Journal, March 1976.

3.4 COST ESTIMATES

The capital cost of the solar system was estimated on March 10, 1977 at $253,369. The breakdown for two solar buildings on the complex was as follows:

MATERIALS (Western Energy)

Solar Collectors (242 each, Type C, Mill Finish Solera 3492, $199 each)	$ 48,158.00
Solar Storage Tanks	
10,000 Gallons, Fiberglass, Lined, 12 Ft. Diam. x 12 Ft. High, R-25 Insulation	5,000.00
12,000 Gallons, Fiberglass Lined, 12 Ft. Diam. x 14 Ft. High, R-25 Insulation	5,500.00
Pipe and Fittings	6,788.42
Framing for Collectors	5,806.52
Pumps and Controls	1,630.00
	$ 72,882.94
6¼% Sales Tax	4,737.39
	$ 77,620.33
Miscellaneous (Fork Lift Rental, Travel, Dues to Local Union Solder, Gas)	1,410.00
Pipe Insulation	10,339.00
Installation	24,500.00
	$ 113,869.33
Design and Engineering and Project Administration	6,500.00
	$ 120,369.33
HVAC System (Skyline Heating & Sheet Metal piping, boiler standby units, valve controls, piping insulation	93,000.00
Solar Passive System (Pacific Sun)	40,000.00
TOTAL	253,369.00

3.4.1 Operational

Solar System Cost Effectivenss	$ .0002144/BTU/Yr.
Solar System Cost (Payback)	16.44 yrs.
Backup Energy Costs	$10,931/Yr.
without Solar	32,448
Therefore	$21,517 Savings/Yr.

SECTION 4

SUBSYSTEM PRELIMINARY DESIGN

The following section is excerpted from correspondence from Renault & Handley to the U.S. Energy Research and Development Administration, November 1, 1976.

ENERGY UTILIZATION

ERDA USE ONLY

- SOLAR ENERGY COLLECTION

1. AVERAGE ANNUAL INSOLATION, UPON COLLECTOR SURFACE BTU/SQ. FT./YR. See Table II
2. UNIT ENERGY COLLECTED, BTU/SQ. FT./YR. See table II
3. TOTAL ENERGY COLLECTION, BTU/YR. See table II
4. SOLAR SPACE HEATING USAGE, BTU/YR. 7.19×10^8
5. SOLAR HOT WATER USAGE, BTU/YR. 1.25×10^8
6. SOLAR COOLING USAGE, BTU/YR. Not applicable
7. TOTAL SOLAR ENERGY USAGE, BTU/YR. 8.44×10^8
8. INSTALLED SOLAR COLLECTOR, $ BTU/YR. N/A
9. INSTALLED SOLAR ENERGY SYSTEM, $ BTU/YR. N/A

- BUILDING ENERY LOAD

10. SPACE HEATING, BTU/YR. 11.9×10^8
11. HOT WATER, BTU/YR. 215×10^8 BTU/Yr
12. COOLING, BTU/YR. Not applicable
13. TOTAL ENERGY LOAD, BTU/YR. 14.4×10^8 BTU/Yr
14. TOTAL, BACK-UP ENERGY USAGE, BTU/YR. 5.96×10^8

- SOLAR SYSTEM OPERATIONS

15. SOLAR SYSTEM OPERATING COST, $/YR. N/A

16. SOLAR SYSTEM MAINTENANCE COST, $/YR. N/A

17. TOTAL SOLAR SYSTEM OPERATIONAL COST $/YR. N/A

- CLIMATIC DATA

LATITUDE 37^{o} DEG.

DEGREE DAYS: HEATING 2566 COOLING Not applicable

SEASON	WINTER		SUMMER	
AVE. TEMP.	48.4	°F	65.9	°F
AVE. INSOLATION	213	LY/Day		LY /Day

4.1 COLLECTOR

PROJECT INFORMATION SUMMARY DATA SHEET 3

ERDA USE ONLY

C SOLAR ENERGY SYSTEM

- SOLAR COLLECTOR

1. TYPE Copper flat plate

2. MFGR: (S) Western Energy, Inc.

- AREA See Table II

LIQUID AIR

- OPERATING FLOW See equipment schedule
- BURST PRESSURE 4340 PSI on Solar-Mechanical supporting drawings
- ABSORBER DESCRIPTION Hydronic: copper Air: Cement
- ABSORBER COATING Flat Black Enamel
- OTHER COMMENTS
- TRANSFER FLUID Hydronic: Water Air : Air
- GLAZING Hydronic: tempered glass Air : plastic

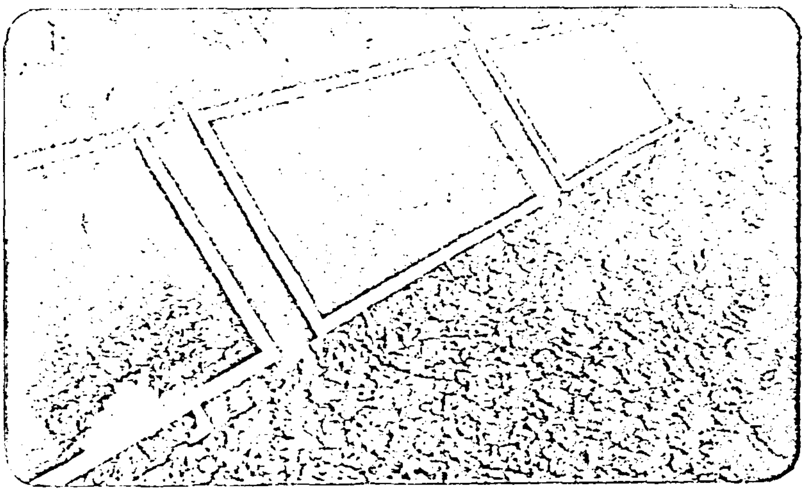
Table II. BUILDING 2

	ACTIVE SOLAR COLLECTION (BTU/MO) x 10^7	PASSIVE SOLAR COLLECTION	TOTAL SOLAR	HEAT LOSS	SOLAR %
OCT	6.1	4.5	10.6	9.3	100
NOV	4.7	4.3	9.0	14.7	61
DEC	4.2	4.1	8.3	19.6	42
JAN	4.4	3.7	8.1	20.3	40
FEB	5.2	3.5	8.7	16.5	53
MAR	6.2	3.4	9.6	15.6	62
APR	6.5	2.6	9.1	12.8	71
MAY	6.5	2.0	8.5	10.0	85
TOTALS	43.8	28.1		118.8	

Based on:

2500 ft^2 Active collectors, 50% efficiency.

1600 ft^2 Passive collectors, 65% efficiency.



Western Energy, Inc.
454 [illegible]
Palo Alto, California
94302
415 327 3371

SOLERA*3492
SOLAR PANEL

DESCRIPTION

COLLECTOR USES
- SPACE, DOMESTIC WATER, SWIMMING POOL HEATING.

COLLECTOR COMPOSITION
- ALL COPPER ABSORBER AND TUBING.
- FLAT-BLACK ABSORBER COATING (SELECTIVE SURFACE OPTIONAL).
- CONTINUOUS THERMO-PRESS* SOLDER BOND.
- POLYURETHANE FOAM ON SIDES AND BACK OF ABSORBER.
- WATER RESISTANT BACKING.
- EXTRUDED ALUMINUM WEATHERPROOF FRAME (ANODIZED ALUMINUM, BRONZE, OR BLACK PAINT OPTIONAL), AND TEMPERED GLASS.

WARRANTY

THE SOLERA* SOLAR COLLECTOR UNIT IS WARRANTEED TO BE FREE FROM DEFECTS IN MATERIALS AND WORKMANSHIP. IF WITHIN 3 YEARS FROM INSTALLATION A DEFECT BECOMES APPARENT, THE MANUFACTURER WILL, UPON WRITTEN NOTICE BY PURCHASER, AND AT MANUFACTURER'S OPTION, REPAIR OR REPLACE THE DEFECTIVE PARTS. TRANSPORTATION COSTS INCURRED IN REPAIR OR REPLACEMENT SHALL BE PAID BY THE PURCHASER.

*"A TRADEMARK OF WESTERN ENERGY, INC."

PERFORMANCE DATA

EFFICIENCY (SEE FIGURE 1)

FLEXIBILITY
- ADAPTABLE TO ALL HYDRONIC SOLAR COMPONENTS.
- CAN BE USED IN FORCED AIR OR HYDRONIC DISTRIBUTION.
- VARIOUS PIPING LAYOUTS POSSIBLE (SEE FIGURE 3).
- ROOF, WALL OR GROUND LOCATION POSSIBLE.
- ADAPTABLE TO NEW AND EXISTING CONSTRUCTION.

DURABILITY
- TOUGH CONSTRUCTION DESIGNED FOR 20 YEAR MINIMUM LIFE.

MAINTENANCE
- OCCASIONAL RINSING OF EXTERIOR GLAZING
- SNAP-OFF GLAZING CLIP FOR EASY INTERIOR ACCESS

SIZE AND WEIGHT

35 IN. x 93 IN. x 3.5 IN.; 95 LB. (W/GLASS)
89 CM. 236 CM. 8.9 CM. 43 KG.

INSTALLATION
- QUICK SWEAT SOLDER OR CLAMP CONNECTIONS.
- NAILING STRIP FOR EASY STRUCTURAL CONNECTION.
- COMPLETE INSTRUCTIONS INCLUDED WITH EACH ORDER.

FIGURE 1
COLLECTOR EFFICIENCY

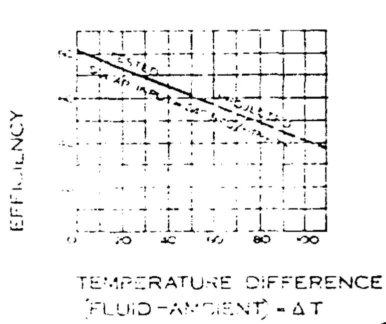


FIGURE 2
COLLECTOR SECTION

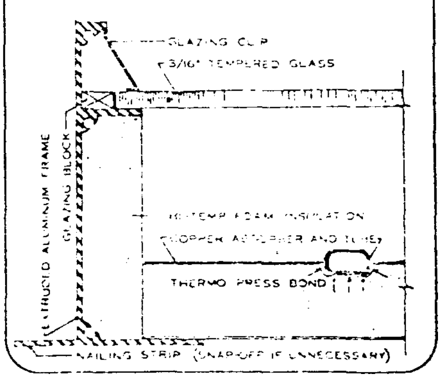
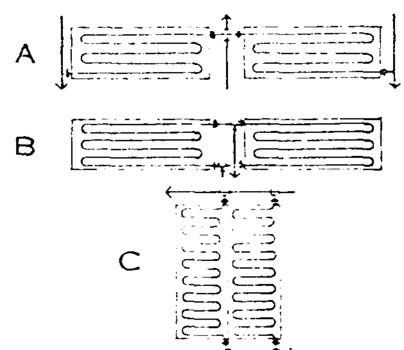
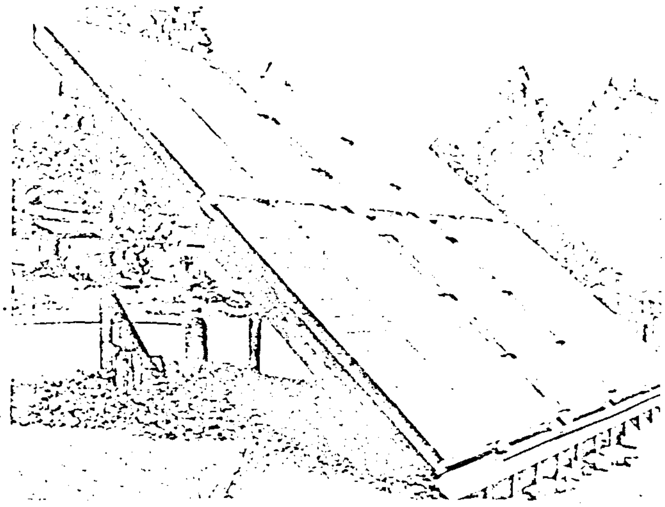


FIGURE 3
PIPING ARRANGEMENTS



SOLERA SWIM*



DESCRIPTION

The Solera Swim* solar energy pool heating system is designed to supply new and existing pools with the heat required to maintain comfortable swimming temperatures. An optional part of the system includes a thermal pool cover designed to extend the normal swimming season into the colder months. The pool cover is also recommended in systems where the solar collectors are the sole pool heating source.

The Solera Swim* pool heating system consists of: (see schematic below)

1. Solera* 3492 copper solar collectors with the Thermo-Press* (patent pending) continuous solder bond. (See back side of this sheet for more data).
2. Solers Swim* control system including: a differential temperature thermostat, thermometer, a check valve, a drain valve, and a pressure relief valve.
3. Water Cozy-Aqua Blanket® made of ¼" insulating Ethafoam® (2 lb./cu. ft.) plastic foam custom fitted to float on the surface of the pool. This thermal cover acts as a pool cover keeping debris out of the pool, and also cutting evaporation and chemical losses. The foam has an ultraviolet ray stabilizer to give it a long useful life.

MAINTENANCE

Occasional rinsing of exterior glazing of solar collectors.

* "A Trademark of Western Energy, Inc."

INSTALLATION

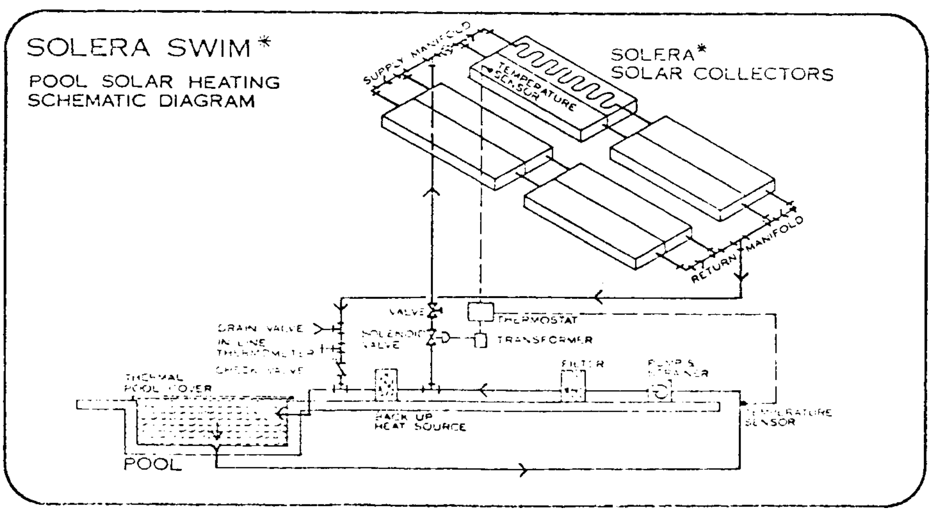
Complete installation instructions available from Western Energy, Inc., including: orienting and sizing the system, solar collector structural connections, piping connections and control system hook-up.

OTHER SOLAR COLLECTOR USES

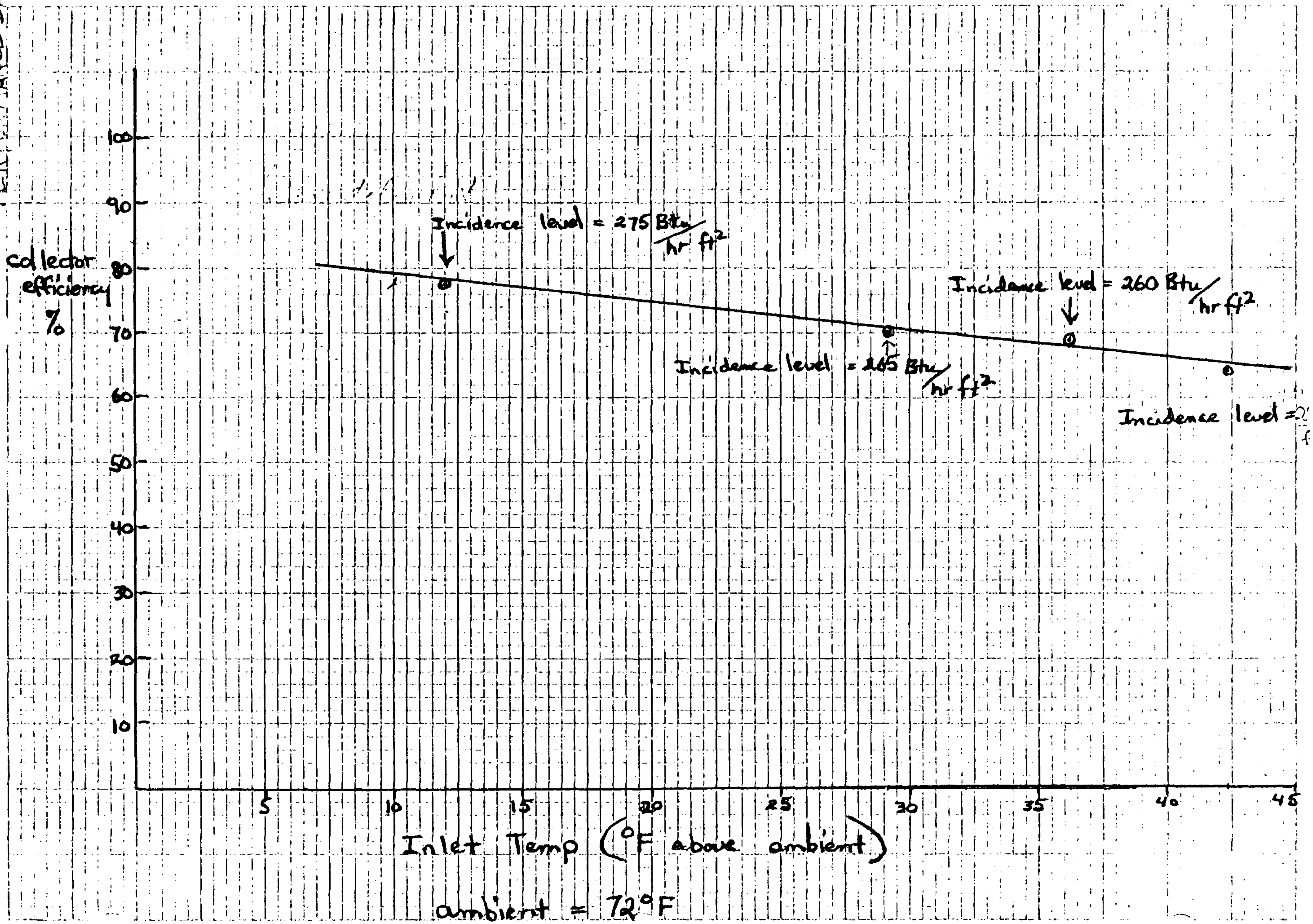
The Solera* 3492 solar collectors can also be used to heat spas, buildings or domestic hot water if year round swimming pool heating is not required. Contact Western Energy, Inc., for more information about how this can be done.

WARRANTEES

See the Solera* 3492 Solar collector warrantee on the back side. The Water Cozy-Aqua Blanket® carries an 18 month warrantee (6 month full, 12 months prorated) on defective materials and workmanship.



PERFORMANCE DATA



Test - Sept 9th, 1975 PERFORMANCE DATA

CLOUD COVER - HIGH LIGHT CIRRUS CLOUDS

AMBIENT TEMP - 72° - 70° Time from Noon to 2:45

WIND - light 5-10 mph

1

Incident Rad. = $(16.98\ ft^2)(8.47\ min)\left(\frac{250\ Btu}{ft^2\text{-}hr}\right)$*

= 599 Btu's

* Incidence fairly constant

T_{in} = .841 = 70°F

dev. = .003 ΔT = 10.9°F

T_{out} = 1.087 = 80.9°F

dev. = .028

$T_{amb.}$ = .889 = 72° F

dev. = .046

FLOW RATE

$\dot{M} = \frac{44.5\ lbm}{8.47\ min} = 5.25\ lbm/min$

$$\eta = \frac{(\dot{M})(c_p)(T_{EXP})(\Delta T)}{I_I}$$

$$= \frac{\left(5.25\ \frac{lbm}{min}\right)\left(\frac{1\ Btu}{lbm\,°F}\right)(8.47\ min)(10.9\ °F)}{599\ Btu's}$$

= 80.9%

* Note - high efficiency may be due to the fact the inlet temp is below ambient

2

Incident Rad = 618.9 Btu's

Average Incidence * $232.4\ \frac{Btu}{ft^2\ hr}$

* Incidence varying between 220 + 240

T_{in} = 1.009 = 77.4°F

dev. = .004 ΔT = 10.0°F

T_{out} = 1.240 = 87.4

dev = .037

$\dot{M} = \frac{47.5\ lbm}{9.41\ min} = 5.05\ \frac{lbm}{min}$

η = 76.8%

3

Incident Rad. = 739 Btu's

average Incidence = $\frac{223\ Btu}{hr\ ft^2}$*

T_{in} = 1.166 = 84.4°F

dev. = .003 ΔT = 11.6°F

T_{out} = 1.432 = 96.0°F

$\dot{M} = \frac{44\ lbm}{11.71\ min}$

= 3.76 lbm/min

η = 69.1%

* Incidence varying 160 - 260

4

Incidence = 770 Btu

average Incidence = $\frac{234.6 \text{ Btu}}{\text{hr ft}^2}$ *

T_{in} = 1.321 = 91.1 °F

dev = .002

T_{out} = 1.601 = 103.5 °F

ΔT = 12.4°F

$\dot{M} = \frac{91.5 \text{ lbm}}{11.6 \text{ min}}$ = 3.58 lbm/min

η = 70.9%

* Incidence varying between 150 - 245

5

Incidence = 1042.5 Btu's

average Incidence = $\frac{252 \text{ Btu}}{\text{hr ft}^2}$ *

Incidence varying between 240-255

T_{in} = 1.546 = 101.1 °F

dev. .003

T_{out} = 1.896 = 116.5 °F

dev. .042

ΔT = 15.4°F

$\dot{M} = \frac{40.6 \text{ lbm}}{14.38 \text{ min}}$ = 2.8 lbm/min

η = 60.0%

* note extremely low flow rate

6

Incidence = 487.98 Btus

Average Incidence 207 Btu/hr ft²

T_{in} = 1.653 = 105.9°F

dev .005

T_{out} = 1.786 = 111.8°F

dev. = .038

ΔT = 5.9°F

$\dot{M} = \frac{44 \text{ lbm}}{8.33 \text{ min}}$ = 5.3 lbm/min

η = 54%

Note = variable insolation measurements make an approximation of total incidence difficult so treat this data with caution.

TEST 2 PERFORMANCE DATA

T_{in} = 1.198 (mean) = 84.0°F
[deviation = .002]

$\dot{m}$ = Flow Rate = 5.31 lbm/min

T_{out} = 1.473 (mean) = 97.9°F
[deviation = .010]

Incident radiation = (Panel Area)(Time exposed)(Insolation)

= (20.75 ft²)(9 min 25sec)(276 Btu/hr·ft²)

= 8966 Btu's

$$\eta = \frac{\dot{m}\,(Cp_{(water)})(Time)(\Delta T)}{\text{Incident Reduction } (I_{si})} = \frac{(5.31\ lbm/min)(1\ Btu/lbm\,°F)(9.42\ min)(13.9}{896.6\ Btu's}$$

$$\boxed{\eta = 77.6\%}$$

TEST 4

T_{in} = 1.651 (mean) = 101.3°F
[deviation = .001]

$\dot{m}$ = 5.06 lbm/min

T_{out} = 1.840 (mean) = 114.0°F
[deviation = .022]

Incident Rad. = 950.4 Btu's

$$\eta = \frac{(5.06\ lbm/min)(1\ Btu/lbm\,°F)(12.7°F)(10.37\ min)}{950.4\ Btu's}$$

$$\boxed{\eta = 70.1\%}$$

Test 5

T_{in} = 1.719 (mean) = 108.3°F
[dev. = (.001)]

T_{out} = 1.988 (mean) = 120.5
[dev. = .019]

$\dot{M}$ = 5.08 lbm/min

Incident radiation = 946.8 Btu's

$$\eta = \frac{\left(5.08\ \frac{lbm}{min}\right)\left(\frac{1\ Btu}{lbm\ {}^\circ F}\right)\left(12.2\ {}^\circ F\right)\left(10.5\ min\right)}{946.8\ Btu's}$$

$\eta = .69$ eff. = 69%

Test 6

T_{in} = 1.868 (mean) = 114.8°F
[dev. = .001]

T_{out} = 2.121 (mean) = 126.3°F
[dev. = .014]

$\dot{M}$ = 4.9 lbm/min

Incident radiation = 828.5 Btu's

$$\eta = \frac{\left(4.9\ \frac{lbm}{min}\right)\left(\frac{1\ Btu}{lbm\ {}^\circ F}\right)\left(11.6\ {}^\circ F\right)\left(9.38\ min\right)}{828.5\ Btu}$$

$\eta = .638$ efficiency = 63.8%

RUN#1 — 1:19 PM

TIME	T_{IN}	T_{OUT}	$T_{AMBIENT}$	FLOW RATE	BTU/HR-FT
0	.836	1.035	.920		
1	.838	1.056	.890	44.5 lb 821 SEC.	
2	.839	1.073	.860		
3	.840	1.063	.890		
4	.840	1.092	.890		
5	.842	1.102	.820		245
6	.844	1.111			250 AVE #1
7	.842	1.112	.952 CHANGE OF LOCATION		
8	.845	1.119			
9					
10					
11					

RUN#2

TIME	T_{in}	T_{out}	$T_{AMB.}$	FLOW RATE	BTU/HR-FT^2
0	1.004	1.185	.996		
1	1.005	1.201	.980	47.5 lb 9 MIN 24 S.	220
2	1.006	1.213	1.000		220
3	1.006	1.219	1.146		232
4	1.009	1.234	1.105		235
5	1.009	1.244	1.140		240
6	1.010	1.256	.876		235
7	1.011	1.261	.840		232
8	1.014	1.285	.830		238
9	1.014	1.301	.855		240
10					

RUN#3

TIME	T_{in}	T_{out}	$T_{AMB.}$	FLOW RATE	BTU/HR-FT^2
0	1.160	1.396	.825	44 lb. 11 MIN 42 S	
1	1.162	1.385	.825		190 VARYING 160-220
2	1.163	1.384	.825		225
3	1.164	1.408	.852		160
4	1.165	1.358	.807		200
5	1.166	1.393	.835		240
6	1.167	1.457	.918		260
7	1.168	1.465	.868		210
8	1.169	1.462	.817		245
9	1.169	1.482	.867		250

CONTINUED

PERFORMANCE DATA

11	11	1.170	1.496	0.907		250
RUN 4	TIME (1:55 PM)	TIN	TOUT	T AMBIENT	FLOW RATE	BTU
	0	1.515	1.542	.809	41.5 lb 11 MIN 37 S	235
	1	1.318	1.589	.835		250
	2	1.320	1.593	.820		150
	3	1.320	1.558	.790		240
	4	1.321	1.593	.825		235
	5	1.321	1.595	.823		220
	6	1.321	1.600	.817		250
	7	1.322	1.616	.860		250
	8	1.324	1.622	.785		250
	9	1.323	1.636	.767		245
	10	1.322	1.634	.822		245
	11	1.323	1.630	.812		245
			RESPITE			
RUN 5	0	1.541	1.806	.875		250
	1	1.543	1.856	.850	40.5 lb 14 MIN 38 S	250
	2	1.543	1.860	.859		240
	3	1.544	1.865	.803		245
	4	1.544	1.872	.822		250
	5	1.544	1.885	.807		255
	6	1.546	1.890	.879		255
	7	1.548	1.904	.789		255
	8	SKIPPED - MISSED				255
	9	1.548	1.914	.814		255
	10	1.546	1.923	.785		255
	11	1.547	1.932	.846		255
	12	1.547	1.938	.829		255
	13	1.548	1.945	.838		255
	14	1.548	1.952	.802		255
RUN 6	0	RESPITE FOR 20 MIN. - SHUT DOWN AT POWER UP SYSTEM			44 lb 8 MIN 45 S	
	1	1.649	1.715	.768		250
	2	1.652	1.779	.789		250
	3	1.654	1.838	.750		260
	4	1.655	1.820	.754		200
	5	1.655	1.830	.751		145
	6	1.656	1.775	.756		170

	TIME	T_{IN}	T_{OUT}	$T_{AMBIENT}$	FLOW RATE	BTU
RUN 6	7	1.656	1.779	.735		120
	8	1.656	1.766	.750		220
	9	1.656	1.770	.767		250
RUN 7	0	1.677	1.828	.755	43.5 lb 8 M 28	255
	1	1.676	1.825	.745		250
	2	1.676	1.328	.803		250
	3	1.677	1.830	.748		220
	4	1.678	1.794	.780		140
	5	1.679	1.746	.767		140
	6	1.677	1.738	.807		210
	7	1.677	1.787	.785		220
	8	1.676	1.806	.781		140
RUN 8	0	1.704	1.822	.780	43 lb? 8 M 30 s	240
	1	1.704	1.832	.789		245
	2	1.705	1.845	.738		245
	3	1.705	1.845	.759		240
	4	1.706	1.847	.813		240
	5	1.707	1.855	.822		240
	6	1.706	1.857	.832		240
	7	1.705	1.864	.816		240
	8	1.705	1.868	.766		240
	9					
RUN 9	0	1.747	1.882	.778	42.5 lb 8 M 26 s	240
	1	1.748	1.891	.802		240
	2	1.748	1.896	.794		240
	3	1.749	1.903	.825		245
	4	1.750	1.904	.816		245
	5	1.749	1.909	.778		245
	6	1.748	1.909	.820		245
	7	1.748	1.915	.770		245
	8	1.747	1.915	.790		245
	9					
	10					

4.2 STORAGE

- TYPE: Steel with lining
- CAPACITY: (GAL.) 12,000 Gallon:
- HEAT EXCHANGER TYPE Copper tube
- BURST PRESSURE 4340 PSI
- HEAT TRANSFER COEFFICIENT Not yet specified (HEAT EXCHANGER)

System and Subsystem Performance/Technical Data–Continued

C. *Storage*

1. Type (Tank, Rock Bed, etc.) Tank
2. Materials
   a. Type Steel 1/4", cylindrical, horizontal
   b. Finishes Interior: Coal tar emulsion/Exterior: Urethane foam, R=20
   c. Commercial Identification Underground warm water storage tank.
3. Physical Dimensions:
   a. Height 95"
   b. Width 95"
   c. Length 327"
4. Thermal Properties*
   a. Thermal Conductivity Available in standard references
   b. Coefficient of Thermal expansion " " " "
5. Operating Temperature Range " " " " °F
6. Operating Pressure Range* " " " " PSI
7. Burst Pressure* " " " " PSI

4.3 HEATING

1. Type Gas fired boiler (see heating, ventilating & air conditioning on solar mechanical sheet in supporting drawings)

2. Commercial Unit

   a. Type See E.I.

   b. Size See E.I.

   c. Commercial Identification ____________

3. Coefficient of Performance (COP, if applicable, data versus pertinent operating conditions (ambient temperature etc.) See E.I.

4. Total Heating Capacity See E.I.

   The total heating capacity of the solar system shall be no less than __________ BTU/HR at __________ CFM of air flow entering at __________ °F dry bulb and __________ % relative humidity. Exposed heated panel (baseboard or ceiling) temperatures shall not exceed ______ °F.

4.4 HOT WATER SUBSYSTEM

1. Type Gas fired (not yet specified)

System and Subsystem Performance/Technical Data–Continued

2. Commercial Unit

   a. Type Not yet specified

   b. Size Not yet specified

   c. Commercial Identification Not yet specified

3. Hot Water (Back Up System) : __________ gallons of potable (of useable) hot water shall be delivered at no less than __________ gal/min at temperature no less than __________ °F. Recovery time shall be no greater than __________ hours.

4. Code and Safety Standard Certified Under __________ Not applicable - City water will be preheated in a heat exchanger in the storage tank on its way to the hot water tank.

4.5 PIPING

1. Provide Sketch/Block diagram of Proposed Solar System giving dimensions and subsystems/components location and identification.

2. Piping Details

   a. Diameter Varies (refer to solar energy system schematic)

   b. Length of Run Varies (refer to solar energy system schematic)

   c. Materials Copper

3. Piping Insulation

   a. Type Foam jacket type (refer to solar energy system schematic)

   b. Thickness 3/4"

   c. Performance R=4

4. Transport Media for each element

   a. Type Water

   b. Flow Rate 100 GPM GPM (Liquid) ________ CFM (Air)

   c. Specify Pressure drop between components. 40 Ft. of head loss between collectors and solar storage tank

5. Provide Flow diagram for Proposed Solar Energy System.
   (refer to solar energy system schematic)

4.6 SYSTEM

1. Operating Requirements

   a. The maximum electrical energy required to drive the solar portion of the system at its rated capacity shall be no greater than 34.72 K.W. Water requirements for cooling condensers and/or air humidification shall be no greater than not applicable gal/hr.

b. Subsystems/Components requiring electrical energy:

1. Pumps 34.72 kw, Function Solar collector water supply
2. Fans ________ kw, Function not applicable
3. Controls ________ kw, Function .004 kw/hr
4. Other ________ kw, Function ________

2. Design Load Data:

ANNUAL SUMMARY TABLE

Month	Heating (BTU)x10^8 bldg.#2	Hot Water (BTU)x10^8 bldg.#2	Cooling BTU
January	2.03	.21	not applicable
February	1.65	"	
March	1.56	"	
April	1.28	"	
May	1.0	"	
June	Negligible	"	
July	"	"	
August	"	"	
September	"	"	
October	.93	"	
November	1.47	"	
December	1.96	"	
Yearly Total	11.88	2.5	
Peak (BTU/HR)	677,233	77,777	

3. Provide the following Summary of System Performance Data:

MONTH	BLDG	SOLAR ENERGY COLLECTED	ELECT. ENERGY REQUIRED FOR COMPONENT	AUXILIARY ENERGY (BTU)	SYSTEM HEAT LOSS (BTU)	EQUIVALENT ENERGY REQUIRED FOR CONVENTIONAL SYSTEM (BTU)
JAN	2	8.1×10^7	1.06×10^7	12.7×10^7	$.485 \times 10^7$	20.3×10^7
FEB	2	8.7×10^7	1.06×10^7	8.2×10^7	$.435 \times 10^7$	16.5×10^7
MAR	2	9.6×10^7	1.06×10^7	6.4×10^7	$.384 \times 10^7$	15.6×10^7
APR	2	9.1×10^7	1.06×10^7	4×10^7	$.273 \times 10^7$	12.8×10^7
MAY	2	8.5×10^7	1.06×10^7	1.8×10^7	$.255 \times 10^7$	10.0×10^7
JUN	2	*	*	None	*	*
JUL	2	*	*	None	*	*
AUG	2	*	*	None	*	*
SEP	2	*	*	None	*	*
OCT	2	10.6×10^7	1.06×10^7	None	$.424 \times 10^7$	9.3×10^7
NOV	2	9×10^7	1.06×10^7	6.1×10^7	$.45 \times 10^7$	14.7×10^7
DEC	2	8.3×10^7	1.06×10^7	11.8×10^7	$.498 \times 10^7$	19.6×10^7

*Not Computed.

SECTION 5

CONSTRUCTION

5.1 CODES AND REGULATIONS

The contractor shall coordinate and obtain inspections required for the work herein. All work performed hereunder shall conform to building and safety codes and ordinances and the rules and regulations of any legal body having jurisdiction. When these specifications require or describe materials or construction of better quality or larger size than required by the governing codes, rules and regulations, the provisions of the specification shall prevail. contractor shall provide a working system without extra cost to the owner even though the work is not specified herein or indicated on the drawings. Nothing shown in the drawings nor in these specifications shall be considered as authorizing any installation that violates the requirements of such codes. In addition, the installation shall conform to, as minimum stardards, all rules and regulations that apply in the following publications:

A. National Electrical Code (NEC) 1971 edition.

B. Title 8, California Administrative Code, Basic Electrical Regulations, sub-chapter 5, Low Voltage and High Voltage Safety Orders.

C. Electrical Code, City of Santa Clara.

D. Standards, Institute of Electrical and Electronic Engineers.

E. Standards, Underwriters Laboratories, Inc.

F. Occupational Safety and Health Act.

G. Rules and Regulations - service Electric Utility.

H. Rules and Regulations - serving Telephone Utility.

I. Rules and Regulations - Fire Marshal's office.

J. The Uniform Plumbing Code.

5.2 BID DATA

SOLAR COLLECTOR SPECIFICATIONS

1. General

   The contractor shall install and plumb 256 modular, high-performance flat plate solar collectors in strict accordance with the layout and plumbing diagrams in the mechanical drawings and specifications elsewhere in this document.

2. Collector Specifications

The flat plate solar collector shall have the following thermal, mechanical and optical characteristics:

A. Absorber plate. The absorber plate shall have tube spacing, plate thickness and bonding characteristics (if applicable) so as to provide superior thermal performance. Absorber plate and flow passages are to be of copper.

B. Absorber coating. The manufacturer shall supply a black chrome electrodeposited selective optical surface to the absorber plate. The surface shall be applied to a nickel-flash substate by a firm fully qualified and experienced with coating processes controlled within the tolerances demanded by solar selective surfaces. The coater shall be Olympic Coatings or a firm of equal technical ability. The absorptivity shall not be less than 0.92, and the infrared emissivity shall be no greater than 0.10.

C. Glazing. Tempered glass with a single-sheet solar transmittance of 90.5% (equivalent to 3/16" water white glass) shall be provided.

D. Insulation. Back insulation shall have minimum insulating value of R-10. Provisions to reduce edge losses shall be included in the design.

E. Frame. The collector shall be mounted in a weather-tight aluminum frame which can be supported at its end points without additional structural support. Provisions for field replacement of glazing shall be included.

F. Sizing. Collector modules shall have exterior gross dimensions of 35" x 93", with an effective area of 20.86 ft^2.

G. Thermal performance. The manufacturer shall provide thermal performance test results compiled by a recognized, independent testing facility. Testing procedures will follow NBS Interim Report 112-74-635: "Method of Testing for Rating Solar Collector Based on Thermal Performance."

H. Guarantee. Manufacturer shall guarantee the collectors (excluding glazing) for a minimum of five years against manufacturing and material defects.

I. Manufacturer. Collectors shall be SunAid oversize modular units as manufactured by Revere Copper and Brass, Inc., Rome, New York.

3. Handling Procedures

The contractor shall provide suitable lifting equipment to safely unload the solar collectors upon delivery. Further, the contractor shall take full responsibility for the safe storage of said collectors until such time as they are installed. Upon installation, the following procedures are to be followed.

A. All employees engaged in the installation and handling of collectors shall be provided with suitable eye protection in the event of glass breakage, as well as hand protection to prevent burns.

B. Prior to filling and testing, collector glazings shall be protected with a non-abrasive opaque covering (such as black plastic film) to prevent unnecessary overheating under non-circulating conditions.

C. Prior to installation on the roof structure, the contractor shall review his installation plan with the engineer, emphasizing those provisions directed at minimizing collector damage. The contractor shall be liable for any and all collector damage attributable to careless and/or unprofessional handling procedures.

4. <u>Piping Procedures</u>

Once secured to the collector support structure, the collectors shall be plumbed with copper or brass fittings and high temperature silicone rubber hose in strict accordance with the drawings and applicable piping/plumbing specifications. These include:

A. Observance of all professional procedures for connections piping.

B. Careful adherence to the plumbing specifications, including but not limited to thermal expansion joints, balancing devices, air control fittings and piping logic.

C. Collector piping and manifolds shall be adequately supported by the structure, with all due consideration to thermal expansion effects.

5. <u>Testing and Filling Procedures</u>

The contractor shall perform all necessary testing and filling procedures in strict accordance with the start-up and Acceptance Test Program (ATP). The contractor is especially warned to avoid situations which would lead to collector freezing. The execution of the precautionary methods are completely the responsibility of the contractor, and the contractor shall be liable for any and all damages attributable to negligence.

6. Insulation

The contractor shall have all collector manifolding, headers and piping specialties insulated. Insulation work shall not commence until all hydraulic testing of the collectors loops has been completed and authorization has been received from the engineer.

TANKAGE

1. General

All the provisions of the General Conditions, Supplementary General Conditions, and any applicable provisions elsewhere in the contract documents shall apply to the work of this section as fully as if repeated herein.

2. Scope

The contractor shall furnish a 6500-gallon steel atmoshperic pressure tank, API 620 construction, for each of the two buildings. Tank details shall be in accordance with drawing MS-5. The contractor shall submit shop drawings to the engineer for approval before initiating construction.

3. Rigging and Mounting

The contractor shall bear full responsibility for receiving the tanks on site and placing said equipment in the buildings. Due to the building configuration, tanks cannot be positioned by crane. The contractor shall develop a plan to transport the tank through a 12' x 14' rear service door and position it upon the structural pad according to the drawings. This plan shall be submitted to the engineer for approval.

4. Type

The tank shall be of steel, designed for atmospheric pressure (API 620 construction).

5. Tank Lining

Epoxy, or approved equal, suitable for treated hot water storage (212°F max, 180°F continuous) with 15% makeup per year, commercially applied and fully replaceable at end of service life. All fittings and weldments shall be properly coated.

6. Capacity

The tank shall have a capacity of 6500 gallons as measured from bottom plate to fill level.

7. <u>Fill Valve</u>

Tank shall include an automatic fill float valve with a maximum fill rate of 25 gpm with 75 psi supply pressure.

8. <u>Penetrations</u>

Port layout as shown on drawings. All ports 1" and larger shall be 125 lb flange with a minimum 8" clearance from the tank wall to accommodate 6" of insulation. Instrumentation ports as indicated shall be 3/4" FPT and closed off with brass plugs.

9. <u>Manhole/Cleanout</u>

As required by code, a 24" diameter bolt-down hatch shall be positioned as shown on drawings.

10. <u>Seismic Loading</u>

As required by code for Zone 4. Bolting pattern and detail shall be submitted to the Architect for approval.

11. <u>Lifting Lugs</u>

As required to facilitate unloading and installation on site. Note that tank cannot be crane-positioned on site. Submit layout and detail for approval.

12. <u>Surface Preparation</u>

Tank exterior shall be cleaned and painted with one coat of grey primer in preparation for insulation. Interior shall be cleaned of debris and washed down.

<u>MECHANICAL ROOM</u>

1. <u>General</u>

An interior mechanical room 14' x 36' shall enclose major components of the solar energy systems, as shown on the drawings.

2. <u>Major Equipment</u>

A. 6500-gallon atmospheric pressure hot water storage tank.

B. Heat transfer package.

C. Circulation pumps and automatic control valves.

D. 120-gallon domestic hot water storage tank (solar).

E. 80-gallon electric domestic hot water storage tank (backup).

F. Motor Control Panel (MCP).

G. Temperature Control Panel (TCP).

H. IBM data-acquisition package (ERDA-specified and supplied).

I. Space accommodation is included for the future addition of one 25-ton Arkla absorption chiller.

3. Structural Pad

Structural concrete pad shall be provided for the 6500-gallon hot water storage tank, as required by manufacturer's specifications. Pad shall be insulated from the floor slab with R-5 or greater urethane or equal.

4. Walls

Walls shall be full height, floor-to-ceiling, water-resistant sheet rock.

5. Observation Window

One double-glazed 2'-0" x 3'-0" observation window shall be provided as indicated.

6. Insulation

Ceiling and partition walls shall be insulated to R-19 and R-11, respectively, for heat and sound insulation.

7. Access

Double 3'-0" x 6'-8" high doors shall be provided as indicated for future equipment installation and replacement. Subsequent building floor plans should maintain provisions for future placement of an ARKLA 25-ton absorption chiller (3' x 10' x 6').

8. Water Containment

Room perimeter shall be provided with a 4" high conrete curb for emergency water containment.

9. Utilities/Drainage

Mechanical room shall be provided with city water, natural gas, 200V AC 3PH, 200 AMP and 100V AC 1PH 50 AMP service. At least one 4" floor drain shall be provided.

10. Ventilation

Power ventilation with outside make-up air shall be provided. Capacity shall be 600 cfm and be thermostatically operated with manual override.

11. Fire Protection

As required by code, and shall include two 10 BC fire extinquishers, CO_2 or Halon.

SOLAR-RELATED HEATING AND VENTILATING EQUIPMENT

1. General

All the provisions of the General Conditions, Supplementary General Conditions and any applicable provisions elsewhere in the contract documents shall apply to the work of this section as fully as if repeated herein.

2. Scope

A. The work covered by this specification shall include furnishing all labor, material, equipment and services to construct, install and place in operation specific piping, ducting, fans, hot water coils and pumps related to the solar portion of the overall HVAC system, to the extent indicated and as shown on the accompanying plans and specified herein, and subject to the General Conditions of the contract. All the work covered under this section of the specification shall hereinafter be referred to as the solar mechanical system.

B. A partial system of temperature controls shall be furnished and installed complete as hereinafter described. All wiring, conduit and electrical cable, complete with all electrical accessories and materials, as required for the installation of the temperature control system, shall be furnished and installed under the solar mechanical section of the contract, but shall conform to the specification requirements as set forth under the electrical section.

C. Thermal and acoustic duct and pipe insulation.

3. Work Not Included in This Solar-Related Section

A. Work involving unitary air handlers, air distribution and direct expansion air-conditioning systems which will be covered under a separate, non-solar specification.

B. Electrical connections to all motors, electric starters, disconnect and over-current protective devices, unless specifically called for by this contractor, or unless the equipment is furnished as an integral part of the mechanical system equipment, as hereinafter specified or noted on the drawings.

C. Electrical wiring and conduit, except where specifically called for, on the drawings, or hereinafter in this specification, to be furnished by the mechanical contractor; such as certain temperature control wiring, etc.

D. Work involved in zone-to-zone air-distribution systems, including installation and testing.

4. <u>Hot Water Fan Coil Heating Circuit</u>

A. Hot water coils shall be Trane type W, 33" x 48", 11 ft^2 face area, 4 row, 18 fin series, with water side turbulators.

B. Necessary plumbing and piping specialties shall be installed as per the mechanical drawings and component schedules.

C. Unless otherwise shown on the drawings, all piping shall be run parallel to the building construction. All piping shall be thoroughly cleaned and maintained in a clean condition throughout construction. Temporarily plug or cap end of pipe as necessary to maintain this condition.

D. Hot water supply and return shall be hard drawn, type "L" copper tube, made up with wrought or forged copper fittings and 95-5 tin-antimony solder. See insulation section of this specification for insulation requirement on piping systems.

E. All coil connections shall be made with brass nipples.

Unions	Copper to FPT	Mueller No. C-109
	Copper to Copper	Mueller No. C-107
Flanged Unions	With Tube Stop	Mueller No. F-900
Adapters	Copper to MPT	Mueller No. C-101
	Copper to FPT	Mueller No. C-102

F. "Epco" or approved equal isolating fittings shall be located at all junctions in piping systems where dissimilar metals join.

G. All valves listed in this schedule are Nibco, unless otherwise noted.

Type	Size Range	Number
Ball	2" and smaller	5-595-Y, 400 WOG, bronze, exterior handle
Gate	2-1/2" and larger	5-113, 200 WOG, bronze

H. A partial system of temperature controls shall be furnished and installed as per the control specifications.

I. All screwed valves shall be IPS threaded. Valves in copper tube shall be installed with male IPS to sweat copper adapters.

5. Piping Hangers, Supports, Anchors and Guides

A. Supports, hangers, anchors and guides shall be provided for all horizontal and vertical piping. Submit shop details, before construction of all piping 1-1/2" diameter and over and all piping in shafts. Shop drawings are to show locations and joints, hangers, etc.

B. Anchor points as shown on drawings or as required shall be located and constructed to permit the piping system to take up its expansion and contraction freely in opposite directions away from the anchored points.

Guide points for expansion joints shall be located and constructed wherever required or shown on drawings and at each side of an expansion joint or loop, to permit only free axial movement in piping systems but shall not be further than 3 pipe diameters on each side of joint.

C. All pipe supports shall be designed to avoid interferences with other piping, hangers, electrical conduits and supports, building structures and equipment.

D. Provide all steel required for support of pipes other than steel shown on structural engineer's drawings.

E. Pipe supports shall be of the following type and figure number as manufactured by Grinnell, or as approved, and as hereinafter indicated:

Ring Hanger.	269
Clevis Hanger.	260
Clevis Roller Hanger	181
Two Rod Roller Hanger.	171
U-Bolt	137
Roll Chair	175
Adj. Steel Pipe Stanchion.	259
Welded Steel Bracket	195 or 199
Riser Clamp.	261
Pipe Alignment Guide	256
Double Bolt Pipe Clamp	295
Welded Beam Attachment	66

F. Hanger Rods shall conform to the following table:

Pipe Size	Rod Diameter
1/2" to 2"	3/8"
2-1/2" to 3-1/2"	1/2"
4" to 6"	5/8"

G. At the contractor's option, trapeze hangers may be used where parallel runs of pipe occur if proper allowance for piping expansion is provided. All rods on trapeze hangers shall be 1/2" minimum size.

H. Wherever insulated pipe is supported by ring hangers, the rings shall pass freely around the insulation. The insulation shall be protected at a point of contact with ring hangers or trapeze bar, as the case may be, by means of Insul-Shield protection saddles.

I. Hanger spacing shall be as follows:

1) 10 feet on center pipe sizes 2" and over.

2) 6 feet on center pipe sizes 1-1/2" and under.

J. A pipe support shall be provided on the top of each branch, regardless of length.

K. Special pipe hanger and equipment support fabrications shall be furnished and installed as indicated in detail on the drawings.

6. South-Wall Air Collector System

A. The contractor shall furnish and install the South-wall solar air collection system, complete with ducting, dampers and necessary temperature controls, as detailed in the drawings and elsewhere in these specifications.

B. The size and characteristics of the air handler shall be specified in the conventional HVAC specification (client-specific). It is noted herein that all blower components shall be capable of withstanding temperatures of 160°F. Blower drive motors shall be externally mounted of Class B designation.

C. South-wall ducting shall be damper relieved such that South-wall glazing will not be exposed to a vacuum greater than 2.0" H_2O.

D. The collector glazing system shall be installed in strict accordance with the drawings and manufacturer's specifications. Outer glazing of the double-glazed unit shall be patterned low-iron glass as approved by the Engineer. Particular care shall be directed towards the grouting and weatherproofing of the vertical glazing system.

E. Concrete wall surfaces covered by the South-wall collector shall be painted by qualified personnel with a dark brown paint, as specified by the architect.

F. Interior ducting and registers shall be in accordance with the plans and specifications. Metal duct work shall be fabricated according to accepted practice, as delineated in the following paragraphs.

7. Rectangular Sheet-Metal Duct Work

A. All rectangular supply, return and exhaust ducts, access doors, single-leaf dampers and plenums shall be fabricated from prime grade galvanized steel sheets of lock form quality and shall be constructed in accordance with appropriate tables of the latest ASHRAE "Guide and Data Book" and with SMACNA "Duct Manual and Sheet Metal Construction for Ventilating and Air Conditioning Systems" handbook.

B. Standing seams will be permitted in equipment areas.

C. Fabricate access doors in ducts and single-leaf dampers of 18-gauge material.

D. Duct dimensions shown are internal. Where ducts are lined internally, fabricate ducts with allowance for thickness of lining such that inside dimensions equal the indicated duct size. See insulation specification.

E. Each duct or plenum shall be diagonally cross-broken for rigidity.

F. Make all joints in ducts air-tight; seal all openings, joints and seams with Foster 30-02 flame resistance duct sealant.

G. All duct bends, fitting, transitions, etc., shall be fabricated in accordance with Fabrication Standards, as shown on the drawings.

H. Support ducts to joists or similar structural members. Ducts with a greater side of 31" or more shall be supported on trapeze-type hangers consisting of 1-1/2" x 1-1/2" x 1/8" angle and 3/8" diameter hanger rods hung from support brackets bolted to structural members. See also special fabrications as shown on the drawings. Duct supports shall be eight (8) feet maximum on center.

I. Special duct fabrications not fully described in this specification shall be per details on drawings.

8. Round Duct Work and Fittings

A. All round duct work and fittings shall be as manufactured by United Sheet Metal Company or an approved equal manufacturer.

B. Duct shall be spiral fabricated from standard galvanized steel sheet conforming to the following schedules.

Duct Diameter	Guage Steel
3" to 8"	25
9" to 22"	24
23" to 28"	22
29" to 36"	22

C. Fittings shall be United Sheet Metal, or approved equal, in accordance with the following schedule:

90° tee	Type LT-3
Conical 90° tee	Type L-Con. T-3
34° ell	Type EO-45
90° ell	Type EO-90
Reducer	Type LR-1
CPL	Type L-14-1
45° tee	Type LL-3

D. Make all joints in duct air-tight; seal all openings, joints and seams with Foster 30-02 flame-resistant duct sealant.

9. Duct Specialties

A. Splitter Dampers. All splitter dampers shall be fabricated from 18-gauge galvanized steel sheet and shall be securely attached to damper operator.

B. Damper Operators and Bearings. Young, or approved equal, No. 403B lever type, with matching end bearing.

10. Insulation

A. General. Unless noted otherwise, all insulation shall be Fiberglas, or approved equal, material. Application shall be performed in accordance with the best accepted practice of the trade and the manufacturer's recommendations. The performance of all insulation work shall be by experienced insulation applicators. Piping insulation shall be installed after the specified tests have been applied to the piping systems, and the systems have been inspected and approved. Fiberglas trade names and/or numbers have been used to establish a standard of quality.

B. Hot Water Supply and Return Piping

1) Refer to Insulation Section.

C. Duct Insulation (Exterior)

1) Insulate all supply duct and plenums with 1" thick Fiberglas-faced duct wrap, types ED-100, as manufactured by Owens Corning Fiberglas Corporation, or approved equal

2) Insulation shall be wrapped tightly on the duct work with all circumferential joints butted and longitudinal joints overlapped a minimum of 2". Adhere insulation with 4" strips of insulation bonding adhesive, at 8" o.c. Additionally, secure insulation to the bottom of concealed rectangular duct work 24" wide with suitable mechanical fasteners at not more than 18" o.c.

3) On circumferential joints, the 2" flange on the facing shall be stapled with 9/16" flare-door staples on 6" centers and taped with minimum 3" wide foil reinforced Kraft tape. On longitudinal joints, the overlap shall be stapled (9/16" flare-door staples) on 6" centers and taped with minimum 3" wide foil reinforced Kraft tape. All pin penetrations or punctures in facing shall also be taped.

11. Space Temperature Controls

A. Furnish all labor, materials, equipment and services as necessary for the proper installation of system of automatic temperature control, as indicated in schematic diagrams on the solar-mechanical drawings.

B. The temperature control system shall be as manufactured by Barber-Colman, or approved equal, in accordance with schematic diagrams on the drawings.

C. All electric wiring, conduit and other electric devices required to complete the installation of the temperature control systems shall be installed by the temperature control contractor and shall comply with all requirements as set forth in the electrical section of this specification.

D. The furnishing and installation of the complete control system shall be by the respective temperature control manufacturer or by the manufacturer's authorized representative.

E. All pneumatic tubing, except in boiler rooms shall be "FR" plastic tubing. Pneumatic lines in boiler rooms shall be type "L" hard copper tube.

F. All wiring required for the installation of the control system shall be in conduit, except an approved cable may be used in low-voltage wiring.

G. After completion of the installation, the contractor shall adjust all thermostats, control valves, motors, and other equipment provided under this contract. He shall place them in complete operating condition subject to the approval of the architect.

H. The final connections and supervision of all control wiring and interlock wiring shall be the responsibility of the temperature control contractor.

I. The contractor shall submit to the architect for approval the required number of shop drawings of the entire control system before starting work.

J. Upon completion of the work, the contractor will provide diagrammatic layouts of the automatic control system specified herein. Layouts shall show all control equipment and the function of each item shall be fully described.

DOMESTIC HOT WATER

1. General

These specifications are intended to complement the piping notes shown on the plumbing drawings and the general piping specifications. Therefore, both plans and specifications should be reviewed by the contractor for information regarding materials and methods for the Domestic Hot Water system.

A. Install piping generally level, free of traps and unnecessary bends to conform with system requirements, and provide space for other work. Piping is to be free of unusual noises and installed to avoid any possible galvanic action by isolating dissimilar metals with suitable dielectric insulating fittings. Dielectric unions shall be "EPCO" or approved equal.

B. Inspect each piece of pipe, tubing, fittings and equipment for defects and obstructions. Protect enameled or polished equipment from damage, tool marks, etc.

C. All piping shall be hard drawn, type "L" copper tube, made up with wrought or forged copper fittings and 95-5 tin-antimony solder applied in strict accordance with manufacturer's directions.

D. Threaded connections shall be avoided where possible. Apply Teflon tape or liquid Teflon to male pipe threads and not inside fittings.

2. Components

The Domestic Hot Water system shall be comprised of the following components:

A. <u>120-gallon solar tank</u>. 120-gallon stone-lined tank with internal copper fin tube double-wall heat exchanger. Ford Storex TC-120 DW. (Pacific Sun, Marketing Division: (415) 328-4588)

B. 80-Gallon Back-Up Tank. Electric, commercial grade, 18 kw, 240VAC, 3 phase, 123 GPH at 60°F rise. A.O. Smith model DRE-80 or equal.

C. Tempering Valve. Watts N170L, 1", bronze body, 100°-130°F temperature range. Set at 110°F.

D. Heat Exchanger Circulating Pump P4. Grundfos UP-25-42 SF 1/20 hp, two speed, all stainless steel, isolation valve flange connection, 110VAC.

E. Combined Check Valve. Balance valve and flow meter for heat exchanger circulating loop (pump P4) shall be a Taco Monitor No. 781, 3/4" NPT, range 1.5-8 gpm, or equal.

F. DHW Circulating Pump P5. Grundfos UM-25-18, 1/35 hp, one-speed, all stainless steel, union connection, 110VAC.

INSULATION

1. General

Due to the importance of insulation in solar piping loops, application work shall be performed in strict accordance with the best accepted practice of the trade, and the manufacturer's recommendations. The performance of all insulation work shall be by experienced insulation applicators. Piping insulation shall be installed after the specified tests have been applied to the piping systems, and the systems have been inspected and approved. Fiberglass trade names and/or numbers have been used to establish a standard of quality. The nature of this demonstration project requires the physical appearance of exterior and mechanical room piping to represent the highest standards of workmanship in the insulation trade.

2. Initiation of Work

Insulation work shall not commence until all piping and hydraulic circuits have been inspected, leak-tested and accepted by the engineer.

3. Tank Insulation

Six-inch thick fiberglass blanket (R-20 or greater at 200°F), Johns-Manville 1000 Spin-Glas or equal. Insulation shall be compatible with 212°F tank temperature. Insulation shall be covered with a 0.016" aluminum jacket. Pipe penetrating the tank shall be insulated according to pipe insulation specifications. Tank bottom shall be insulated with 3" thick fiberglass board (R-10 or greater at 200°F), Johns-Manville 1000 Spin-Glas or equal, between supporting I-beams.

4. Pipe Insulation

A. Unless noted otherwise, all insulation shall be fiberglass or approved equal.

B. Collector, domestic and heating hot water supply and return piping shall be insulated with preformed glass fiber pipe insulation having a minimum density of six (6) pounds per cubic foot complete with factory applied all service jacket (ASJ). Domestic hot water supply and return piping shall be 1" wall thickness. All other fiberglass insulation shall be 2" wall thickness.

C. The ASJ applied in accordance with manufacturer's instructions and with all fittings, corners and valves covered shall be the finished surface for piping runs exclusive of all exterior piping and all mechanical room piping.

D. Mechanical Room piping shall be finished by covering with CertainTeed Snap*Form, one-piece, PVC, molded jacket cover secured by stainless steel tack fasteners inserted into the jacket throat overlap seam. All pipe insulation straight runs shall be jacketed with matching PVC sheet stock and end joints taped with 2" tape end overlap on itself, facing down. Finish shall be applied in strict accordance with manufacturer's recommendations.

E. Alternate finish shall be canvas applied in the following manner:

1) Preformed fiberglass pipe insulation shall be provided complete with factory applied presized glass (PSG) cloth jacket. Paste jacket and butt strips in place and size with a dilute coat of Seal-fas, Foster's 30-36 (3 parts Seal-fas to 1 part water).

2) In general, all fittings, valves, instrument ports and circuit setters shall be insulated with "Zeston" fitting closures. In cases where certain sizes or shapes are not manufactured, fittings, valves, flanges and other irregular pipeline accessories shall be insulated with mitered sections of pipe insulation on fittings greater that 2" in size, and OC-110 insulation cement on fittings smaller than 2" in size. Where necessary, oversized pipe insulation shall be used for flanges, valves and other irregular pipeline accessories. Fittings, valves, flanges and other irregular pipeline accessories shall be covered with 8-ounce canvas dipped in Seal-fas. Torn canvas strips will not be permitted, but shall be neatly cut to prevent any visible ragged edges.

3) Seal off all cut ends of insulation with canvas and Seal-fas.

4) After size coat has dried thoroughly, finish all insulation surfaces with a second, undiluted coat of Seal-fas.

F. Silicone hose insulation on the collector array piping shall be FR/Armaflex closed cell foam, 3/4" wall thickness or equal. FR/Armaflex shall be slipped over hose prior to connection wherever possible. Where the slip-on technique is not possible, foam insulation shall be slit and applied to the pipe and the seams and butt joints sealed with Armaflex 520 adhesive. Butt joints between Armaflex and header connection and collector frame shall be weathersealed with silicone chaulk. One coat of white Armaflex Finish vinyl lacquer type coating shall finish the foam insulation.

G. Exterior fiberglass insulation shall be protected with a 0.010" aluminum or 0.010" stainless steel jacket, factory or field applied, to the standards of Johns-Manville Micro-Lok 650 factory applied metal jacket.

TEMPERATURE-CONTROL SYSTEM

1. General

A. The temperature control system shall be solid-state electronic type as manufactured by Barber-Colman Company or approved equal.

B. The system shall be installed by the control manufacturer.

C. All low-voltage control wiring and line-voltage interlock wiring shall be installed by the temperature control manufacturer.

D. The installation shall conform to the National Electrical Code and all local codes.

2. Operating and Maintenance Instructions

Furnish to the Owner three sets of Operating and Maintenance Instructions, including as-built drawings.

3. Temperature Control System

Furnish and install a factory-prewired temperature-control panel with all equipment mounted internally and prewired to numbered terminal strips. All temperature setpoints and adjustments shall be at the temperature control panel.

4. System Operation*

Collector loop pump P1 starts if collector plate temperature is greater than 130°F. Pump P3 is interlocked to operate with P1.

An adjustable time delay relay, energized by collector plate thermostat, provides an off-delay for P1 (Nominally 5 minutes). At the end of the delay period, pumps P1 and P4 continue to operate if the temperature at the collector plate is 5°F greater than the loop temperature.

In the charge mode, valve AV1 connects the P4 loop to the center and bottom of the storage tank and valve AV2 modulates to maintain 120°F loop temperature. As the P4 loop temperature increases, valve AV2 modulates to allow more water flow into the storage tank.

Fan coil pumps P2 and P3 are energized by their respective zone thermostats. These pumps are interlocked to operate only if the loop temperature exceeds 90°F or if the water temperature at the top of the storage tank exceeds 90°F. Pump P4 is interlocked to operate with either P2 or P3.

If, when the pump P4 is energized, the loop temperature falls below 110°F, valve AV1 changes position to supply water from the top of the tank and the action of AV2 is reversed to modulate flow of water from the tank, to the loop. AV2 strives to maintain a 120°F loop temperature.

For stability, the system is returned from discharge mode to the charge mode in two stages. When the P4 loop temperature exceeds 125°F, an adjustable time delay is energized. At the end of the delay period, the charge mode is engaged (AV2 reversing logic, AV1 changing position) if the loop temperature remains at 125°F or greater.

If the collector plate temperature is 240°F or the temperature at the top of the storage tank is greater than 200°F, valve AV3 connects the solar loop to the dump coil, energizes the coil fan, de-energizes P4, and energizes P1.

If DHW storage tank temperature is less than 140°F and main storage tank temperature is greater than DHW storage plus 10°F, then DHW tank heat exchanger pump P4 is energized.

If DHW return line temperature is less than 100°F, the DHW circulation pump P5 is energized.

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* All temperatures herein are field adjustable.

5. Perimeter Zone Controls

The temperature of air supplied to the perimeter zones shall be reset in accordance with variations in outdoor temperatures.

Anti-drain control for Perimeter System control valves V4 and V5 shall perform two functions:

a) Modulate H.W. flow through perimeter coils.

b) Act as shutoff valves connected so that on a stop command for pump P2 the valves will be driven closed before pump P2 is de-energized.

6. South-Wall, Air Heating System

A. Return air for the south perimeter heating system air shall be routed through the South-wall solar heating array.

B. When heating is called for, entering air temperature to the blower shall be limited to the reset schedule requirement with the modulating bypass damper as shown on the drawings.

C. When no heating is required, the South-wall system shall be totally deactivated.

7. Guarantee

All equipment shall be guaranteed for a period of one year from the date of acceptance.

5.3 SCHEDULES

Construction of the project is to begin in December of 1976 and completion of construction is scheduled for June of 1977. Some of the solar energy system work such as burial of the storage tanks and some of the underground piping will be carried out in the early construction stages. Most of the solar installation work on both the hydronic and air systems will be executed near the final stages of construction; such as placement of the solar collectors, most of the piping layout and the control system wiring.

The following milestones reflect an updated schedule:

Design Review	Initial	Revised
Initial	8-16-77	
50% Complete	10-28-77	
90% Complete (Final)	10-28-77	

Solar System's Contract	Initial	Revised
Bid Request	1-78	
Award of Contract	5-78	
Equipment Delivery	5-78	
Solar System		
Solar System Installation	5-78	
Complete Installation	10-78	6-79
Initiate Operation	6-78	6-79
Complete Acceptance Test	1-79	7-79

5.4 COST

The final construction cost for the system was $370,843 of which DOE paid $168,334. The cost is anticipated to be $735/MBTU. The projected cost from June 1978 is detailed as follows:

Direct Material		
Collectors	$75,792	(plumbing & collector hook-up $32K
Special Installation	15,248	Collector installation $24.5K
		Collector Framing $19.2K)
Consultants		
Management	15,000	
Design/Bids/Acceptance	16,144	
Other Direct: Subcontracts		
Installation	234,268	
Special Plumbing	6,125	
Special Construction	1,116	
TOTAL	$363,693	(6/78)

System and Subsystem Performance/Technical Data—Continued

7. Design Life and Maintenance

   a. Describe Periodic Maintenance provisions and requirements.
   To be supplied at time of installation

   b. Specify design life of all components (if available).

   1. Heating 20 yrs.
   2. Cooling Not Yet Specified yrs.
   3. Auxiliary Energy Not Yet Specified yrs.
   4. Storage 20 yrs.
   5. Potable 20 yrs.
   6. Collector 20 yrs.
   7. Energy Transport 10-15 yrs.
   8. Controls 10-15 yrs.
   9. Hot Water 20 yrs.
   10. Pumps 10-15 yrs.
   11. Fans Not Specified yrs.
   12. Other ______ yrs.

   c. Provide Warranty period and extent of coverage of the proposed Solar Energy System and subsystems.

   3 years on solar collectors, 1 year on most of the remaining parts of the system.

5.6 ENERGY CONSERVATION CONSIDERATIONS

ENERGY CONSERVATIONS TECHNIQUES USED IN THIS PROJECT INCLUDE:

1. THE USE OF LIGHT REFLECTIVE MATERIALS ON THE BUILDING TO CUT DOWN THE HEAT GAIN IN THE WARMER MONTHS. ALSO, THE SOLAR COLLECTOR EFFICIENCY SHOULD BE SLIGHTLY INCREASED DUE TO THE REFLECTION OF THE SUN'S RAYS INCIDENT UPON THE ROOF INTO THE SOLAR COLLECTOR.

2. THE USE OF OVERHANGS ON THE SOUTH SIDE OF THE BUILDING WILL ALLOW SOLAR PENETRATION ONTO THE BLACK SOLAR AIR WALL IN THE COLDER MONTHS. DURING THE WARMER MONTHS WHEN THE SUN IS RELATIVELY HIGH, THE OVERHANGS WILL SHADE THE SOUTH WALLS DURING THE HEAVIEST HOURS OF HEAT GAIN.

3. THE USE OF ECONOMIZER CYCLES IN THE BUILDING'S MECHANICAL SYSTEMS WILL ALLOW THE MOST ENERGY CONSERVING MIXTURE OF INSIDE AND OUTSIDE AIR TO BE CONDITIONED.

4. THE USE OF R-19 INSULATION IN THE CEILING, R-11 INSULATION IN THE WALLS, AND THERMOPANE GLAZING WILL HELP TO INSULATE THE BUILDING AGAINST EXCESSIVE HEAT GAIN AND HEAT LOSS.

5. THE USE OF SKYLIGHTING ON TOP OF THE BUILDING OVER ACTIVITY AREAS WILL HELP TO CUT LIGHTING ENERGY USE. THE EXACT SKY-LIGHTING SCHEME WILL BE WORKED OUT WHEN THE CLIENT'S SPACIAL REQUIREMENTS ARE KNOWN.

6. THE USE OF DECIDUOUS TREES ALONG THE SOUTHERN PORTION OF THE BUILDING WILL ALLOW SOLAR PENETRATION IN THE COOLER MONTHS, WHILE PARTIALLY SHADING THE BUILDING IN WARM MONTHS.

7. THE USE OF VARIOUS HEATING AND COOLING ZONES WILL ALLOW THE USE OF HEATING AND COOLING ONLY IN THE AREAS WHERE IT IS NEEDED.

8. THE USE OF PREHEATED VENTILATION AIR FROM THE AIR SOLAR ENERGY SYSTEM ALONG THE SOUTH WALLS WILL CUT DOWN THE QUANTITY OF COLD OUTSIDE AIR THAT MUST BE DRAWN IN.

9. THE USE OF A NIGHT SET-BACK THERMOSTAT WILL ALLOW ROOM TEMP-ERATURE DROPS DURING NON-WORKING NIGHT AND MORNING HOURS, CUTTING BACK OVERALL HEATING REQUIREMENTS FOR THE FULL DAY.[1]

   1. D. QUENTZEL, "NIGHT-TIME THERMOSTAT SETBACK", ASHRAE JOURNAL, MARCH, 1976.

5.7 PROBLEMS

During initial selection of contractors, a change in contractors caused a delay.

SECTION 6

ACCEPTANCE TESTING

6.1 TEST PLAN

A. All equipment and installations shall be operated by the contractor, and he shall demonstrate that all system are performing according to the requirements of the specifications and to the satisfaction of the owner and engineer.

B. Upon completion of the tests, the contractor shall submit in triplicate to the architect and engineer a written report containing the following:

1) Certification that all required tests have been performed.

2) Certification that all equipment furnished under this contract has been tested and is ready for operation.

3) Valves: Test all valve bonnets for tightness. Test-operate all valves at least once from closed-to-open-to-closed position while valve is under test pressure.

Test all automatic valves, including solenoid valves, expansion valves, water-regulating valves, pressure-reducing valves, pressure-relief valves for proper operation at the setting indicated. Test pressure-relief valves not less than three times.

4) Piping Specialties: Test all thermometers, pressure gauges and water meters for accurate indication, automatic water feeders, air vents, trap primers and vacuum breakers for proper performance.

Test all air vent points to ensure that all air has been vented.

Test all other piping specialties for proper operation.

SYSTEM STARTUP AND ACCEPTANCE TEST PROCEDURE

1. General

Testing and startup of the solar/mechanical piping system shall be accomplished under strictly controlled conditions. Special precautions must be taken to avoid freeze damage of the solar collector array. The contractor should note that, because of radiative losses to the night sky, collector plates can be freeze-damaged even though ambient temperatures are above 32°F. In addition, general piping cleanliness is of the utmost importance to avoid blockage of the small collector flow passages.

Under no circumstances shall the system be filled with water or heat transfer fluid without direct authorization from the engineer.

2. Cleaning

Before any filling or testing operations commence, all equipment and piping shall be thoroughly cleaned of iron and copper cuttings, teflon tape and other foreign matter. Cleaning shall be a continuous process during installation. Particular attention should be given to:

A. Solar collector array

B. Pump packing glands or mechanical seals

C. Valve seats and glands

D. Flange and union faces or seats

E. Strainers, orifices, gauge glasses, instrumentation ports

3. Collector Protection

During and after installation and prior to circulating water through solar collector panels, glass covers shall be protected with a nonabrasive opaque covering (such as black plastic film) to prevent unnecessary overheating of the solar panels. Aborber plates can reach temperatures approaching 400°F under full sun and no-flow conditions, preventing easy filling of the system for testing, cleaning and charging. Only after water is circulating through collector absorber fluid passages and the energy dump coil is operational, shall the contractor remove glass cover protection material.

4. Safety Provisions

The contractor shall furnish all test pumps, gauges and equipment so as to adequately test all safety controls and devices. The contractor shall submit to the architect and engineer a written report stating that all safety controls have been properly tested and that they are in perfect operating condition.

5. Pretest Inspection

Before any hydraulic testing commences, the contractor and/or his representative shall supervise an on-site tour of the mechanical system with the engineer and architect. The entire mechanical system shall be inspected for overall piping logic, proper installation of piping specialties (including, but not limited to, pump alignment, piping closure), general workmanship and readiness for filling and testing. Filling and testing shall not commence without the architect's and engineer's prior approval.

6. Filling and Leak Testing

Fill and testing of the solar collector/hot water coil loop shall be made only on approval of the engineer. Test and make tight at 75 psi water (gauge). Retain for four hours, repair all leaking joints as directed and re-test. Under no circumstances shall the solar collector loop be filled during freezing weather or allowed to remain filled except during supervised testing until the final filling for operation. Damage resulting to the solar collectors during unauthorized fill and testing shall be the responsibility of the contractor.

7. Collector Loop Flushing

Upon successful completion of leak-testing, clean water shall be circulated through the collector loop with pump P1 for a period of one hour.

A. Flow rates in the collector loop shall be set at approximately 50 GPM.

B. All air vents, vacuum breaks, air controllers and similar piping specialties will be checked for proper operation.

C. At the end of the one-hour circulation period, all strainers shall be cleaned and inspected for abnormal debris. Circulation shall be resumed until strainers' conditions indicate that the piping system is clean.

D. The system shall be thoroughly drained after successful completion of the aforementioned tests. Under no circumstances shall the contractor allow untreated water to remain in the collector loop when freezing conditions are even remotely possible.

8. Collector Loop Washing

Wash system with a 1-2% solution of sodium orthosilicate compatible with steel, copper and brass or copper alloy. Drain completely and rinse with city water to remove dirt, pipe scale and other impurities. Clean all strainers. This is the final operation prior to filling the system with the propylene glycol water antifreeze heat transfer solution.

9. Collector Loop Charging

The contractor shall fill the system through the chemical injection pump with the specified antifreeze heat transfer fluid to 30 psig, venting all high points and equipment of air and gases. As air is released from the system under circulation, maintain proper expansion tank level by adding heat transfer fluid through the injection pump. Heat transfer fluid shall be a 30/70 mix of Dowfrost inhibited propylene glycol and water.

After the glycol/water mixture is circulating through the collector array and the energy dump coil is fully operational, the contractor shall remove the glass cover protection material and shall thoroughly clean collector glass covers to ensure maximum performance of the collector.

10. Filling of Storage Tank

Upon successful completion of the aforementioned tests, the contractor shall fill the 6500-gallon storage tank with city water. Filling shall commence only after thorough cleaning of the tank internals. During filling the tanks shall be carefully inspected for leaks or abnormal structural conditions.

11. Filling and Testing of Storage Loop

The contractor shall pressure test the hot water storage loop at 100 psi gauge, inspect and correct leaks. Loop pump P3 shall then be engaged and, with valve AV2 in full bypass mode, the loop flow shall be adjusted to approximately 50 gpm and run for a period of 30 minutes. At the end of this period, all pertinent strainers should be cleaned and inspected for foreign matter. Repeat flushing as necessary.

12. Corrosion Inhibitor

Corrosion inhibitor shall be provided for the hot water storage and tank loop at 1 pound per 50 gallons. It shall also be added as required to the glycol/water collector loop to maintain proper pH and buffering. Inhibitor shall be Calgon CS.

A. Composition. Combination of sodium nitrate, borax, benzotriazole and inorganic corrosion inhibitors.

B. Physical Form. Light tan, free-flowing, granular product with bulk density of 79 lbs/ft^3.

C. Solubility. 4 ounces per gallon at 75°F.

D. pH Value. pH of a 1% aqueous solution of 25°C shall be 7.5 minimum.

E. Water Insoluble Matter. Less than 0.1% by weight.

F. Performance

1) Controls corrosion of ferrous, non-ferrous and multimetal systems.

2) Compatible with glycol-base antifreeze and will not form sludge.

3) Will not adversely affect pump glands, rubber hose, water seals and valve packings.

4) Will not cause dermatitis when handled by operators with reasonable care.

5) Safe for use in high-temperature systems.

G. Stock. The contractor shall provide the owner with one 100 lb drum of Calgon CS and one Calgon test kit No. K-0065 for determing CS residual in glycol system.

13. Warning

Under no circumstances shall the glycol-based collector loop be subjected to any chromate corrosion protection treatment. Calcon CS shall be the only pH control used without express written permission of the engineer.

14. Hydraulic System Balancing

After the system has been tested as outlined, all heat transfer fluid systems shall be balanced and all control devices adjusted. The final balancing of the system shall be performed by a firm who maintains a staff of competent personnel experienced in balancing and adjusting hydronic systems. The name of this firm that the contractor proposes to engage to perform this work of balancing the system shall be submitted to the architect for approval prior to final acceptance of the system. The balancing firm shall submit a report in triplicate certifying to the proper performance of the system. The following information shall be included in the report:

A. Motor current readings and voltage readings.

B. Flow in GPM at all specified points under all specified operating modes.

C. Static pressure at designated points under all specified operating modes.

D. Water quality analysis.

15. Thermal Performance Tests

Upon successful completion of the aforementioned mechanical and hydraulic testing and balancing procedures, the contractor, in conjunction with the temperature controls sub-contractor, shall verify that all operational control modes are working to the satisfaction of the owner. The contractor should recognize that these tests may span several days or weeks before all modes are fully tested, although constant system monitoring is neither expected nor desired. During these tests, and under different operational modes, the following data are to be compiled:

A. All loop flow rates in GPM.

B. All pertinent loop temperatures.

C. Selected tank temperatures.

D. Insolation values.

These data will be supplied to the engineer for compilation and preliminary assessment of system performance. It is not unlikely that some modifications to circuit or control logic will be dictated, and such work will be subject to negotiation of price and terms under the covenants of the general specifications.

16. DHW Startup Procedure

The contractor shall exercise the following sequence of events to activate the solar DHW system.

A. 1" isolation valves shall be placed in their normal operating position, as indicated on the plumbing schematics.

B. Electric backup heater thermostat shall be set at 110°F.

C. Mixing valve shall be set to provide 110°F outlet water temperature.

D. DHW circulator aquastat shall be set to engage circulation pump P5 at 100°F water temperature in the return lines.

E. Set circulator pump P5 flow rate at 1.0 GPM.

F. Solid-state differential temperature controller for the heat exchanger pump shall be set at the minimum "on" differential of 10°F.

G. With the 6500-gallon hot water storage tank filled, engage P4 with speed selector on "low" and set the flow rate at 6 GPM. If the specified flow is not in range of the low speed setting, change the speed selector to "high" and establish a 6 GPM flow through the heat exchanger. Set the controller to automatic mode.

17. Collector Array Cleaning

Upon successful completion of all system tests, the collector array glazing shall be carefully washed down with a mild detergent and cold water solution and rinsed thoroughly. High water pressure cleaning equipment shall not be used to avoid glazing seal damage and leakage.

SECTION 7

SYSTEM THERMAL PERFORMANCE

7.1 SOLAR SYSTEM

This section will report in detail the solar system performance in the 1980-1981 and 1981-1982 heating seasons.

The flow of solar energy through the Oakmead Industries solar system is presented in Figure 2, for the 1980-1981 season. This Energy Flow Diagram represents the amount of energy collected, transported, lost, and consumed at each point in the system. The Energy Flow Diagram shows good solar energy collection and good distribution to the loads. A high loss of 82.32 million BTU is noted between the liquid collector and storage tank. This loss represents collector loop losses, storage to load loop losses, and energy losses in April and May when the north zone solar control continually delivered solar energy when there was no space heating load.

The flow of solar energy for the 1981-1982 heating season is shown in Figure 3. During this period the air collector subsystem was deactivated. Storage performance evaluation was invalidated, due to a problem with flow meter W201.

The solar energy coefficient of performance (COP) is presented in Table 2. The COP simply provides a numerical value for the relationship of solar energy used or collected and the amount of conventional electrical energy required to collect or deliver it. The greater the COP value, the more efficient the process. The overall solar energy system at Oakmead Industries performed at a weighted seasonal average solar COP value of 23.87. The collector subsystem functioned at a COP of 46.01, the DHW subsystem COP was 73.46 and the space heating subsystem COP was 91.05. The high COPs represent a low operating energy expenditure compared to solar energy used, resulting in increased energy savings.

The overall solar energy system COP was 12.60 for 1981-1982 (see Figure 3). Note that as solar energy utilization increases, there is an increase in solar COP also. The collector subsystem operated efficiently at a COP of 36.55. Since the collector pump operated many times during the night, the solar COP was lower than expected. The DHW subsystem COP was very high during the summer months, but lower during the space heating season. This performance was due to the fact that the heating subsystem has priority use of solar energy and also that pump P4 was operating continuously from December 1981 through April 1982. These factors resulted in the COP of 22.15. The space heating subsystem had the highest COP of 62.35. This value was reduced somewhat because pump P2 was operating continuously during June 1981 and July 1981 with no contribution to the load.

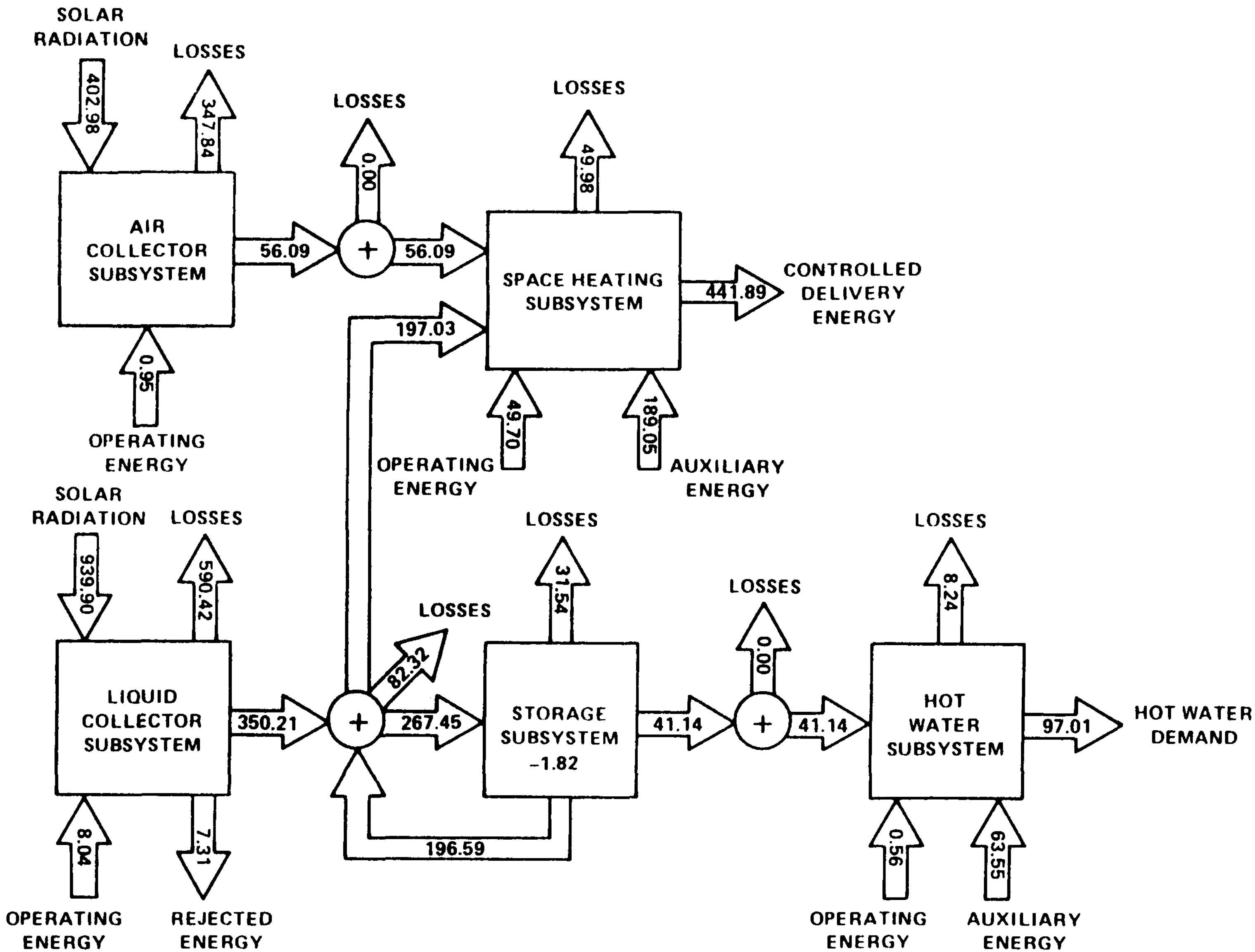
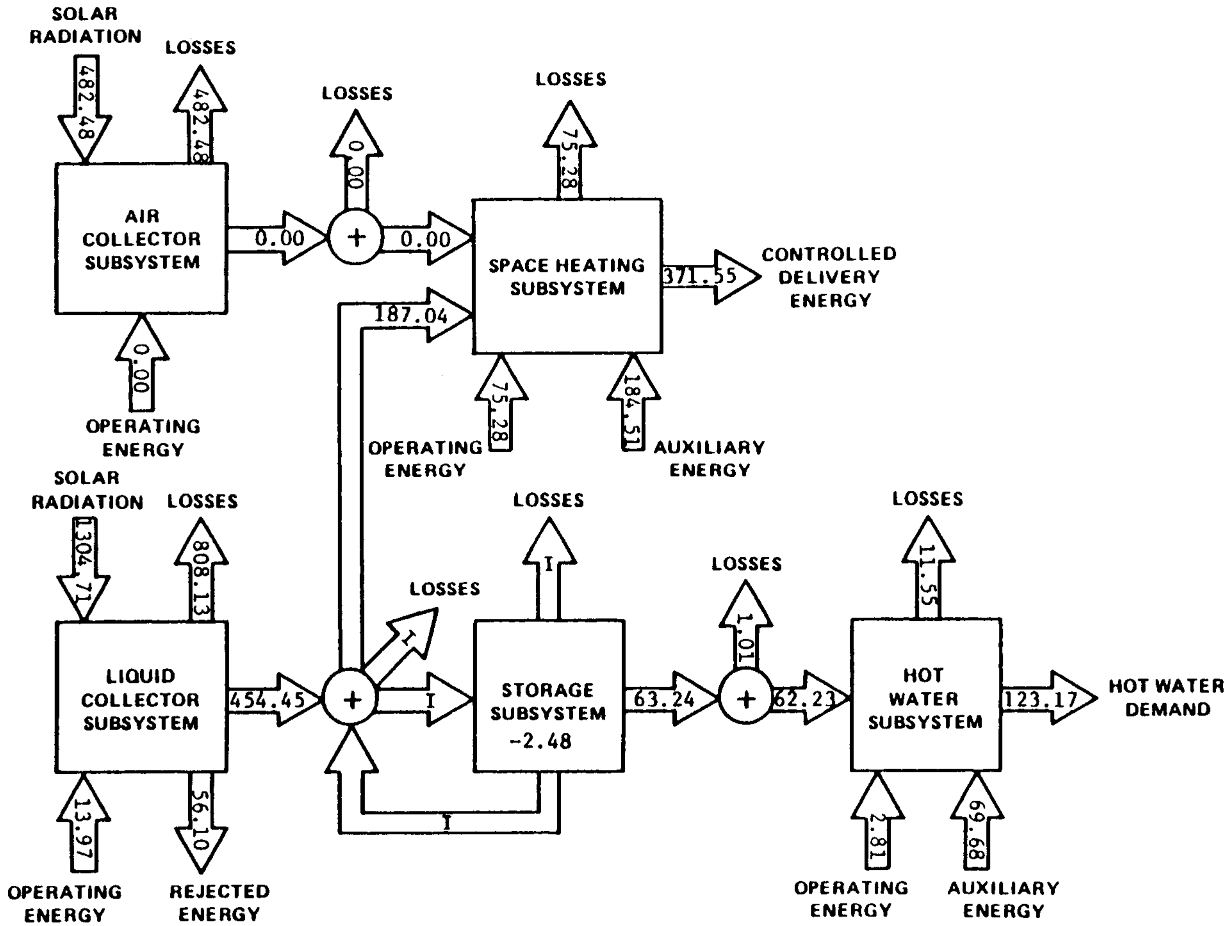


Figure 2. Energy Flow Diagram for Oakmead Industries
October 1980 Through May 1981
(Figures in million BTU)



I Denotes invalid data.

Figure 3. Energy Flow Diagram for Oakmead Industries
June 1981 through April 1982
(Figures in million BTU)

Table 2. SOLAR COEFFICIENT OF PERFORMANCE OAKMEAD INDUSTRIES OCTOBER 1980 THROUGH MAY 1981

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	DOMESTIC HOT WATER SOLAR	SPACE HEATING SOLAR
OCT	34.02	67.97	85.47	161.00
NOV	9.54	45.59	81.11	91.41
DEC	23.04	32.15	40.00	130.65
JAN	19.95	28.99	27.00	115.76
FEB	29.75	54.94	44.29	90.38
MAR	26.87	42.06	44.50	119.24
APR	33.20	81.64	84.75	102.18
MAY	7.59	57.69	95.25	6.44
WEIGHTED AVERAGE	23.87	46.01	73.46	91.05

Table 3. SOLAR COEFFICIENT OF PERFORMANCE OAKMEAD INDUSTRIES JUNE 1981 THROUGH APRIL 1982

MONTH	SOLAR ENERGY SYSTEM	COLLECTOR SUBSYSTEM	DOMESTIC HOT WATER SUBSYSTEM	SPACE HEATING SUBSYSTEM
JUN	6.13	65.41	98.11	0.00
JUL	5.32	49.96	62.64	0.00
AUG	6.46	42.73	63.64	0.00
SEP	9.96	41.97	75.22	0.00
OCT	6.64	39.98	54.38	0.00
NOV	12.26	22.96	9.86	81.59
DEC	10.06	20.35	4.22	78.96
JAN	13.62	26.31	4.13	78.29
FEB	21.25	41.01	7.82	86.20
MAR	14.38	25.41	4.97	91.69
APR	24.07	46.87	8.54	112.10
WEIGHTED AVERAGE	12.60	36.55	22.15	62.35

7.2 PREDICTED VERSUS ACTUAL

The as-built system was modeled using f-Chart Version 5.1. The manufacturer's collector performance parameters, together with the measured loads, temperatures and insulation data were used in this model. The f-Chart model predicted a solar fraction of 54% for the year, which is identical to the actual measured solar fraction during the 1980-1981 heating season. There are significant variations throughout the season, however.

	f-Chart	Measured
OCT	90	82
NOV	59	46
DEC	29	45
JAN	26	37
FEB	60	63
MAR	51	57
APR	100	77
MAY	100	64

For the 1981-1982 heating season, f-Chart predicted a higher solar fraction (61%) than was actually measured (49%). The following presents the solar fractions for the specific months.

	f-Chart	Measured
JUN	100	60
JUL	100	60
AUG	100	65
SEP	100	63
OCT	97	26
NOV	52	48
DEC	38	40
JAN	34	31
FEB	54	56
MAR	57	51
APR	75	73

7.3 SOLAR SUBSYSTEM

7.3.1 Collection

7.3.1.1 Liquid Subsystem Performance

The Oakmead Industries solar site employs two types of collector arrays. The main collector array is a liquid flat-plate array which is utilized for DHW preheating, and for space heating for the north and south zones of the commercial building. The liquid-based collector array is composed of 116 Revere (two banks of 58 collectors each), Sun-Aid flat-plate collectors with a gross area of 2,622 square feet. The Sun-Aid collectors are single glazed with a selective surface. The collectors are oriented due south at a tilt of 45 degrees to the horizontal and are connected in a parallel series arrangement. The collectors are mounted on the north side facia of the concrete wall. A solution of 10% propylene glycol by weight in water is used as the transfer medium to the heat exchanger in the thermal control loop (TCL). The propylene glycol solution is circulated in the collector loop by collector pump P1 which is activated by the collector controller. A heat rejector dissipates excess collected energy for collector protection.

The controls were designed to activate the collector when the collector plate stagnation temperature was greater than 120°F. An adjustable time delay, nominally five minutes, maintained pump operation. At the end of the delay period, the collector pump would continue to operate if the plate temperature was 5°F greater than the TCL temperature. Otherwise, the pump would deactivate and the cycle will begin again. It should be noted that the TCL pump P3 operates in conjunction with the collector pump. This control device functioned extremely well until November 30 when the control device experienced problems and activated the collector pumps at night. Since November 30, the control device has not operated as well as before and system performance was degraded to a small degree. The control problem was corrected on March 25, but the controller operation was changed to function only on a temperature differential between collector plate temperature and TCL temperature.

The performance of the liquid collector is presented in Table 4 for the 1980-1981 heating season.

During the eight-month period, there were 939.90 million BTU of solar energy incident on the liquid collector array. Of this total, 798.63 million BTU were incident while the collector loop was operating. The collector subsystem collected 357.52 million BTU, representing 38% of the total available insolation and 45% of the energy available during collector loop operation.

Solar energy collection required 8.04 million BTU of operating energy for collector pump P1, TCL pump P3, and heat rejector fan power. To prevent the collector subsystem from overheating, 7.31 million BTU of solar energy were rejected to the atmosphere.

The collector subsystem performed very well during the 1980-1981 heating season except for the times when the collector pump was activated all day long. This was caused by sporadic control problems which occurred between November 30 and March 25. Overall, the collector subsystem performed well and provided a solar contribution of 238.17 million BTU to the loads.

Table 4. LIQUID COLLECTOR SUBSYSTEM PERFORMANCE
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	COLLECTED SOLAR ENERGY	COLLECTOR SUBSYSTEM EFFICIENCY (%)	OPERATIONAL INCIDENT ENERGY	COLLECTOR ARRAY OPERATIONAL EFFICIENCY (%)	ECSS REJECTED ENERGY	ECSS OPERATING ENERGY	SOLAR ENERGY TO LOADS	SOLAR ENERGY TO STORAGE	DAYTIME AMBIENT TEMPERATURE (°F)
OCT	137.11	40.78E	30	108.82	37	5.61	0.60	28.92	27.97	79
NOV	104.63	37.76	36	84.34	45	0.56	0.85	25.96	33.05	71
DEC	95.06	38.15	40	90.90	42	0.00	1.39	30.85	30.46	64
JAN	76.30	29.96	38	74.66	40	0.00	1.45	22.32	25.72	61
FEB	105.84	47.86	45	95.64	50	0.00	0.86	40.02	34.31	67
MAR	115.55	51.37	45	108.25	48	0.00	1.30	41.40	33.26	65
APR	155.12	63.19	41	127.63	50	0.55	0.75	37.55	46.01	72
MAY	148.27	48.45	33	108.39	45	0.59	0.84	11.15	36.67	73
TOTAL	939.90	357.52	-	798.63	-	7.31	8.04	238.17	267.45	-
AVERAGE	117.49	44.69	38(1)	99.83	45(1)	0.91	1.01	29.77	33.43	69

E - Denotes estimated value.
(1) Weighted average.

For the 1981-1982 heating season, the collector array efficiency was 39% while the collector array operating efficiency was 46%. The collector performance was enhanced due to the lower collector inlet temperatures provided by the oversized storage tank. However, the collector array required the rejection of 56.10 million BTU for protection from high temperatures. The collector array performance is shown in Table 5.

The large losses (81% of the losses) between collected solar energy and solar energy used occurred during DHW preheating from June 1981 through October 1981. Another 11% of the losses was due to collector loop losses, and the remaining losses are attributed to storage and temperature control loop losses.

Some minor problems were experienced with the collector subsystem. The collector control activated the collector pump occasionally during the night. The problem occurred during low insolation levels that were apparently in the dead-band zone of the controls. The heat rejector unit had a low set point of approximately 174°F, which caused unnecessary energy rejection. Also, the collector manifold connections leaked during the summer months, when high temperatures were common.

Table 5. LIQUID COLLECTOR SUBSYSTEM PERFORMANCE
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	INCIDENT SOLAR RADIATION	COLLECTED SOLAR ENERGY	COLLECTOR SUBSYSTEM EFFICIENCY (%)	OPERATIONAL INCIDENT ENERGY	COLLECTOR ARRAY OPERATIONAL EFFICIENCY (%)	ECSS REJECTED ENERGY	ECSS OPERATING ENERGY	SOLAR ENERGY TO LOADS	DAYTIME AMBIENT TEMPERATURE (°F)
JUN	152.96	56.25	37	122.95	46	0.00	0.86	8.83	82
JUL	151.78	54.46	36	117.34	46	0.00	1.09	8.77	79
AUG	151.53	52.99	35	116.73	45	21.48	1.24	8.91	78
SEP	138.39	49.52	36	107.55	46	15.73	1.18	13.54	79
OCT	130.19	45.98	35	97.10	47	16.35	1.15	8.70	74
NOV	81.57	33.75	41	73.79	46	2.47	1.47	24.89	67
DEC	64.89	27.67	43	61.76	45	0.00	1.36	19.72	62
JAN	95.12	40.52	43	91.75	44	0.00	1.54	31.32	57
FEB	101.94	46.34	46	90.88	51	0.07	1.13	40.59	66
MAR	102.16	41.67	41	98.21	42	0.00	1.64	33.93	61
APR	134.18	61.40	46	125.88	49	0.00	1.31	50.07	68
TOTAL	1,304.71	510.55	-	1,103.94	-	56.10	13.97	249.27	-
AVERAGE	118.61	46.41	39(1)	100.36	46(1)	5.10	1.27	22.66	70

(1)Denotes Weighted Average.

The operation of the collector array can be seen in Figure 4, a collector efficiency plot. The line on the graph is plotted from the manufacturer's ASHRAE test parameter. The measured data falls one percent above the test panel results, but the measured slope is flatter. The control problem (extended collector pump operation) in the latter measured months degraded the collector performance by five percent.

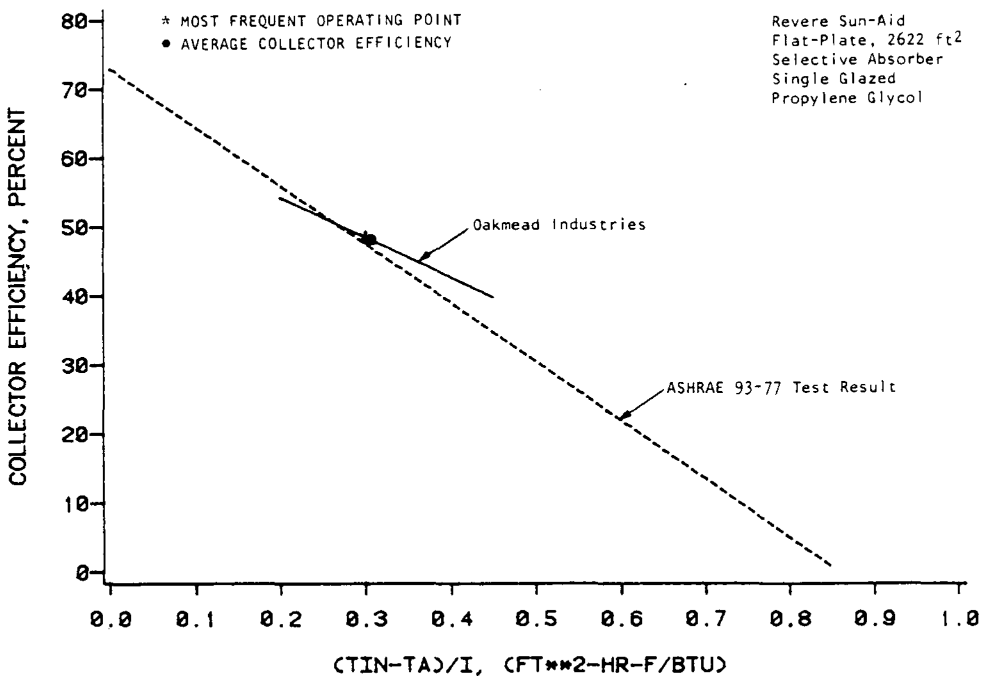


Figure 4. Comparison of NSDN Measured Collector Performance vs. ASHRAE 93-77 Test Result Oakmead Industries, Santa Clara, CA

7.3.2 Storage

The solar storage tank at Oakmead Industries is a 6,500-gallon steel tank with six inches of fiberglass insulation. Storage performance is depicted in Table 6. For the 1980-1981 heating season the energy delivered to storage was 267.45 million BTU while the energy removed from storage was 237.73 million BTU. The changed energy in the storage was -1.82 million. The resultant storage loss was 31.54 million BTU, which seems high. Flow meter W201 measures energy into and out of storage. This flow meter was installed near valve AV2 which modulates flow. This flow meter is not able to measure low flow rates and could have affected the high storage loss. Also during December, January, and March the energy removed from storage was greater than energy delivered to storage. This difference could be due to modulation effects that were not measured by flow meter W201.

The storage tank maintained an average temperature of 121°F and exhibited a storage efficiency of 88%. The storage subsystem performed well.

Table 6. STORAGE PERFORMANCE
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMP. (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/hr °F)	LOSS FROM STORAGE
OCT	27.97	23.19	-2.16	75	157	0.62	6.94
NOV	33.05	28.56	-3.90	75	136	0.54	8.39
DEC	30.46	32.72	0.90	110	91	1.50	-3.16
JAN	25.72	30.00	1.40	122	86	2.42	-5.68
FEB	34.31	30.58	-2.08	83	110	0.68	5.81
MAR	33.26	33.71	0.74	104	96	2.37	-1.19
APR	46.01	30.92	3.33	74	139	0.52	11.76
MAY	36.67	28.05	-0.05	76	151	0.28	8.67
TOTAL	267.45	237.73	-1.82	-	-	-	31.54
AVERAGE	33.43	29.72	-0.23	88(1)	121	1.12	3.94

(1) Weighted average

Table 7. STORAGE PERFORMANCE
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE EFFICIENCY (%)	AVERAGE STORAGE TEMPERATURE (°F)	EFFECTIVE HEAT LOSS COEFFICIENT (BTU/ft^2-hr°F)	LOSS FROM STORAGE
JUN	38.60	30.64	0.38	80	151	0.29	7.58
JUL	35.11	31.28	0.74	91	149	0.12	3.09
AUG	25.93	24.30	-0.16	93	157	0.05	1.79
SEP	29.54	28.80	0.08	98	152	0.06	0.66
OCT	I	I	0.53	I	152	I	I
NOV	I	I	-3.72	I	97	I	I
DEC	I	I	-0.64	I	86	I	I
JAN	I	I	1.44	I	83	I	I
FEB	I	I	-1.67	I	94	I	I
MAR	I	I	-0.78	I	86	I	I
APR	I	I	1.32	I	97	I	I
TOTAL	I	I	-2.48	I	-	I	I
AVERAGE	I	I	-0.23	I	119	I	I

I Denotes invalid data.

The storage subsystem performance for the 1981-1982 heating season is depicted in Table 7. Most performance factors have been invalidated due to inaccurate measurements on flow meter W201 caused by the modulating valve, AV2. The storage tank did maintain an average storage temperature of 119°F with a high temperature of 157°F in August and a low temperature of 83°F in January. The storage tank may be slightly oversized for the system since the ratio of the storage capacity to collector area is 2.5 and a typical "rule of thumb" value is 2.00. However, this larger volume permitted lower collector inlet temperatures which increased the wintertime collector performance.

7.3.3 Space Heating

The space heating performance for the reporting period was good with solar supplying 57% of the total load. Solar energy was delivered for space heating by both the liquid and air collectors directly and from solar hot water storage. The space heating performance was lower partially due to collector control problems which removed energy from storage, and a problem with solar space heating pump P2 which remained off for the first 14 days during November. Overall, the space heating subsystem operated satisfactorily for 1980-1981 heating season.

Oakmead Industries employs a unique recirculation loop between the liquid collector heat exchanger and the solar storage tank. This recirculation loop, designated as the thermal control loop (TCL), provides a connection between the heat exchanger, storage tank, and north and south space heating zones. As a result of this connection, the space heating subsystem is able to utilize energy from storage or energy directly from the collector loop. The TCL strives to maintain a constant 120°F water temperature to the space heating coils. Total control of this loop is accomplished by control valves AV1 and AV2. (See System Description for additional details.) This strategy tends to minimize losses and uses energy directly from the collector loop when available.

The space heating performance for the Oakmead Industries solar site for the reporting period is shown in Tables 8 and 9.

The space heating load of 441.89 million BTU was satisfied by 253.12 million BTU of solar energy and 189.05 million BTU of auxiliary thermal energy. The solar fraction of this load was 57%. The space heating subsystem used a total of 49.70 million BTU for operating energy.

Table 8. SPACE HEATING SUBSYSTEM I
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	CONTROLLED DELIVERED ENERGY	TOTAL SOLAR ENERGY USED	TOTAL AUXILIARY THERMAL USED	SOLAR FRACTION OF LOAD (%)	BLDG TEMP (°F)	AMB TEMP (°F)
OCT	16.48	16.48	16.10	0.47	97	72E	68
NOV	46.38	46.38	20.11	26.27	43	72E	61
DEC	107.35	107.35	52.26	55.11	49	71E	57
JAN	96.87	96.87	39.36	57.51	41	70E	56
FEB	53.04	53.04	37.96	15.07	72	72E	60
MAR	79.35	79.35	50.08	29.34	63	70E	58
APR	38.63	38.63	33.71	5.03	87	I	62
MAY	3.79	3.79	3.54	0.25	93	I	64
TOTAL	441.89 (2)	441.89 (2)	253.12 (2)	189.05 (2)	-	-	-
AVERAGE	55.24	55.24	31.64	23.63	57 (1)	71E	61

E - Denotes estimated value (based upon return air from the building).
I - Denotes invalid data.
(1) - Weighted Average.
(2) - A minor software error caused the heating load to be not exactly equal to the sum of the solar energy used and the auxiliary thermal energy used. The average error is 0.06% and is insignificant.

The space heating subsystem provided a fossil fuel savings of 421.88 million BTU, while incurring a solar specific electrical operating energy expense of 2.78 million BTU. The building temperature was estimated at approximately 71°F.

On April 14, 1981, the north zone solar space heating control began to operate continuously with the air handling unit time clock, despite no heating demand. A problem with the controller delivered solar energy to the north zone distribution system, but the fan was off and the dampers were closed. This energy was lost to the environment and is shown as a loss on the Energy Flow Diagram (Figure 2), from storage to space heating. It was necessary to estimate the building temperature because the sensor was not properly located. Building return air temperature was used as an estimate of the building temperature.

Table 9. SPACE HEATING SUBSYSTEM II
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	MEASURED SOLAR ENERGY USED	SOLAR ENERGY LOSSES TO LOAD	TOTAL OPERATING ENERGY	SOLAR SPECIFIC OPERATING ENERGY	FOSSIL FUEL SAVINGS	AUXILIARY FOSSIL FUEL	HEATING DEGREE DAYS
OCT	16.48	16.10	0.00	6.42	0.10	26.83	0.78	33
NOV	46.38	20.11	0.00	6.92	0.22	33.52	43.78	150
DEC	107.35	52.26	0.00	8.67	0.40	87.10	91.86	257
JAN	96.87	39.36	0.00	8.63	0.34	65.60	95.85	283
FEB	53.04	37.96	0.00	6.21	0.42	63.27	25.13	147
MAR	79.35	50.08	0.00	8.39	0.42	83.47	48.91	216
APR	38.63	33.71	0.00	3.71	0.33	56.19	8.37	139
MAY	3.79	3.54	0.00	0.75	0.55	5.90	0.42	67
TOTAL	441.89	253.12	0.00	49.70	2.78	421.88	315.10	1,292
AVERAGE	55.24	31.64	0.00	6.21	0.35	52.74	39.39	162

During the 1981-1982 heating season, the space heating subsystem operated well, but the performance could have been better. Several problems lowered the space heating performance. The space heating time clocks caused the system to operate all day long in January and February 1982. This problem increased the space heating load which was primarily made up by auxiliary energy during the evening hours, and reduced the solar contribution to the DHW subsystem because the space heating subsystem has priority of solar utilization. From October 12, 1981 through November 6, 1981, no solar energy was used for space heating due to pump P2 not operating. The high heating subsystem operating energy from July 22 through November 6 is due to the continuous operation of the south zone fan.

The space heating performance is presented in Tables 10 and 11. The space heating load of 371.55 million BTU was satisfied by 187.04 million BTU of solar energy and 184.51 million BTU of auxiliary energy for a solar contribution of 50%. Solar energy provided a fossil fuel savings of 311.73 million BTU or 3,053 therms of natural gas.

Table 10. SPACE HEATING SUBSYSTEM
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	CONTROLLED DELIVERED ENERGY	TOTAL SOLAR ENERGY USED	TOTAL AUXILIARY THERMAL USED	SOLAR FRACTION OF LOAD (%)	AMB TEMP (°F)
JUN	0.00	0.00	0.00	0.00	0	71
JUL	0.00	0.00	0.00	0.00	0	70
AUG	0.00	0.00	0.00	0.00	0	70
SEP	0.00	0.00	0.00	0.00	0	70
OCT	19.20	19.20	0.00	19.20	0	65
NOV	42.17	42.17	22.03	20.14	52	62
DEC	41.31	41.31	18.16	23.15	44	57
JAN	89.74	89.74	29.75	59.99	33	50
FEB	62.37	62.37	37.93	24.44	61	59
MAR	57.32	57.32	32.09	25.23	56	56
APR	59.44	59.44	47.08	12.36	79	60
TOTAL	371.55	371.55	187.04	184.51	-	-
AVERAGE	33.78	33.78	17.00	16.77	50[1]	63

[1]Denotes weighted average.

Table 11. SPACE HEATING SUBSYSTEM (Continued)
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SPACE HEATING LOAD	MEASURED SOLAR ENERGY USED	TOTAL OPERATING ENERGY	SOLAR-SPECIFIC OPERATING ENERGY	AUXILIARY FOSSIL SAVINGS	AUXILIARY FOSSIL FUEL	HEATING DEGREE-DAYS
JUN	0.00	0.00	0.49	0.49	0.00	0.00	4
JUL	0.00	0.00	1.84	0.42	0.00	0.00	0
AUG	0.00	0.00	4.04	0.00	0.00	0.00	0
SEP	0.00	0.00	3.21	0.00	0.00	0.00	1
OCT	19.20	0.00	9.52	0.00	0.00	32.00	42
NOV	42.17	22.03	9.57	0.27	36.71	33.57	120
DEC	41.31	18.16	8.53	0.23	30.27	38.58	262
JAN	89.74	29.75	10.58	0.38	49.58	99.99	455
FEB	62.37	37.93	9.54	0.44	63.22	40.74	180
MAR	57.32	32.09	9.06	0.35	53.48	42.05	293
APR	59.44	47.08	8.90	0.42	78.47	20.60	178
TOTAL	371.55	187.04	75.28	3.00	311.73	307.53	1,535
AVERAGE	33.78	17.00	6.84	0.27	28.34	27.96	140

7.3.4 Domestic Hot Water

The DHW subsystem uses a solar heated preheat tank in series with an electric DHW tank. (Refer to site schematic.) A very significant change in the DHW consumption profile was made in September 1980. A soldering type machine that requires hot water was attached to the DHW subsystem. The greater consumption of hot water significantly reduced the solar contribution in comparison to the original design figures. Since the design figures were not altered, it appears the DHW subsystem was poorer than expected. However, the DHW subsystem performed satisfactorily. Vitro Corporation recommended the replacement of pump P4 to increase the solar energy contribution to the DHW subsystem. This replacement was delayed due to electrical installation problems.

The DHW subsystem performance for the 1980-1981 season is depicted on Table 12.

The actual hot water demand of 97.01 million BTU was satisfied by 41.14 million BTU of solar energy and 63.55 million BTU of auxiliary electrical energy. The hot water load of 104.69 million BTU includes a standby loss of 7.68 million BTU. The solar fraction of the load was 39% with a solar specific operating energy expense of 0.56 million BTU. The DHW subsystem provided an electrical energy savings of 40.58 million BTU. A daily average of 1,047 gallons of DHW was consumed at an average temperature of 112°F.

Table 12. DOMESTIC HOT WATER SUBSYSTEM PERFORMANCE
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD	SOLAR FRACTION OF LOAD (%)	HOT WATER DEMAND	SOLAR FRACTION OF DEMAND (%)	SOLAR ENERGY USED	AUXILIARY THERMAL USED	AUXILIARY ELECT USED	OPERATING ENERGY	SUP. WATER TEMP (°F)	HOT WATER TEMP (°F)	HOT WATER CONSUMPTION (GAL)
OCT	18.82	68	15.85	66	12.82	6.00	6.00	0.15	68	115	41,263
NOV	13.45	54	12.32	54	7.30	6.15	6.15	0.09	67	117	29,272
DEC	11.08	11	10.48	11	1.20	9.88	9.88	0.03	63	106	29,470
JAN	10.39	5	9.94	5	0.54	9.85	9.85	0.02	62	100	31,491
FEB	11.98	26	11.83	25	3.10	8.88	8.88	0.07	63	112	29,028
MAR	11.80	15	10.98	14	1.78	10.02	10.02	0.04	65	103	34,595
APR	13.63	50	12.95	49	6.78	6.85	6.85	0.08	69	121	30,167
MAY	13.54	56	12.66	56	7.62	5.92	5.92	0.08	71	123	29,030
TOTAL	104.69	-	97.01	-	41.14	63.55	63.55	0.56	-	-	254,316
AVERAGE	13.09	39 (1)	12.13	38	5.14	7.94	7.94	0.07	66	112	31,790

(1) Weighted average.

Two problems lowered the DHW subsystem performance. The DHW controller which activates pump P4 was 5°F-10°F too high. This decreased the potential solar contribution. Also, the DHW controller will not activate pump P4 unless the solar storage tank top temperature is greater than 100°F. The solar storage tank remained below 100°F during a large period of time, which resulted in the low solar contribution at these times. This low storage temperature coincides with the space heating periods which have priority over the DHW subsystem. Despite these problems, the DHW subsystem operated satisfactorily and provided 39% of the DHW load.

The DHW subsystem performance during 1981-1982 is displayed in Table 13. The DHW load was 131.91 million BTU. The solar energy used was 62.23 million BTU and the auxiliary energy used was 69.68 million BTU, representing a solar contribution of 47%. The DHW demand was 123.17 million BTU, which shows very little standby losses. A total of 326,469 gallons of hot water was used at an average supply temperature of 69°F and a hot water temperature of 116°F.

Table 13. DOMESTIC HOT WATER SUBSYSTEM
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD	SOLAR FRACTION OF LOAD (%)	HOT WATER DEMAND	SOLAR ENERGY USED	AUX THERMAL USED	AUX ELECT FUEL	OPERATING ENERGY	SUP WATER TEMP (°F)	HOT WATER TEMP (°F)	TEMPERED HOT WATER CONSUMPTION (GALLONS)	UNTEMPERED HOT WATER CONSUMPTION (GALLONS)
JUN	14.84	58	13.90	8.83	6.01	6.01	0.09	72	127	30,444	27,769 E
JUL	14.53	60	13.40	8.77	5.76	5.76	0.14	73	127	29,559	26.899
AUG	13.68	65	12.27	8.91	4.77	4.77	0.14	72	127	26,946	24,538
SEP	21.38	63	20.71	13.54	7.84	7.84	0.18	73	109	68,514	62,785
OCT	13.82	63	13.36	8.70	5.12	5.12	0.16	71	128	28,221	26,094
NOV	9.39	31	8.72	2.86	6.53	6.53	0.29	70	115	23,336	20,317
DEC	7.27	21	6.63	1.56	5.71	5.71	0.37	67	115	16,547	15,114
JAN	9.96	16	9.27	1.57	8.39	8.39	0.38	66	111	24,835	22,669
FEB	9.44	28	8.83	2.66	6.78	6.78	0.34	65	106	26,013	23,921
MAR	8.64	21	7.92	1.84	6.80	6.80	0.37	67	100	28,438	26,081
APR	8.96	33	8.16	2.99	5.97	5.97	0.35	66	107	23,616	21,873
TOTAL	131.91	-	123.17	62.23	69.68	69.68	2.81	-	-	326,469	298,060
AVERAGE	11.99	47[1]	11.20	5.66	6.33	6.33	0.26	69	116	29,679	27,096

[1] Denotes Weighted Average.
E Denotes estimated value.

An increase in DHW demand occurred in September without a proportionally greater impact on the solar fraction; i.e., solar fraction remained at 63%. This implies that the solar DHW subsystem is capacity limited due to design or equipment size. If a larger capacity pump and preheat coil were used, the DHW solar fraction might have increased. Another improvement could be to simply have the cold water supply run through an immersed heat exchanger in the hot storage tank. This would save operating costs and might lower initial capital costs. A control problem with pump P4 caused the pump to operate almost continuously from December 1981 through April 1982. This problem increased the operating energy costs with very little additional benefit. Overall, the DHW subsystem performance was 47%.

7.3.5 Parasitics

Operating energy is defined as the electrical energy required to support the functioning of the collector, storage, space heating, and DHW subsystems without directly affecting their thermal states. This energy is interpreted as pumping energy, fan power, and electrical power required to operate the entire solar system including those distribution fans in the conventional HVAC system.

Table 14. SOLAR UNIQUE OPERATING ENERGY
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	DHW OPERATING ENERGY	SHS OPERATING ENERGY	TOTAL SOLAR UNIQUE OPERATING ENERGY
OCT	0.60	0.15	0.10	0.85
NOV	0.86	0.09	0.22	1.17
DEC	1.89	0.03	0.40	2.32
JAN	1.64	0.02	0.34	2.00
FEB	0.88	0.07	0.42	1.37
MAR	1.47	0.04	0.42	1.93
APR	0.81	0.08	0.33	1.22
MAY	0.84	0.08	0.55	1.47
TOTAL	8.99	0.56	2.78	12.33
AVERAGE	1.12	0.07	0.35	1.54

At Oakmead Industries, the solar unique operating energy, that is used exclusively for the collection and delivery of solar energy, is classified in three subsystems. Pumps P1, P3, heat rejector fan, and south zone collector fan operate the energy collection and storage subsystems, pump P2 operates the space heating subsystem , and pump P4 operates the DHW subsystem.

Measured monthly values of the solar specific operating energies for the Oakmead Industries solar system are presented in Table 14. Table 14 depicts the solar unique operating energy for each subsystem during 1980-1981.

A total of 12.33 million BTU were consumed to operate the equipment which collects and delivers solar energy. In addition to the solar exclusive equipment, other fans were used to transport auxiliary energy in the HVAC system. The entire system used 59.25 million BTU of operating energy. The solar unique energy represents 21% of the total system operating energy.

Measured monthly values of the solar-specific operating energy for 1981-1982 are shown in Table 15. The ECSS solar operating energy accounted for 71% of the total-specific operating energy.

Table 15. SOLAR-SPECIFIC OPERATING ENERGY
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU)

MONTH	ECSS OPERATING ENERGY	DHW OPERATING ENERGY	SHS OPERATING ENERGY	TOTAL SOLAR OPERATING ENERGY
JUN	0.86	0.09	0.49	1.44
JUL	1.09	0.14	0.42	1.65
AUG	1.24	0.14	0.00	1.38
SEP	1.18	0.18	0.00	1.36
OCT	1.15	0.16	0.00	1.31
NOV	1.47	0.29	0.27	2.03
DEC	1.36	0.37	0.23	1.96
JAN	1.54	0.38	0.38	2.30
FEB	1.13	0.34	0.44	1.91
MAR	1.64	0.37	0.35	2.36
APR	1.31	0.35	0.42	2.08
TOTAL	13.97	2.81	3.00	19.78
AVERAGE	1.27	0.26	0.27	1.80

7.4 ENERGY SAVINGS

Solar energy system savings are realized whenever energy provided by the solar energy system is used to meet system demands which would otherwise be met by auxiliary energy sources. The operating energy required to transport solar energy from the collector to storage is subtracted from the solar energy contribution to the loads to determine net savings.

The auxiliary energy sources for the space heating subsystem are two natural-gas-fired furnaces located in the north and south zones of the commercial building. The natural-gas-fired units are considered to be 60% efficient for computing energy savings.

Energy savings for 1980-1981 are presented in Table 16. During this eight-month period, the solar system saved 28.81 million BTU of electrical energy and 421.88 million BTU of fossil fuel. These savings are equivalent to 8,436 kwh of electrical energy and 413,190 cubic feet (4,131.9 therms) of natural gas.

Table 16. ENERGY SAVINGS
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING SAVINGS		DOMESTIC HOT WATER SAVINGS	ECSS OPERATING ENERGY	TOTAL NET ENERGY SAVINGS	
		ELECTRICAL	FOSSIL FUEL	ELECTRICAL		ELECTRICAL	FOSSIL FUEL
OCT	28.92	-0.10	26.83	12.67	0.60	11.97	26.83
NOV	27.41	-0.22	33.52	7.21	0.86	6.13	33.52
DEC	53.46	-0.40	87.10	1.17	1.89	-1.12	87.10
JAN	39.90	-0.34	65.60	0.52	1.64	-1.46	65.60
FEB	41.06	-0.42	63.27	3.03	0.88	1.73	63.27
MAR	51.86	-0.42	83.47	1.74	1.47	-0.15	83.47
APR	40.49	-0.33	56.19	6.70	0.81	5.56	56.19
MAY	11.16	-0.55	5.90	7.54	0.84	6.15	5.90
TOTAL	294.26	-2.78	421.88	40.58	8.99	28.81	421.88
AVERAGE	36.78	-0.35	52.74	5.07	1.12	3.60	52.74

The overall savings in dollars are approximately $2,095.90 for the eight-month period. The computed savings are based on an actual fuel rate at the site of $0.03 per kwh and 44.6 cents per therm of natural gas.

Energy savings during 1981-1982 are presented in Table 17. The solar system provided a fossil fuel energy savings of 311.73 million BTU and an electrical energy savings of 42.45 million BTU. These energy savings are equivalent to 3,053 therms (305,310 cubic feet) of natural gas and 12,429 kwh of electric energy. The savings in dollars are $2,023.66 based on an actual fossil fuel rate of $0.50 per therm of natural gas and $0.04 per kwh of electrical energy.

Table 17. ENERGY SAVINGS
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING ELECTRICAL	SPACE HEATING FOSSIL FUEL	DOMESTIC HOT WATER ELECTRICAL	ECSS OPERATING ENERGY SOLAR-UNIQUE	NET ENERGY SAVINGS ELECTRICAL	NET ENERGY SAVINGS FOSSIL FUEL
JUN	8.83	-0.49	0.00	8.74	-0.86	7.39	0.00
JUL	8.77	-0.42	0.00	8.63	-1.09	7.12	0.00
AUG	8.91	0.00	0.00	8.77	-1.24	7.53	0.00
SEP	13.54	0.00	0.00	13.36	-1.18	12.18	0.00
OCT	8.70	0.00	0.00	8.54	-1.15	7.39	0.00
NOV	24.89	-0.27	36.71	2.57	-1.47	0.83	36.71
DEC	19.72	-0.23	30.27	1.19	-1.36	-0.40	30.27
JAN	31.32	-0.38	49.58	1.19	-1.54	-0.73	49.58
FEB	40.59	-0.44	63.22	2.32	-1.13	0.75	63.22
MAR	33.93	-0.35	53.48	1.47	-1.64	-0.52	53.48
APR	50.07	-0.42	78.47	2.64	-1.31	0.91	78.47
TOTAL	249.27	-3.00	311.73	59.42	-13.97	42.45	311.73
AVERAGE	22.66	-0.27	28.34	5.40	-1.27	3.86	28.34

7.5 ENVIRONMENTAL CONDITIONS

Oakmead Industries is located in Santa Clara, California at 37 degrees N latitude and 122 degrees W longitude.

Monthly values of the total solar energy incident in the plane of the liquid collector array and the average outdoor temperature measured at the site are presented in Table 18. Also presented in the table are the corresponding long-term average monthly values of the measured weather parameters. These long-term average weather data were obtained from nearby representative National Weather Service and SOLMET meteorological stations. The long-term average insolation values are total global horizontal radiation converted to collector angle and azimuth orientation.

Table 18. WEATHER CONDITIONS FOR LIQUID SUBSYSTEM
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

	DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT²-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
MONTH	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
OCT	1,687	1,685	68	63	33	90	139	19
NOV	1,330	1,362	61	56	150	276	40	0
DEC	1,170	1,154	57	50	257	456	0	0
JAN	963	1,200	56	50	283	481	0	0
FEB	1,442	1,481	60	53	147	350	6	0
MAR	1,422	1,760	58	55	216	322	6	0
APR	1,972	1,895	62	58	139	228	48	12
MAY	1,824	1,872	64	62	67	123	32	20
TOTAL	11,810	12,409	-	-	1,292	2,326	271	51
AVERAGE	1,476	1,551	61	56	162	291	34	6

Note: Collector Tilt 45°

During October 1980 through May 1981, the average daily total incident solar radiation on the collector array was 1,476 BTU per square foot per day. This radiation was five percent below the estimated average daily solar radiation for this geographical area during the reporting period of 1,551 BTU per square foot per day for a south-facing plane with a tilt of 45 degrees to the horizontal. During the period, the highest monthly average insolation was 1,972 BTU per square foot per day during April and the lowest monthly average insolation was 963 BTU per square foot per day during January. The average ambient temperature during the reporting period was 61°F as compared with the long-term average of 56°F. The highest monthly average ambient temperature was 68°F during October, and the lowest monthly average ambient temperature was 56°F during January. The number of heating degree-days for the period (based on a 65°F reference) was 1,292 as compared with the long-term average of 2,326. The range of heating degree-days was from a high of 283 during January to a low of 33 during October. The number of cooling degree-days for the period was 271 as compared with the long-term average of 51.

The daily average ambient temperature was calculated using the same method as the National Weather Service (NWS). This method estimates the average temperature by averaging the daily maximum and minimum temperatures. The long-term weather data and reference data were recorded by the San Jose, California weather station.

Summary weather conditions are presented in Table 19 for 1981-1982. The weather conditions were poorer than expected due to less sunshine during the heating season. The ambient temperature was 63°F versus the long-term average of 60°F. However, this temperature sensor could have been measuring some heat from roof convection due to its location.

Table 19. WEATHER CONDITIONS
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

MONTH	DAILY INCIDENT SOLAR* ENERGY PER UNIT AREA (BTU/FT^2-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS		COOLING DEGREE-DAYS	
	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
JUN	1,945	1,853	71	66	4	50	189	71
JUL	1,867	1,889	70	68	0	12	144	117
AUG	1,864	1,897	70	68	0	15	158	111
SEP	1,759	1,907	70	68	1	13	164	94
OCT	1,602	1,687	65	63	42	90	45	19
NOV	1,037	1,365	62	56	120	276	19	0
DEC	798	1,157	57	50	262	456	0	0
JAN	1,170	1,2[illegible]3	50	50	455	481	0	0
FEB	1,388	1,484	59	53	180	350	5	0
MAR	1,257	1,762	56	55	293	322	0	0
APR	1,706	1,897	60	58	178	228	19	12
TOTAL	-	-	-	-	1,535	2,293	743	424
AVERAGE	1,490	1,646	63	60	140	208	68	39

*Liquid collector subsystem at 45 degree tilt.

SECTION 8

OPERATIONAL HISTORY

8.1 TYPICAL SYSTEM OPERATION

April 16, 1982 represents a sunny day of solar system operation. The variation of key solar system parameters for this day is presented in Figures 5, 6 and 7. This day is representative of solar system operation during the entire reporting period, except when the collector pump was operating all day long.

Figure 5 shows the intensity of solar radiation on the collector array during the day. The figure depicts excellent sunshine throughout the day with a maximum intensity of 320 BTU/ft^2-hr. The insolation is measured at a collector orientation of 45 degrees to the horizontal. The collector operating period is shown on the isolation curve.

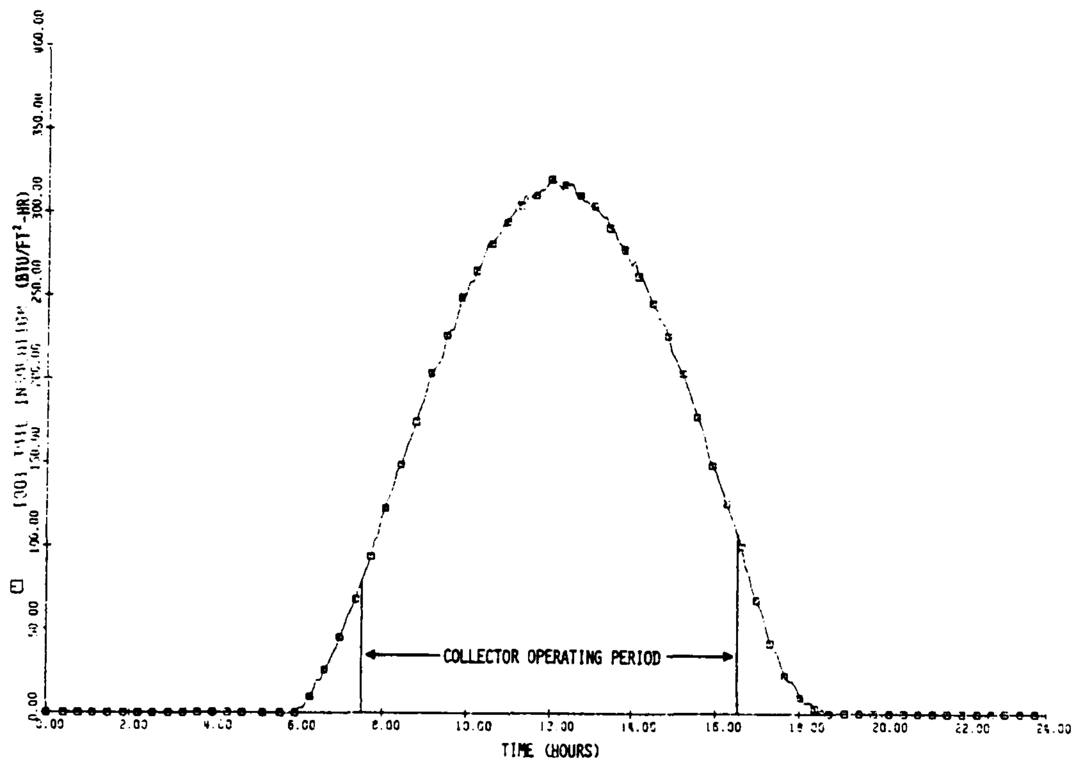


Figure 5. Typical Insolation Data
Oakmead Industries
April 16, 1982

The collector array inlet and outlet temperature profile is presented in Figure 6. The collector pump was activated at 0722 hours when the collector absorber plate temperature was higher than the temperature in the Thermal Control Loop (TCL). (Refer to System

Description). The temperature differential between the collector inlet and outlet is small during startup conditions and the curves show a negative differential soon after startup. However, the temperature increases very rapidly and so does the collector temperature differential after startup. But, as 0946 hours, the flow to storage stops and results in a decrease in the collector inlet and outlet temperature differential.

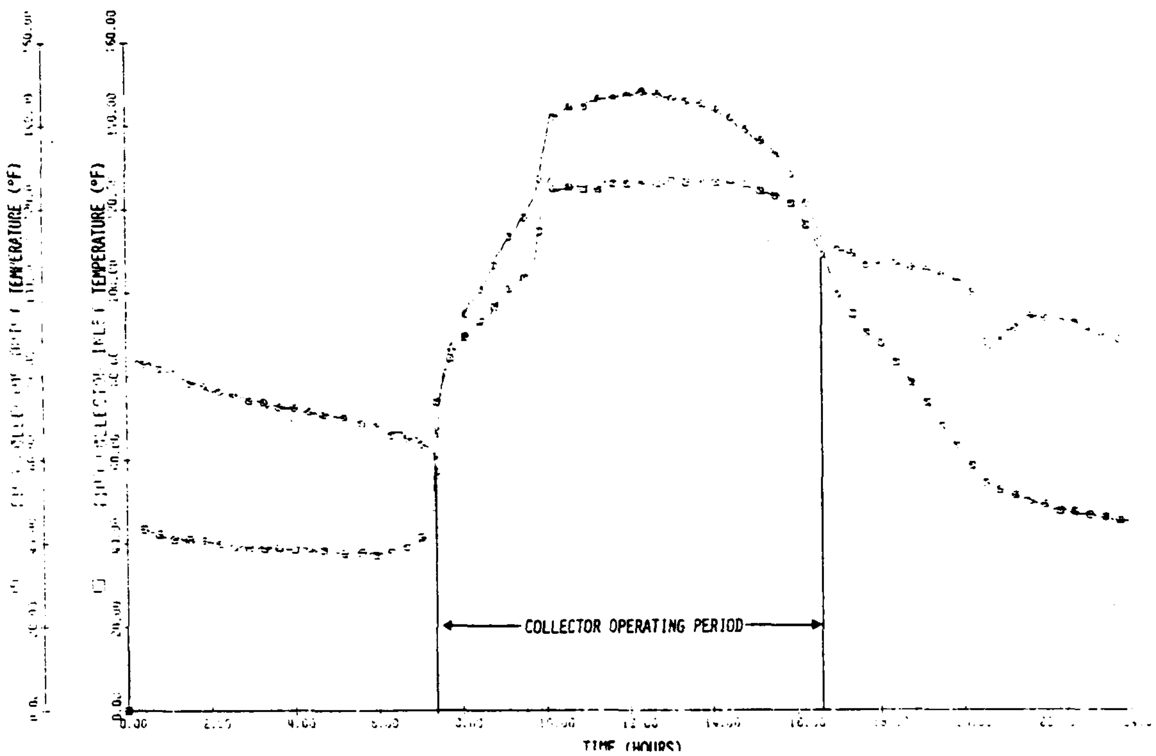


Figure 6. Typical Collector Array Temperatures, Inlet/Outlet
Oakmead Industries
April 16, 1982

At 1012 hours, storage flow starts again and causes the collector inlet and outlet differential to increase. The collector array temperature difference is very high now and illustrates good collector performance. The collector pump is deactivated at 1636 hours when the collector temperature difference decreases below the set point. The collector pump operating period is shown in this figure.

The storage tank temperatures are illustrated in Figure 7. The storage tank shows very little stratification except during addition of solar energy from the collector array. From midnight to 0337 hours, energy was removed from storage to the space heating and DHW subsystems. Between 0337 hours and 0748 hours, only a small amount of energy was lost from the storage tank. Solar energy was added to the storage tank from 0748 hours to 0946 hours and from 1007 hours to 1838 hours. The tank temperature rose to a maximum of 113°F. Note that the middle tank temperature is greater than the top tank temperature during additions of solar energy to storage. This higher temperature occurs because solar energy always enters into the middle of the storage tank exactly where temperature sensor T203 is located. The sensor indicates the fluid temperature prior to mixing with the remaining fluid. From 1636 hours to midnight, solar energy is again used for the space heating and DHW subsystems. The storage performance is very highly dependent on the performance of control valves AV1 and AV2.

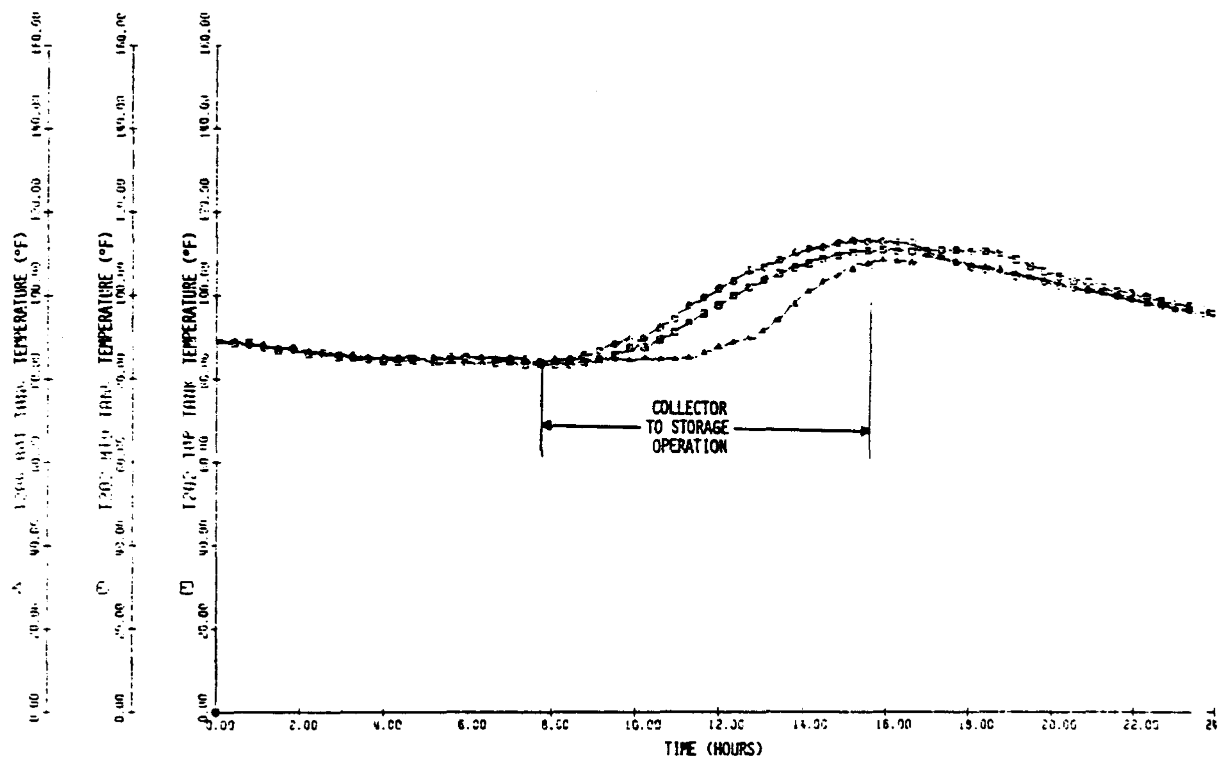


Figure 7. Typical Storage Fluid Temperatures
Oakmead Industries
April 16, 1982

8.2 SYSTEM OPERATING SEQUENCE

Figure 8 is a bar chart depicting the system operating sequence for April 16, 1982. This data correlates with the curves shown in Figures 5, 6 and 7, and provides some additional insight into those curves.

There are several observations to be made from Figure 8. The collector to storage flow is regulated by modulating valve AV2 and does not supply flow to storage at all times. Due to the temperature control loop (refer to System Description), solar energy can be delivered from the collector heat exchanger directly to the space heating load. This design feature enhances the system performance because solar energy can be used directly. The space heating load is satisfied by a combination of solar and auxiliary energy. Due to a control problem with pump P4, the pump was on at all times. Also, the electric resistance heater in the DHW tank operates most of the time to maintain the DHW tank at its internal set point temperature. The DHW usage pattern shows that most of the hot water is used during the day with sporadic usage in the evening and morning hours. The DHW usage is related to occupancy of the building.

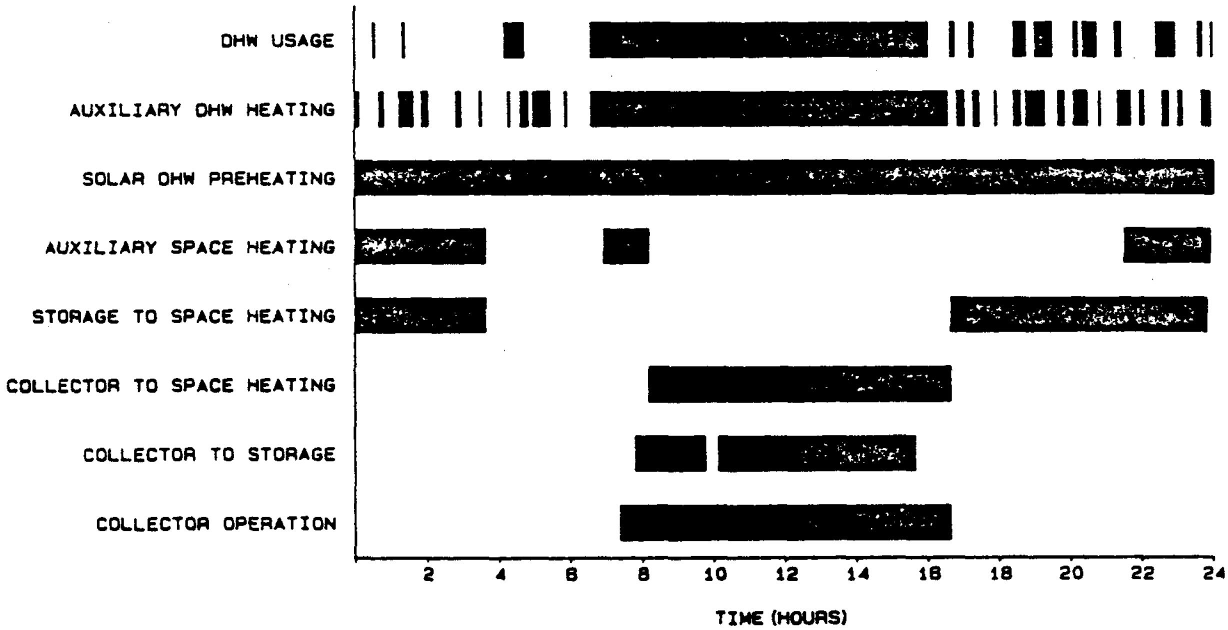


Figure 8. Typical System Operation Sequence
Oakmead Industries
April 16, 1982

8.3 COLLECTOR SUBSYSTEM

The major problem which occurred with the collector subsystem was that the seals between the hose and aluminum insulation jacket needed to be refurbished. The cause of the damage was the silicone rubber hose had been forced up against the sharp edge of the aluminum jacket which protects the manifold insulation. This occurred during manifold thermal expansion and contraction. This problem had previously occurred in 1979; repaired, however, the cause was not reported.

The following figures show a detail of the hose during the original design and the as-built condition. In the original design the rubber hose is well removed from the insulation jacket due to the copper manifold extension being longer. In the as-built condition, the copper extension was shorter and the hose was exposed to the cutting edge of the aluminum jacket.

For the connections with severely damaged hose, 3 inches should be trimmed off the manifold end. The flared tip of the tube could then be cut off and an extension tubing soldered to the manifold stub-out.

FIGURE "A"
REVISION 1 DATED 7/../78

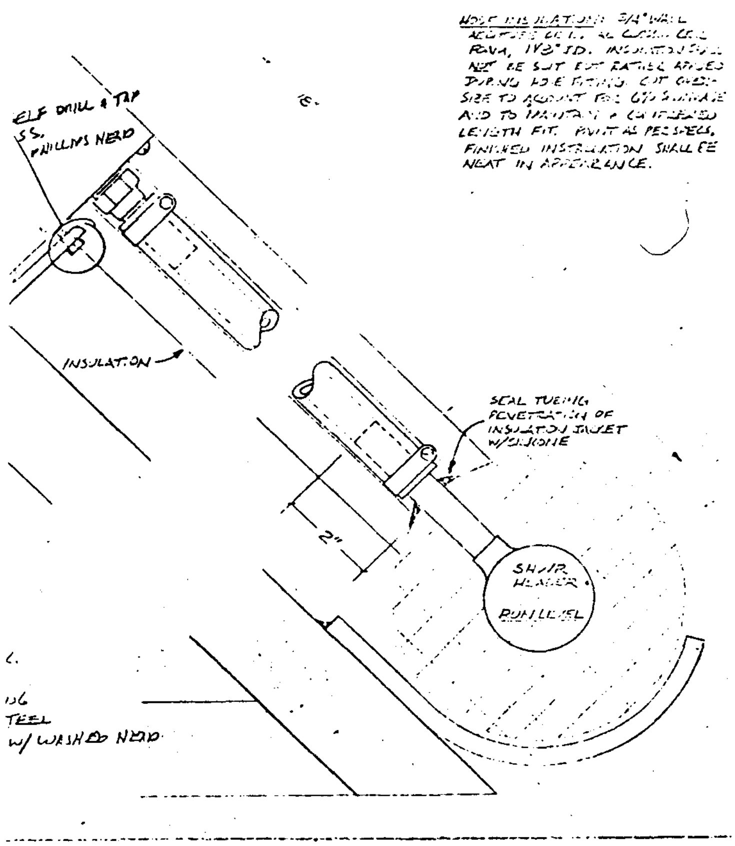
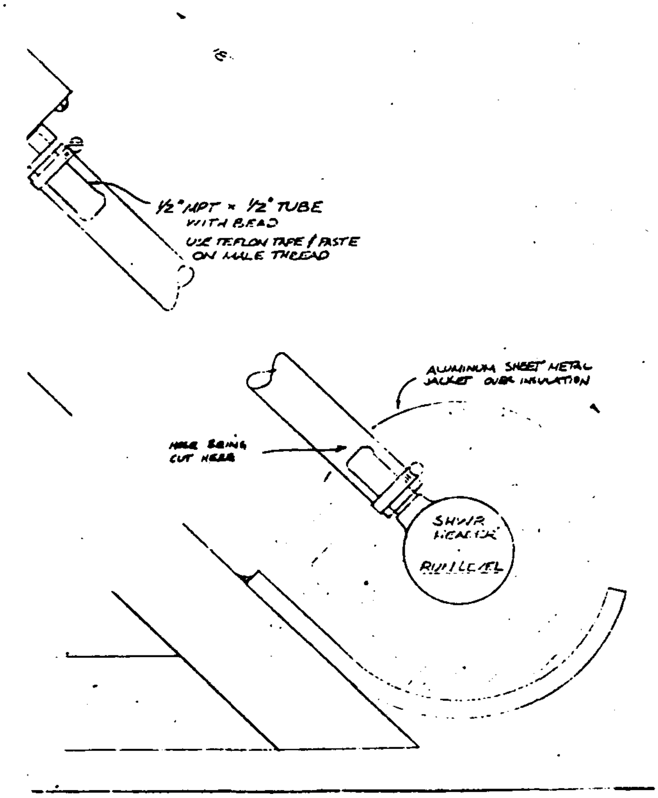


FIGURE "8"
AS BUILT



8.4 CONTROL SUBSYSTEM

Of the system problems which occurred at Oakmead Industries, the largest group happened to the control subsystem. The following depicts the problems which occurred over a two year period.

The controls were designed to activate the collector when the collector plate stagnation temperature was greater than 120°F. An adjustable time delay, nominally five minutes, maintained pump operation. At the end of the delay period, the collector pump would continue to operate if the plate temperature was 5°F greater than the TCL temperature. Otherwise, the pump would deactivate and the cycle will begin again. It should be noted that the TCL pump P3 operates in conjunction with the collector pump. This control device functioned extremely well until November 30, 1980 when the control device experienced problems and activated the collector pumps at night. Since November 30, the control device has not operated as well as before and system performance was degraded to a small degree. The control problem was corrected on March 25, 1981 but the controller operation was changed to function only on a temperature differential between collector plate temperature and TCL temperature.

Subsequently, the collector control problems allowed for unnecessary removal of solar energy from storage. The north zone space heating control began to operate continuously with the air handling unit time clock, despite no heating demand. A problem with the controller delivered solar energy to the north zone distribution system, but the fan was off and the dampers were closed. The energy was lost to the environment.

Also, the collector pump operated all day and night at times due to improper control operation. This resulted in energy loss through the collectors and energy removed from storage. The problem occurred during low insolation levels that were apparently in the dead-band zone of the controls.

The heat rejector was improperly activating at a lower set point temperature of 174°F, which caused unnecessary energy rejection.

The storage to preheat tank pump, P4, had a control deficiency which operated the pump all day long after November 1981 through April 1982.

The DHW controller, which activates pump P4 was 5°F to 10°F too high. This decreased the potential solar contribution. Also the DHW controller would not activate pump P4 unless the solar storage tank top temperature was greater than 100°F. The solar storage tank remained below 100°F during a large period of time, which resulted in the low solar contribution. The low storage temperature coincides with the space heating periods, which has priority over the DHW subsystem.

On April 14, 1984, the north zone solar space heating control began to operate continuously with the air handling unit time clock, despite no heating demand. A problem with the controller delivered solar energy to the north zone distribution system, however the fan was off and dampers were closed. The energy was lost to the environment.

8.5 SPACE HEATING SUBSYSTEM

A few problems occurred to the space heating subsystem.

Pump P2 for space heating remained off for the first 14 days during November 1980.

Solar space heating was not utilized until November 6, 1981 while there was space heating beginning on October 12, 1981.

The space heating time clocks caused the system to operate all day long in January and February 1982. This problem increased the space heating load which was primarily made up by auxiliary energy during the evening hours, and reduced the solar contribution to the DHW subsystem because the space heating subsystem has priority of solar utilization.

The south zone fan was operating at all times from July 22, 1981 through November 6, 1981 to recirculate interior air. This system was deactivated during the 1981-1982 heating season.

SECTION 9

SUMMARY AND CONCLUSIONS

The performance of the Oakmead Industries solar system is summarized in Tables 20 and 21 for the 1980-1981 and 1981-1982 heating seasons, respectively. The solar fraction of the load was 54% in the 1980-1981 heating season and 49% in the 1981-1982 heating season. The solar fraction combined was 52%, significantly below the design solar fraction of the high 80%.

Table 20. SOLAR SYSTEM THERMAL PERFORMANCE
OAKMEAD INDUSTRIES
OCTOBER 1980 THROUGH MAY 1981

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY			OPERATING ENERGY	ENERGY SAVINGS		SOLAR FRACTION (%)
				THERMAL	FOSSIL	ELECTRICAL		FOSSIL	ELECTRICAL	
OCT	40.78E	35.30	28.92	6.47	0.78	6.00	7.17	26.83	11.97	82
NOV	39.23	59.83	27.41	32.42	43.78	6.15	7.87	33.52	6.13	46
DEC	60.76	118.43	53.46	64.99	91.86	9.88	10.59	87.10	-1.12	45
JAN	47.54	107.26	39.90	67.36	95.85	9.85	10.29	65.60	-1.46	37
FEB	48.90	65.02	41.06	23.95	25.13	8.88	7.16	63.27	1.73	63
MAR	61.83	91.15	51.86	39.36	48.91	10.02	9.90	83.47	-0.15	57
APR	66.13	52.26	40.49	11.86	8.37	6.85	4.60	56.19	5.56	77
MAY	48.46	17.33	11.16	6.17	0.42	5.92	1.67	5.90	6.15	64
TOTAL	413.61	546.58	294.26	252.60	315.10	63.55	59.25	421.86	28.81	-
AVERAGE	51.70	68.32	36.78	31.58	39.39	7.94	7.41	52.74	3.60	54 (1)

E - Denotes estimated value
(1) Weighted average.

Several minor problems were encountered during the first season, with a small impact on system performance. These included collector control problems, incorrect time clock settings for the north zone heating distribution subsystem, a failure of pump P2 in November 1980, a larger than expected DHW load, and an improper control set point for the solar preheating DHW mode. These problems are summarized below and are discussed in more detail in the Subsystem Performance sections.

The liquid collector subsystem experienced intermittent control problems, which caused the collector and thermal control loop (TCL) pumps, P1 and P3 to run all day and night. Although the problem

Table 21. SOLAR SYSTEM THERMAL PERFORMANCE
OAKMEAD INDUSTRIES
JUNE 1981 THROUGH APRIL 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY COLLECTED	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY ENERGY			OPERATING ENERGY	ENERGY SAVINGS		SOLAR FRACTION (%)
				THERMAL	FOSSIL	ELECTRICAL		FOSSIL	ELECTRICAL	
JUN	56.25	14.84	8.83	6.01	0.00	6.01	1.44	0.00	7.39	60
JUL	54.46	14.53	8.77	5.76	0.00	5.76	3.07	0.00	7.12	60
AUG	52.99	13.68	8.91	4.77	0.00	4.77	5.42	0.00	7.53	65
SEP	49.52	21.38	13.54	7.84	0.00	7.84	4.57	0.00	12.18	63
OCT	45.98	33.02	8.70	24.32	32.00	5.12	10.83	0.00	7.39	26
NOV	33.75	51.56	24.89	26.67	33.57	6.53	11.33	36.71	0.83	48
DEC	27.67	48.58	19.72	28.86	38.58	5.71	10.26	30.27	-0.40	40
JAN	40.52	99.70	31.32	68.38	99.99	8.39	12.50	49.58	-0.73	31
FEB	46.34	71.81	40.59	31.22	40.74	6.78	11.01	63.22	0.75	56
MAR	41.67	65.96	33.93	32.03	42.05	6.80	11.07	53.48	-0.52	51
APR	61.40	68.40	50.07	18.33	20.60	5.97	10.56	78.47	0.91	73
TOTAL	510.55	503.46	249.27	254.19	307.53	69.68	92.06	311.73	42.45	-
AVERAGE	46.41	45.77	22.66	23.11	27.96	6.33	8.37	28.34	3.86	49(1)

(1)Denotes Weighted Average.

occurred sporadically, it decreased collector subsystem and system performance by rejecting stored energy through the collectors. Despite this control failure, the collector subsystem was able to maintain an average operational efficiency of 45%.

The performance of the air collector subsystem could have been improved. Some of the potentially available solar energy could not be utilized due to the control set point being too high. If adjusted, the performance would have improved.

The time clocks for the space heating subsystem were set incorrectly which increased the space heating load for the building. The time clocks activated the heating system too early in the morning which increased the usage of auxiliary energy. If the time clocks had been operating properly, the space heating load would have been smaller and system performance would have improved.

Solar space heating pump P2 failed to operate on the first 14 days of November. This failure prevented the delivery of solar energy for space heating and lowered system performance.

Due to a higher than expected DHW demand, pump P4 between solar storage and the DHW preheat tank was to be replaced with a larger pump to accommodate the higher load. However, pump P4 has not been replaced and the solar contribution is lower. Also the DHW controller set point was 5°F-10!F too high, which resulted in less solar energy being delivered to the DHW subsystem.

All of these problems contributed to the lower than expected performance, but the solar system still attained a solar fraction of 54%.

The summation of solar energy used and auxiliary thermal energy does not always equal the system load. These small differences are due to minor problems in the software bridging program. The interpolation of small amounts of missing data sometimes caused the sum of the solar and auxiliary energies not to equal the system load. The maximum difference is 0.25%.

During the June 1981 through April 1982 reporting period, the Oakmead Industries solar energy system supplied 49% of the space heating and Domestic Hot Water (DHW) loads. The solar system provided 50% of the space heating load and 47% of the DHW load as compared to the design expectations of 85% for the space heating subsystem and 90% for the DHW subsystem. Solar system operation accounted for a fossil fuel energy savings of 3,053 therms (100 cubic feet) of natural gas and 12,429 kwh of electrical energy. These energy savings are equivalent to $2,023.66 based on actual utility rates. The system thermal performance is summarized in Table

The solar system operated well and encountered very little maintenance. Good solar collector array efficiency and low operating energy accounted for the good energy savings. The oversized storage tank provided low collector inlet temperatures which enhanced the collector array efficiency. The solar portion of the DHW subsystem was underdesigned for the actual loads measured. If pump P4 were larger or if the cold water supply had a heat exchanger immersed in the storage tank, the solar contribution could have been greater, with higher effective savings and less equipment costs. Control, HVAC, and design deficiencies lowered the system performance below expectations. The major deficiencies are summarized below.

- The space heating time clock schedule operated the HVAC equipment beyond the normal occupied periods and caused larger quantities of auxiliary energy to be used.
- The solar storage tank is oversized.
- The collector pump operated all day and night at times due to improper control operation.

- The heat rejector was improperly activating at a lower set point temperature.

- The storage to preheat tank pump, P4, had a control deficiency which operated the pump all day long after November 1981.

- Solar space heating was not utilized until November 6, while there was space heating beginning on October 12.

- The south zone fan was operating at all times from July 22 through November 6 to recirculate interior air. This resulted in larger quantities of operating energy being used.

- The collector connections leaked during part of the summer when high collector temperatures were common.

SECTION 10

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4. ASHREA Standard 93-77, Methods of Testing to Determine the Thermal Performance of Solar Collectors, The American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, NY, 1977.

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*5B. Instrumentation Installation Guidelines, March 1981, Parts 1, 2 and 3, SOLAR/0001-81/15, Vitro Laboratories, Silver Spring, Maryland.

6. Solar Energy System Performance Evaluation, Oakmead Industries, October 1980 through May 1981, SOLAR/2076-81/14, Vitro Laboratories, Silver Spring, Maryland.

7. Solar Energy System Performance Evaluation, Oakmead Industries, June 1981 through April 1982, SOLAR/2076-82/14, Vitro Laboratories, Silver Spring, Maryland.

8. Solar Performance Bulletin, Oakmead Industries, October 1980 through May 1981, SOLAR/2076-82/16, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, Oakmead Industries, June 1981, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, Oakmead Industries, July 1981, Vitro Laboratories, Silver Spring, Maryland.

* Copies of these reports may be obtained from Technical Information Center, P. O. Box 62, Oak Ridge, Tennessee 37830

11. Monthly Performance Report, Oakmead Industries, August 1981, Vitro Laboratories, Silver Spring, Maryland.

12. Monthly Performance Report, Oakmead Industries, September 1981, Vitro Laboratories, Silver Spring, Maryland.

13. Monthly Performance Report, Oakmead Industries, October 1981, Vitro Laboratories, Silver Spring, Maryland.

14. Monthly Performance Report, Oakmead Industries, November 1981, Vitro Laboratories, Silver Spring, Maryland.

15. Monthly Performance Report, Oakmead Industries, December 1981, Vitro Laboratories, Silver Spring, Maryland.

16. Monthly Performance Report, Oakmead Industries, January 1982, Vitro Laboratories, Silver Spring, Maryland.

17. Monthly Performance Report, Oakmead Industries, February 1982, Vitro Laboratories, Silver Spring, Maryland.

18. Monthly Performance Report, Oakmead Industries, March 1982, Vitro Laboratories, Silver Spring, Maryland.

19. Monthly Performance Report, Oakmead Industries, April 1982, Vitro Laboratories, Silver Spring, Maryland.

APPENDIX A

NATIONAL SOLAR DATA NETWORK PROGRAMMATIC INFORMATION

APPENDIX A

NATIONAL SOLAR DATA NETWORK PROGRAMMATIC INFORMATION

One of the principal objectives of the National Solar Heating and Cooling Demonstration Program established by the National Solar Heating and Cooling Demonstration Act of 1974 was the collection and evaluation of solar information, and its dissemination to potential users. In order to achieve this objective and to ensure that all related activities are conducted uniformly, the National Solar Data Program, including the National Solar Data Network (NSDN), was established.

Approximately 5,000 residential and commercial solar demonstration sites have been established since the inception of the National Solar Heating and Cooling Demonstration Program. Approximately 150 of these sites were instrumented and included in the National Solar Data Network.

The Department of Energy (DOE) had responsibility for the solar energy program; however, other government agencies were significantly involved. Those agencies include the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the Department of Defense, the National Bureau of Standards, Argonne National Laboratory, and the Department of Health, Education and Welfare. State and local governments, portions of the private sector, and other groups within DOE were active participants.

The National Solar Data Program had a major goal to collect and analyze data from solar sites throughout the United States to enable determination of solar energy system performance. Specifically, the data which is generated and collected in support of this program is used to:

1. Improve the general knowledge and understanding of the performance and operating characteristics of solar energy systems.

2. Develop definitive solar energy system performance criteria.

3. Provide a basis for component and system improvements.

4. Estimate the economic importance of solar energy systems in reducing the consumption of conventional fuels.

The National Solar Data Network provided data to meet this major goal. Accurate, consistent, and orderly data was obtained from a variety of solar energy systems, located in many buildings and exposed to differing climatic conditions. The data was collected, organized, maintained and analyzed at a central point assuring consistent system analysis and performance evaluation.

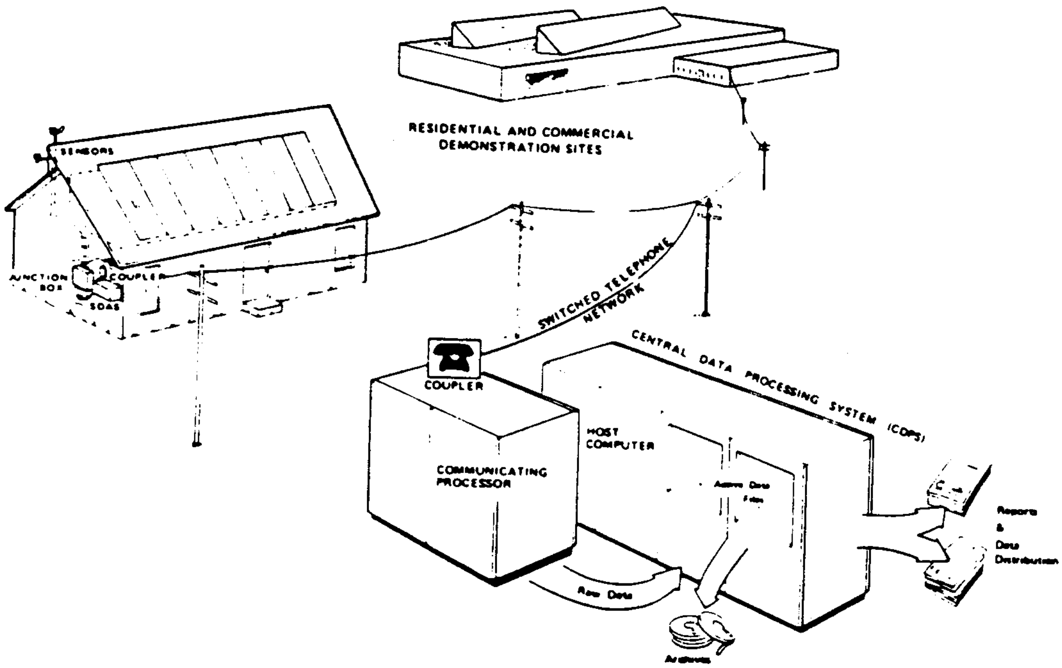


Figure A-1. Schematic Diagram of the NSDN Teleprocessing Network

To meet the goals and objectives of the National Solar Data Program, the National Solar Data Network was operated for the Department of Energy by Vitro Corporation. The network concept was based on automatic collection of data from remote solar sites and transmission of this data to a central computer facility. Thus, the National Solar Data Network was developed to gather, convert, transfer, and analyze solar system data using six basic steps (see Figure A-2).

1. Evaluate each site and its instrumentation requirements.

2. Select sensors and personalize standardized data acquisition equipment in order to meet specific site requirements.

3. Install and check out instrumentation on site.

4. Retrieve automatically collected site data over the telephone network on command from a central computer facility.

5. Process data in centrally located computers; this includes error checking, performance evaluation computations, and data base maintenance.

6. Analyze data received and document this analysis in a standard report format for distribution.

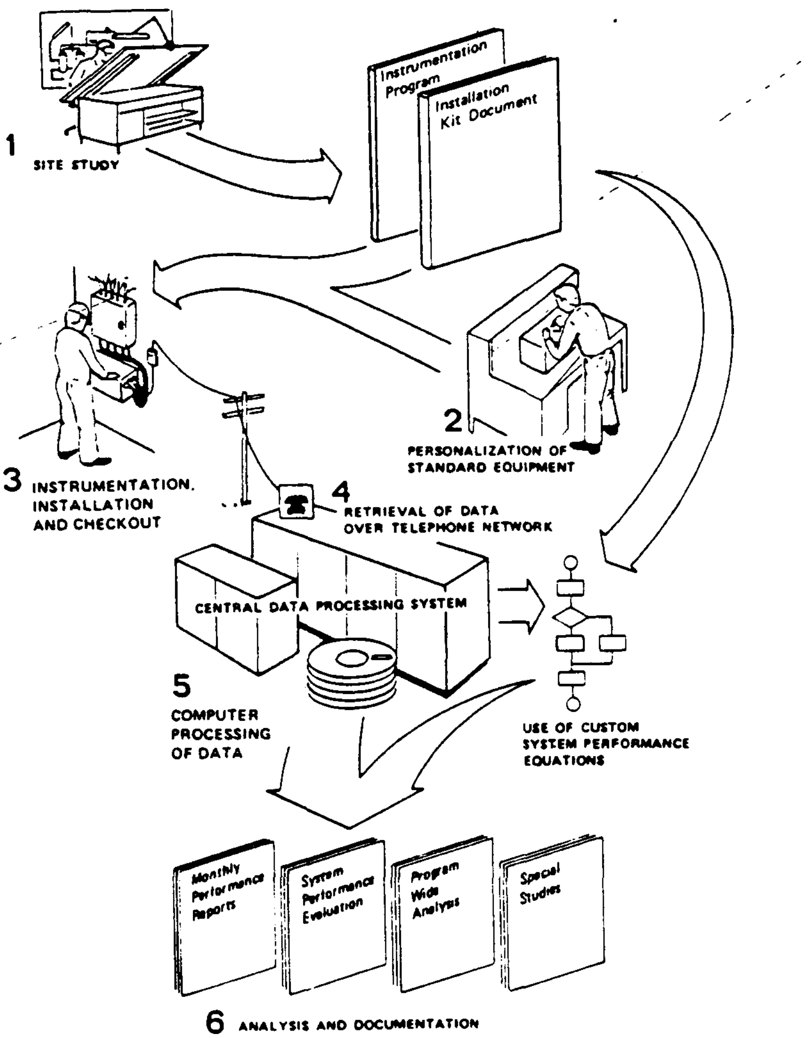


Figure A-2. Instrumentation, Monitoring and Analysis Process

The following discussion will define each step in detail.

Site Evaluation

First, a careful study of the solar energy system design of each demonstration site was conducted. Using detailed information supplied by the solar system designer and the site contractor, the system and its environment was investigated to establish performance evaluation equations and associated site monitoring instrumentation requirements. The details of the site instrumentation were documented in the Instrumentation Installation documents generated for each solar site. (See Figure A-3.)

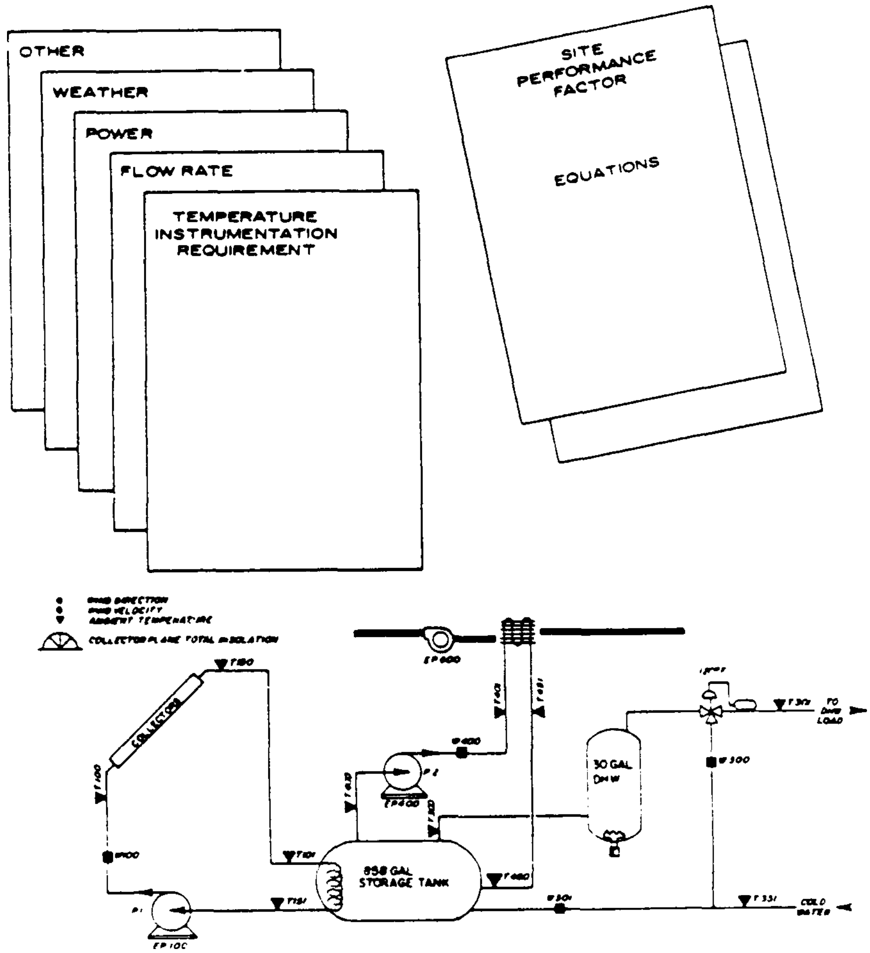


Figure A-3. Site Study - Generates Instrumentation Requirements and Performance Evaluation Equations

Performance evaluation factors were determined using the energy balance concept. Simply stated, energy entering a system (or subsystem) is equal to the sum of energy leaving the system, energy accumulated in the system, energy transferred through thermal leakage, and conversion inefficiency. As stated in the Instrumentation Program, the sensors selected were those necessary to accurately and economically determine this energy balance.

Performance factors were used to:

1. Determine fossil fuel and electrical energy savings resulting from use of solar energy for space heating, space heating, space cooling, and hot water systems.

2. Determine total heating, cooling, and hot water thermal energy demands and the fraction of each supplied by solar energy.

3. Measure solar energy system efficiency for converting available solar energy into useful thermal energy.

4. Measure thermal performance of major subsystems or components and thermal interactions between collector array, storage, and energy conversion equipment.

5. Measure occupant's energy usage by means of parameters such as temperature level maintained and hot water demand.

6. Determine major system operational characteristics and degradation over life of the demonstration.

7. Obtain records of incident solar radiation and other pertinent site environmental parameters that affect system performance over life of the site.

Personalization of Standard Equipment

The second step was to select sensors and personalize the standard data acquisition equipment to meet the requirements specified in the Instrumentation Program. Sensors were selected from a standardized set of sensors which has been established to ensure compatibility with the Site Data Acquisition Subsystem (SDAS) and to minimize software development. The SDAS is a microprocessor-controlled electronic unit, which collects data from the sensors, stores the data, and on command transmits it to the central facility. (See Figures A-4 and A-5.) The scanning process, data treatment procedure, and other functions of the SDAS are directed by a microprogram, which was custom developed for each SDAS, according to the Instrumentation Program for a specific site. Additional personalization was provided through unique wiring of the SDAS and its associated junction-box (see Figure A-6), as described in the sensor Installation Plan. Figures A-7 through A-11 show some of the sensors employed to monitor a solar Domestic Hot Water system.

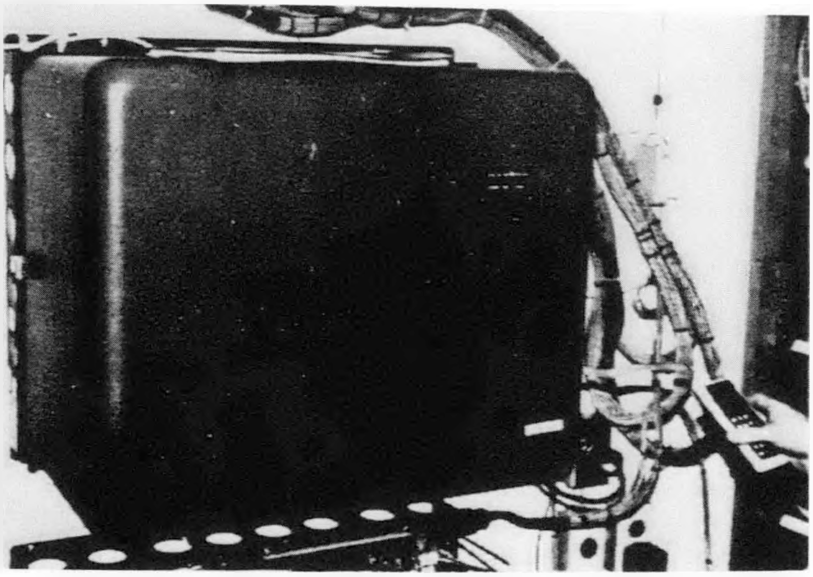


Figure A-4.
SDAS Unit mounted on wall. A micro-terminal is used to obtain sensor measurements for on-site tests.

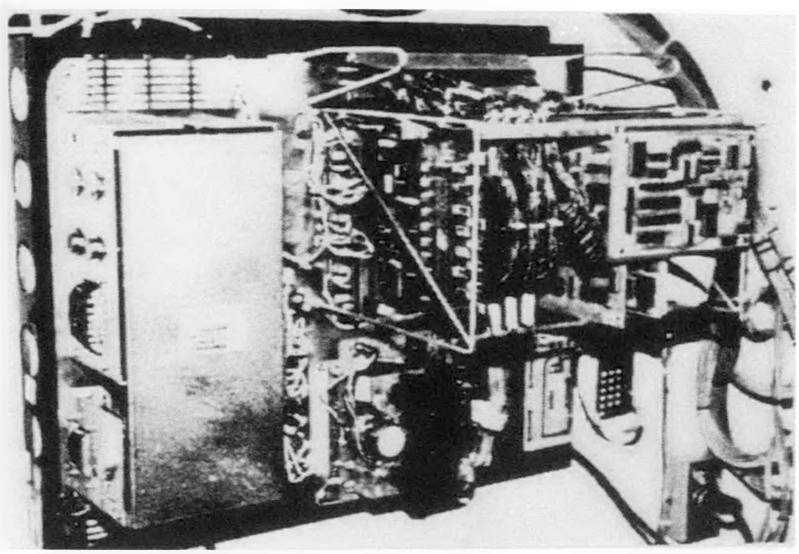


Figure A-5.
SDAS without cover reveals internal power supply, tape recorder and arithmetic processor.

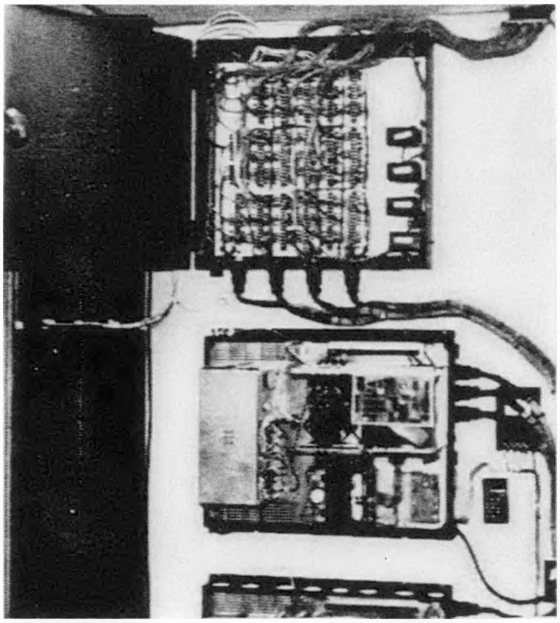


Figure A-6.
SDAS with the associated electrical junction box. Equipment was normally wall-mounted in area easily accessible.

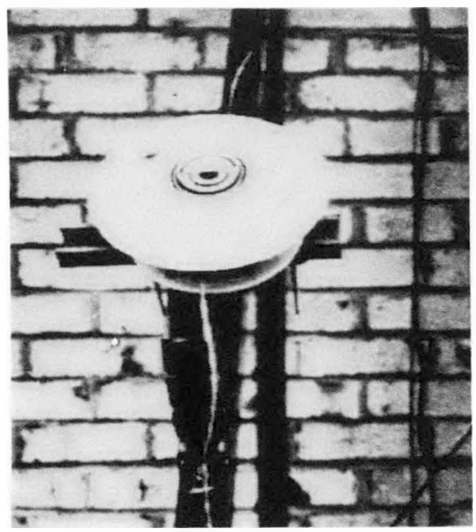


Figure A-7.
Eppley Pyranometer mounted in the plane of the solar collectors

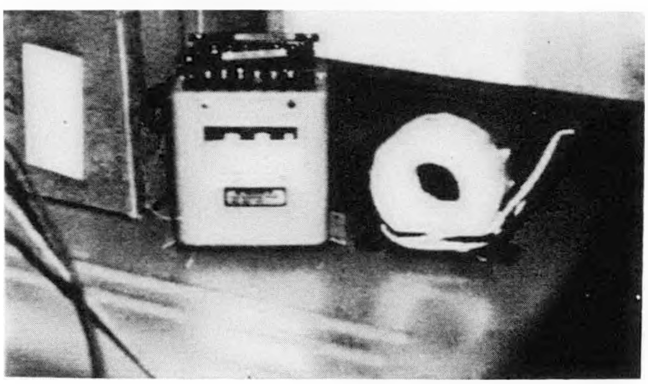


Figure A-8.
Electrical power sensor with current sensor coil used to monitor operational energy.

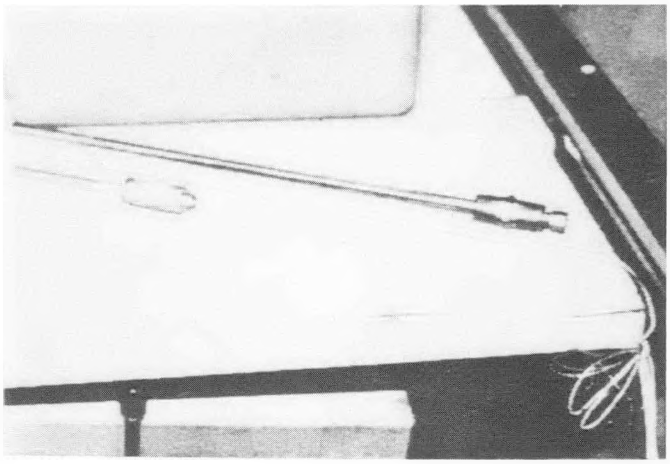


Figure A-9.
Resistance thermal devices (RTD) were used to provide accurate temperature measurements. Stainless steel thermal wells were threaded into pipes and house the RTDs.

Figure A-10.
Hersey totalizing flow meters provide flow rate data for variable flow loops. Not shown, Ramapo flowmeters used for constant flow rate loops.

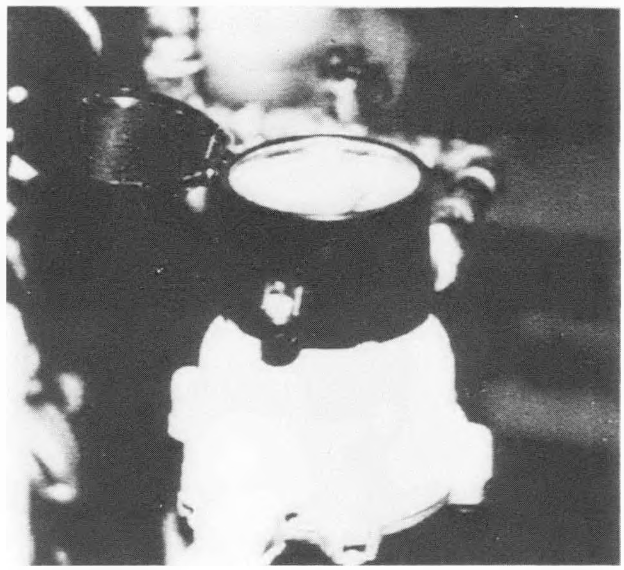


Figure A-11.
WeatherMeasure wind speed and direction vane and ambient air temperature sensor were particularly important on Passive Solar Sites.

On-Site Installation and Checkout

The third step was the installation and checkout of the SDAS and the sensors. The site contractor installed the supplied sensors in accordance with specific installation procedures and verified that the wiring was correct before the SDAS is connected. Sensors were connected to the SDAS through a junction-box, which was wired according to the Installation Plans and attached to the SDAS by standard interface cables. The SDAS was connected to the National Solar Data Network through a telephone interface installed by the local telephone company. Figure A-12 depicts a typical junction-box properly wired to reduce line losses and to allow easy access for trouble shooting.

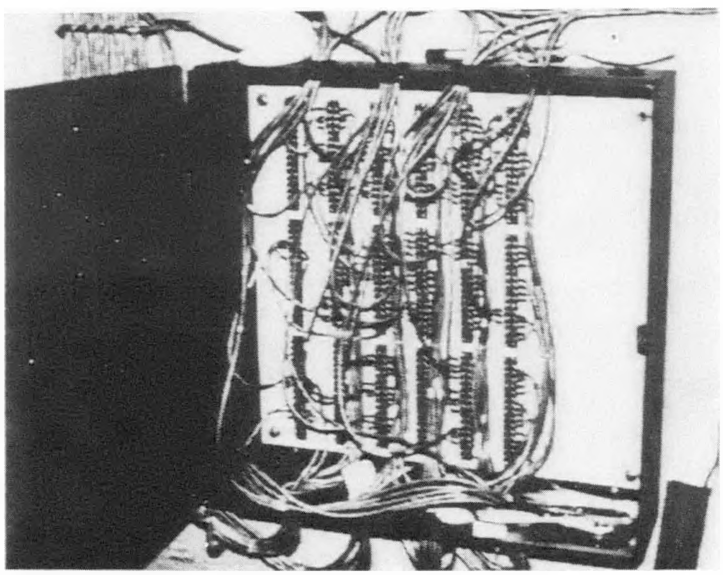


Figure A-12. The junction-box was mounted on a plywood sheet mounted on masonry wall. Wires were terminated with crimped terminals and attached to terminal boards.

After the SDAS has been installed, checkout procedures were initiated to verify correct local operation of the sensors and data acquisition equipment. Portable monitors were used to obtain a direct readout in Engineering Units of the system measurements and thereby verify that the solar system and SDAS are performing correctly.

The final checkout step was to verify correct transmission of the data to the Central Data Processing System (CDPS).

Retrieval Over Telephone Network

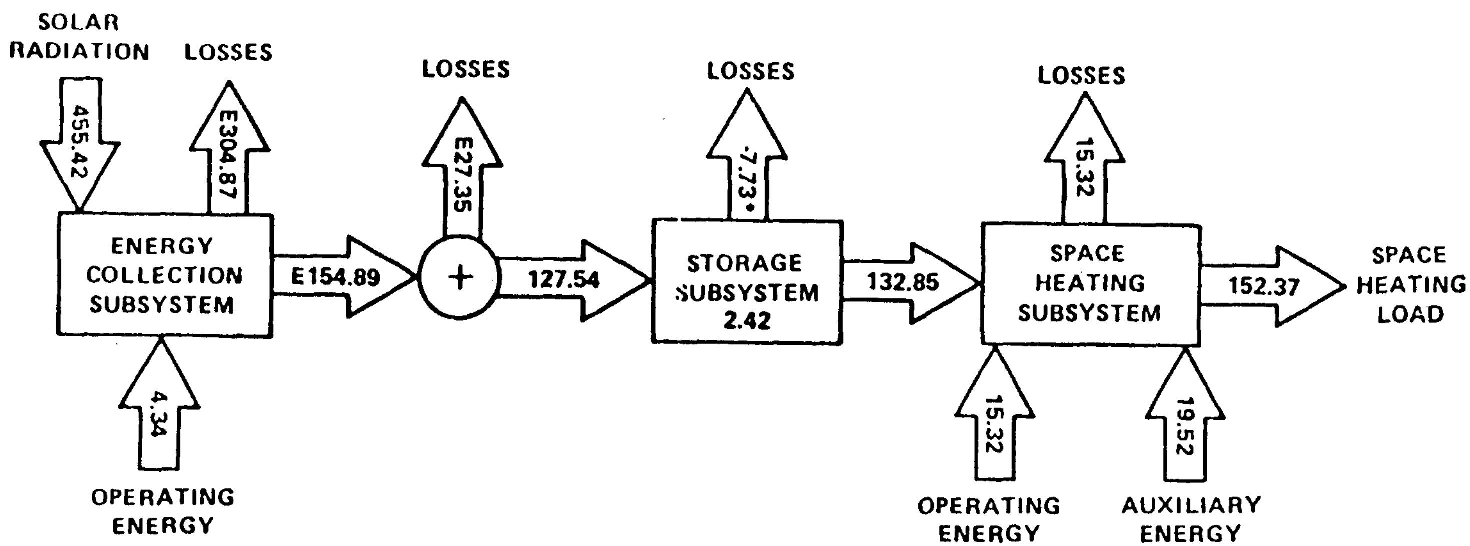
After the site data acquisition equipment had been installed and checked out, data retrieval began. Data was transferred from the on-site SDAS to the Central Data Processing System (CDPS) using the standard commercial telephone network. Each SDAS scanned sensor inputs every five minutes and stored the raw data on a cassette tape. The Communications Processor, IBM System 7, at the CDPS, automatically called each SDAS daily. The SDAS identified itself and then rewound and played back the data sorted on its cassette tape. The Communications Processor received the data, performed error checking and formatting operations, and passed the data to a data storage tape. The SDAS cassette tape was then rewound and proceeded to gather new data. The data storage tape was transferred to the main computer, IBM 3033, for processing.

Analysis and Reporting

The energy balance method of systems analysis was used to evaluate the performance of solar systems. Figure A-13 illustrates this process. By carefully monitoring the energy flow patterns throughout the system, this method not only provided a measure of efficiency for each major component, but it also provides a built-in check of the instrumentation.

Each of the NSDN solar sites was analyzed on a monthly basis. Data collected daily was integrated and performance factors were generated using customized software. Figure A-14 is a summary page for the month of March for one NSDN site. The purpose of this page was to provide the reader with all of the pertinent information regarding the solar system's performance without burdening the reader with details. The remainder of the monthly report contains daily statistics, which could be used to explain operational anomalies. In addition to the monthly reports, the solar analysts also received plots of specific sensor values on a daily basis. This enabled the analysts to detect problems as they occur.

Seasonal reports were also prepared for each of the NSDN sites at the end of the solar system's load season. Since the performance of an individual system was based upon a large number of uncontrollable variables, the evaluation of a system over a larger time horizon was frequently preferable. The seasonal reports provided the same information as a monthly report, however, the conclusions may be drastically different than an individual monthly analysis. The reports also acted as a better check of the system's performance since most systems were designed to operate efficiently over a long time horizon, not a given month.



E DENOTES ESTIMATED VALUE

* SEE THERMAL PERFORMANCE, STORAGE SUBSYSTEM

Figure A-13. Energy Flow Diagram for Oakmead Industries

(Figures in million BTU)

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY.	455.417 MILLION BTU
	39533 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	154.887 MILLION BTU
	13445 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE.	28 DEGREES F
AVERAGE BUILDING TEMPERATURE	[illegible] DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.29
ECSS OPERATING ENERGY.	4.340 MILLION BTU
TOTAL SYSTEM OPERATING ENERGY.	19.662 MILLION BTU
TOTAL ENERGY CONSUMED.	194.070 MILLION BTU

SUBSYSTEM SUMMARY:

	HEATING	SYSTEM TOTAL
LOAD	152.371	152.371 MILLION BTU
SOLAR FRACTION	87	87 PERCENT
SOLAR ENERGY USED	132.849	132.849 MILLION BTU
OPERATING ENERGY	15.321	19.662 MILLION BTU
AUX. THERMAL ENERGY	19.522	19.522 MILLION BTU
AUX. ELECTRIC FUEL	19.522	19.522 MILLION BTU
AUX. FOSSIL FUEL	N.A.	N.A. MILLION BTU
ELECTRICAL SAVINGS	123.774	119.433 MILLION BTU
FOSSIL SAVINGS	N.A.	N.A. MILLION BTU

SYSTEM PERFORMANCE FACTOR: 1.168

N.A. DENOTES NOT APPLICABLE DATA.

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978, SOLAR/0004-78/18. READ THIS BEFORE TURNING PAGE.

Figure A-14. Monthly Report: March 1980
Site Summary: Oakmead

Comparative reports were also prepared periodically for classes of solar systems. A single comparative report may be based on 20 or more domestic hot water or space heating systems for the purpose of highlighting the effectiveness of systems in a particular environment or under specific load conditions or to identify system components which consistently operate well.

APPENDIX B

PRELIMINARY DESIGN DRAWINGS

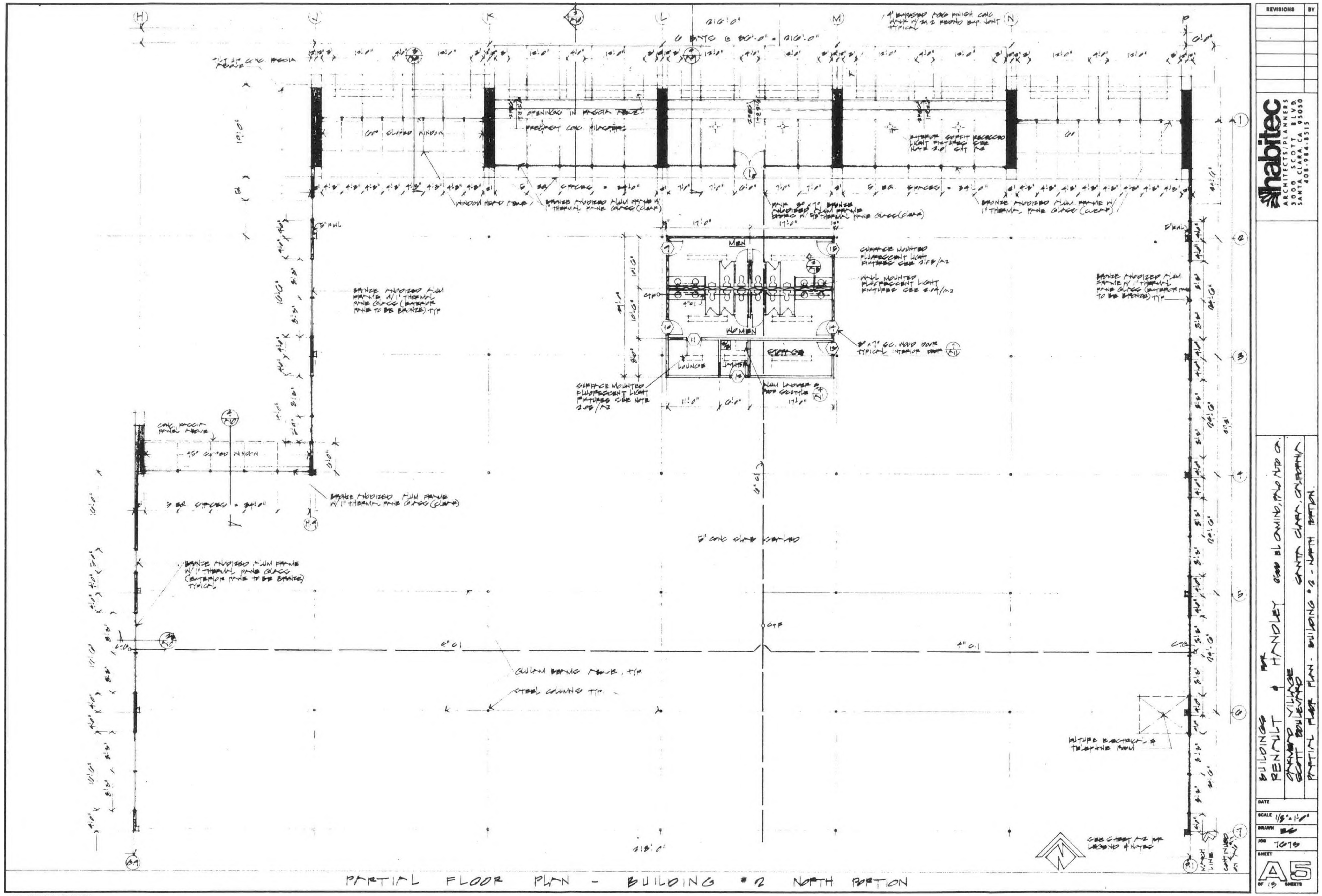


Figure B-1. Partial Floor Plan, North Portion
Oakmead Industries

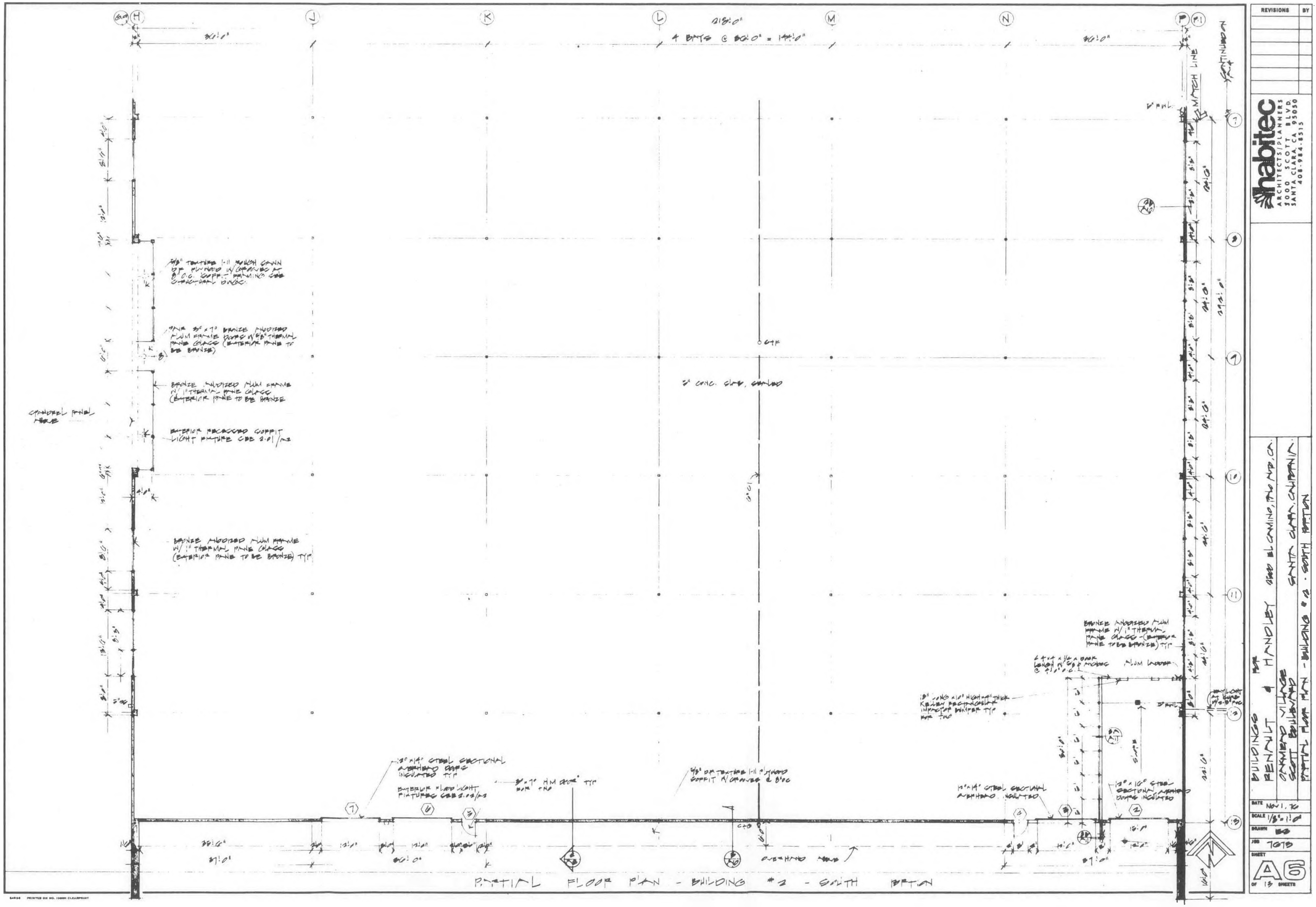


Figure B-2. Partial Floor Plan, South Portion
Oakmead Industries

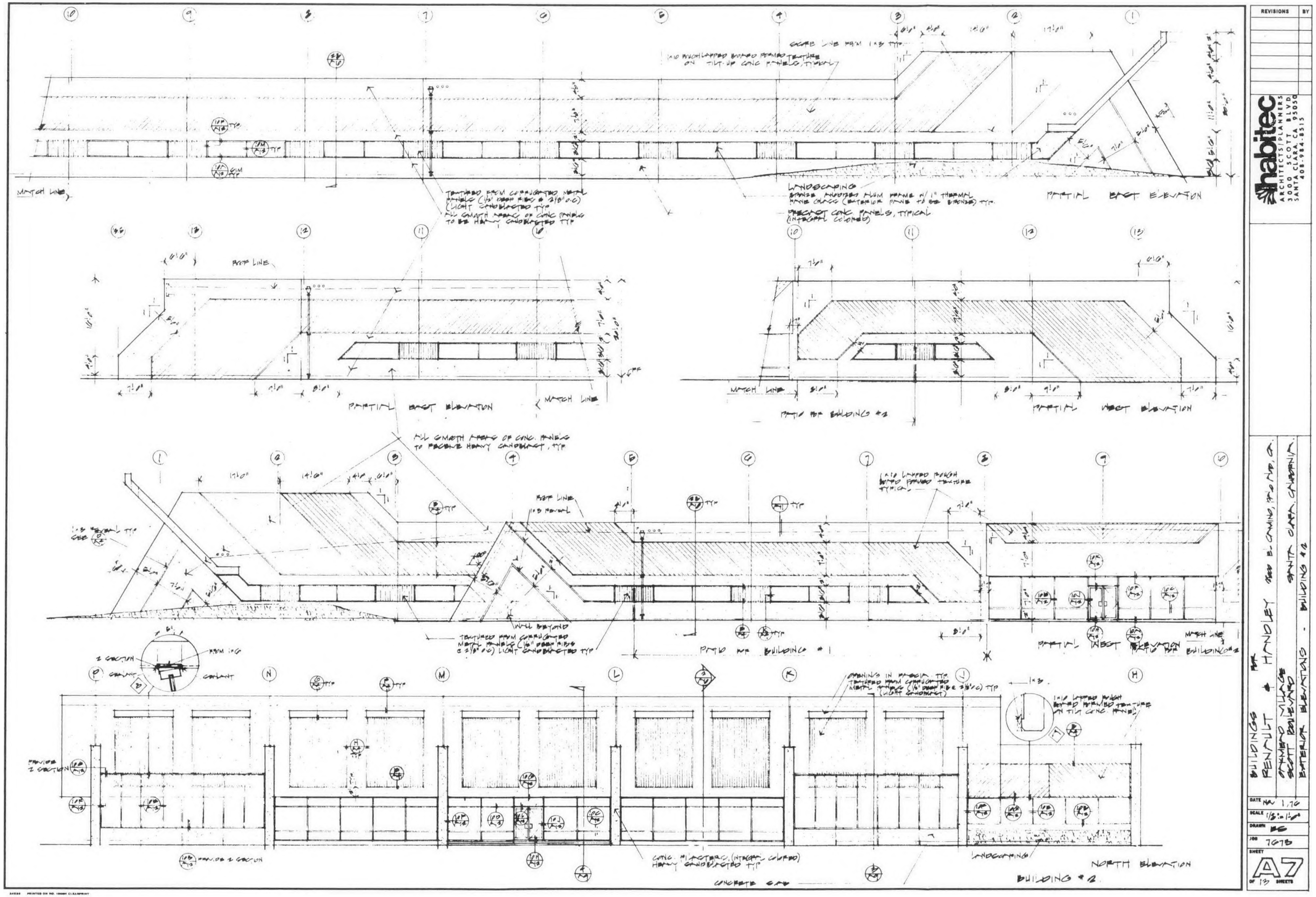


Figure B-3. Exterior Elevations
Oakmead Industries

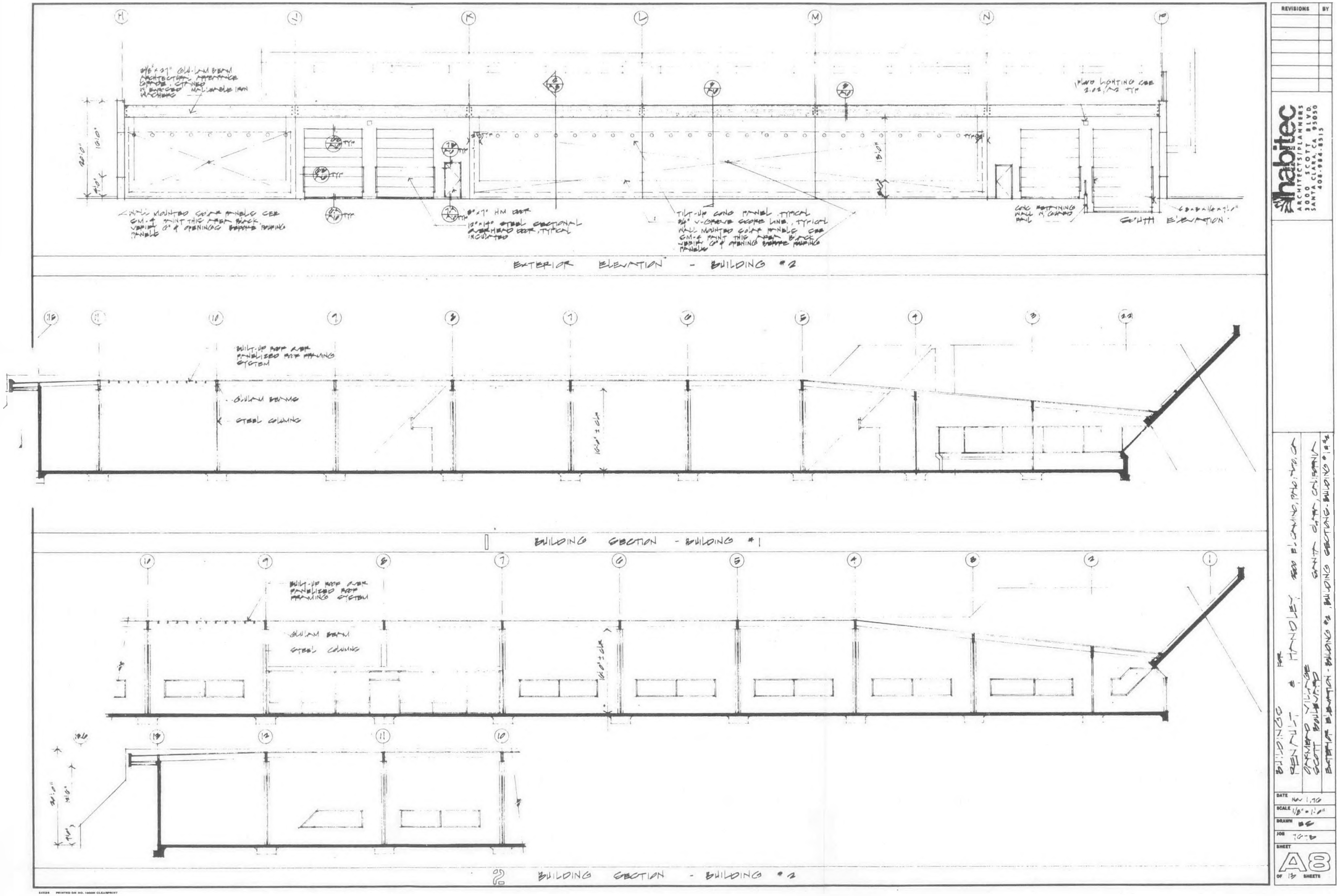


Figure B-4. Exterior Elevation and
Building Sections
Oakmead Industries

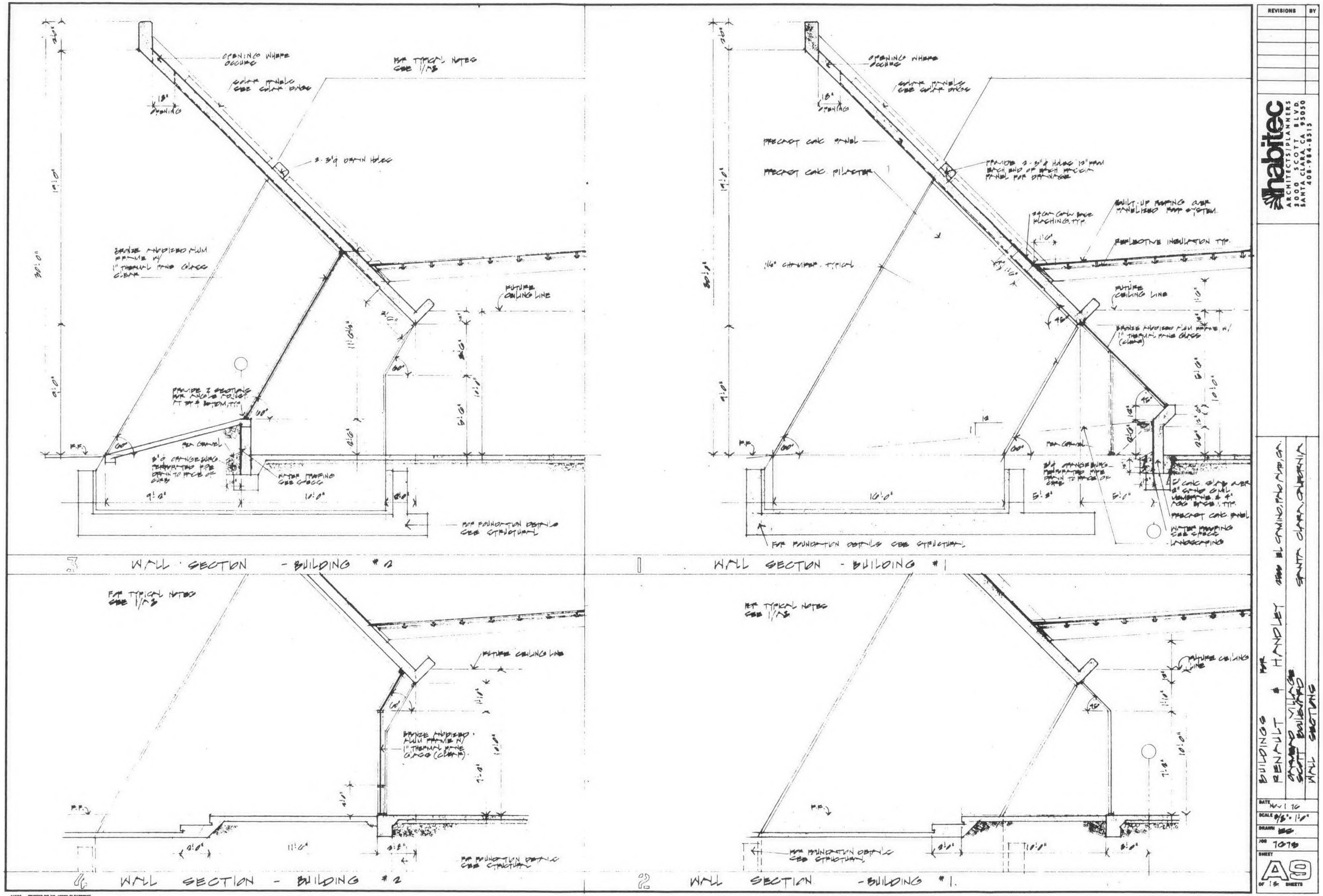


Figure B-5. Wall Sections
Oakmead Industries

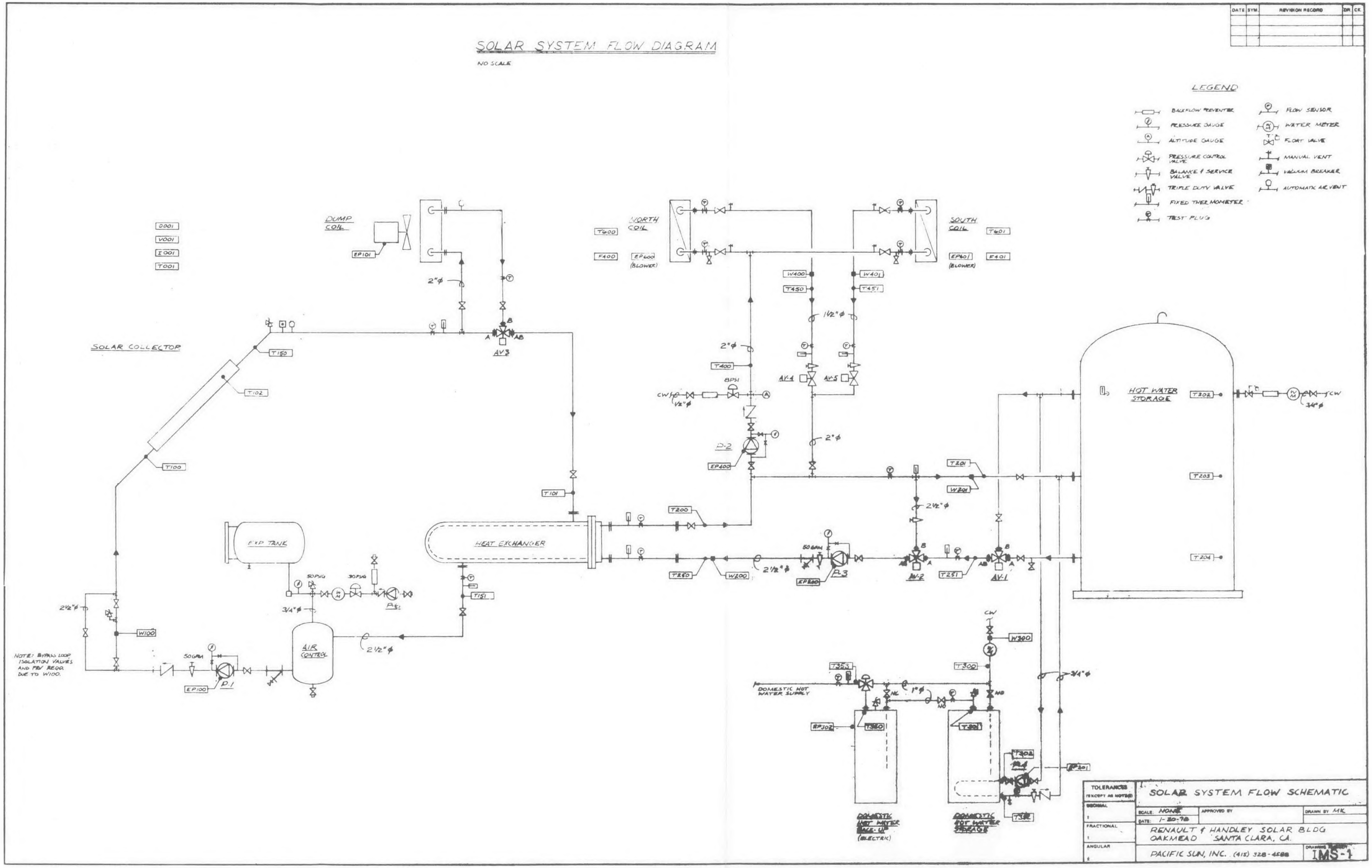


Figure B-6. Solar System Flow Schematic
Oakmead Industries

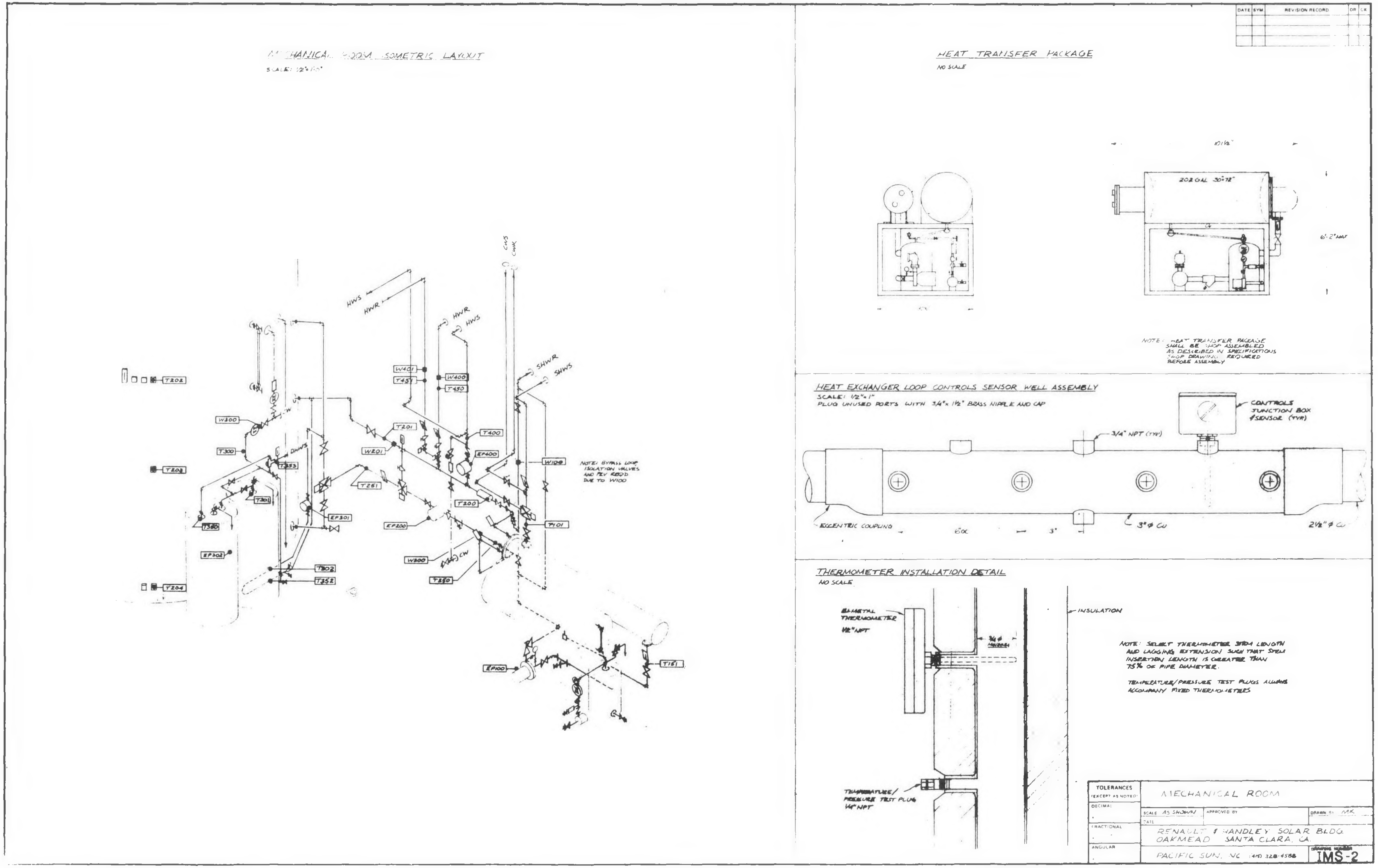


Figure B-7. Mechanical Room
Oakmead Industries

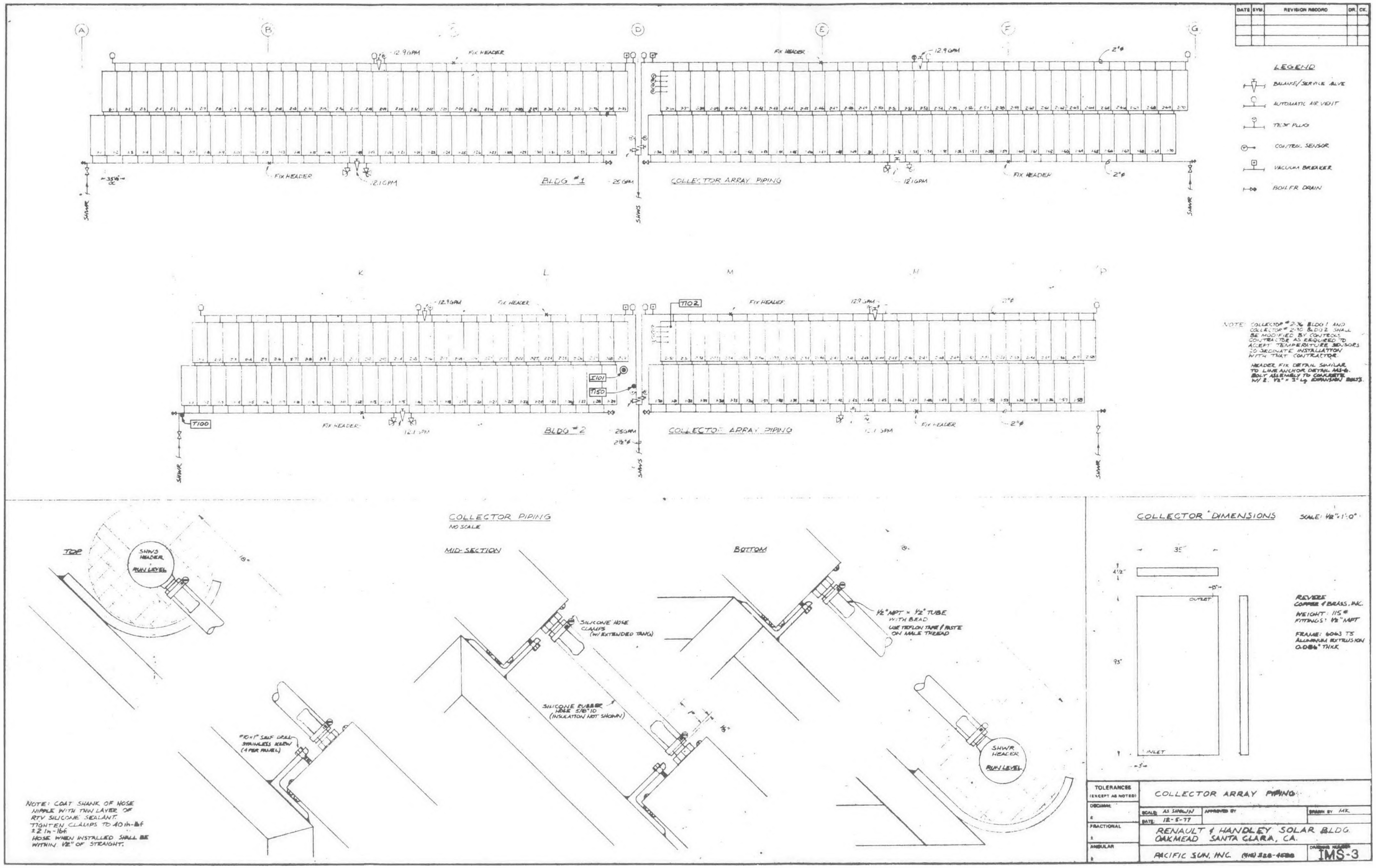


Figure B-8. Collector Array Piping
Oakmead Industries

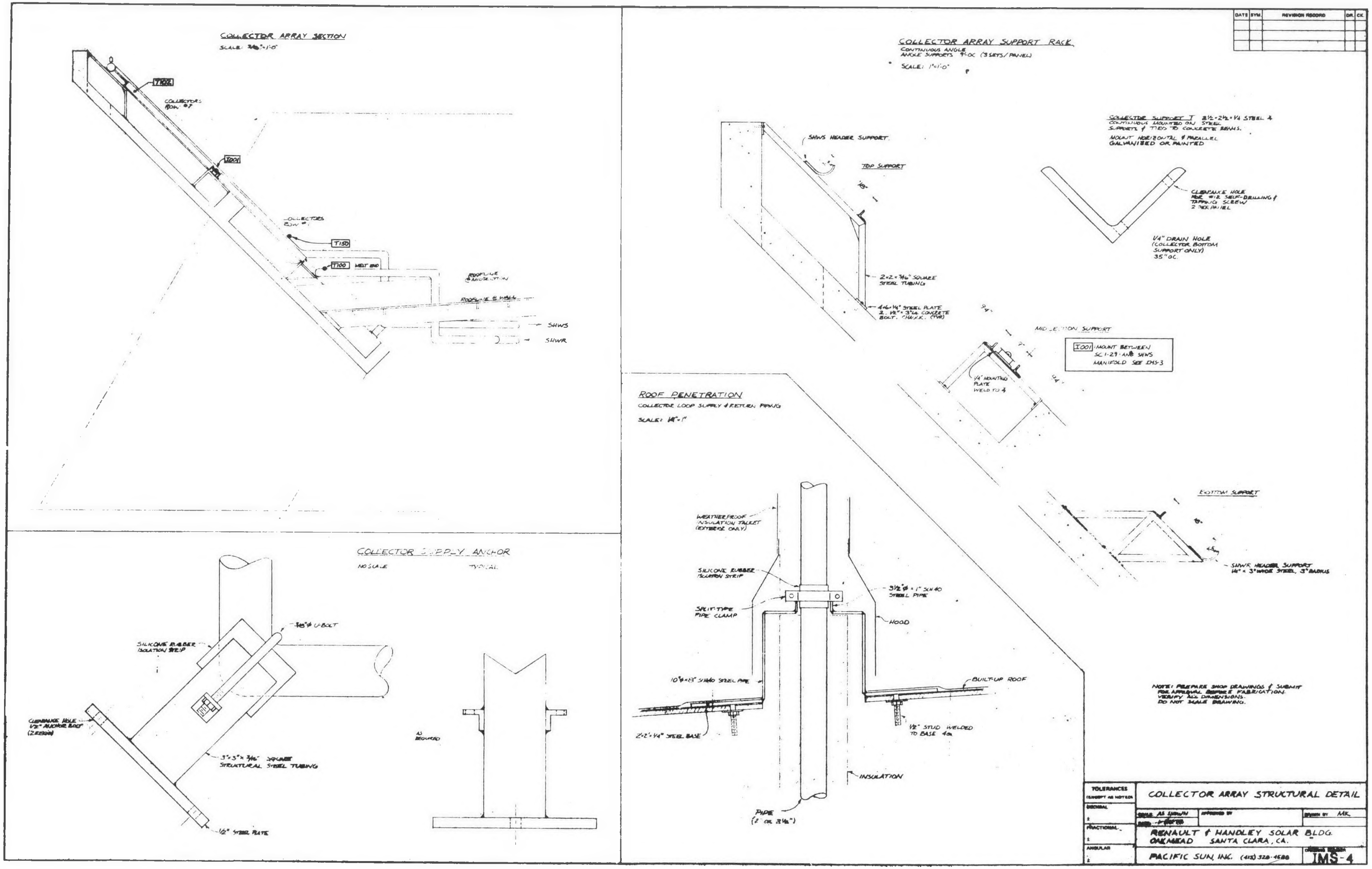


Figure B-9. Collector Array Structure
Oakmead Industries

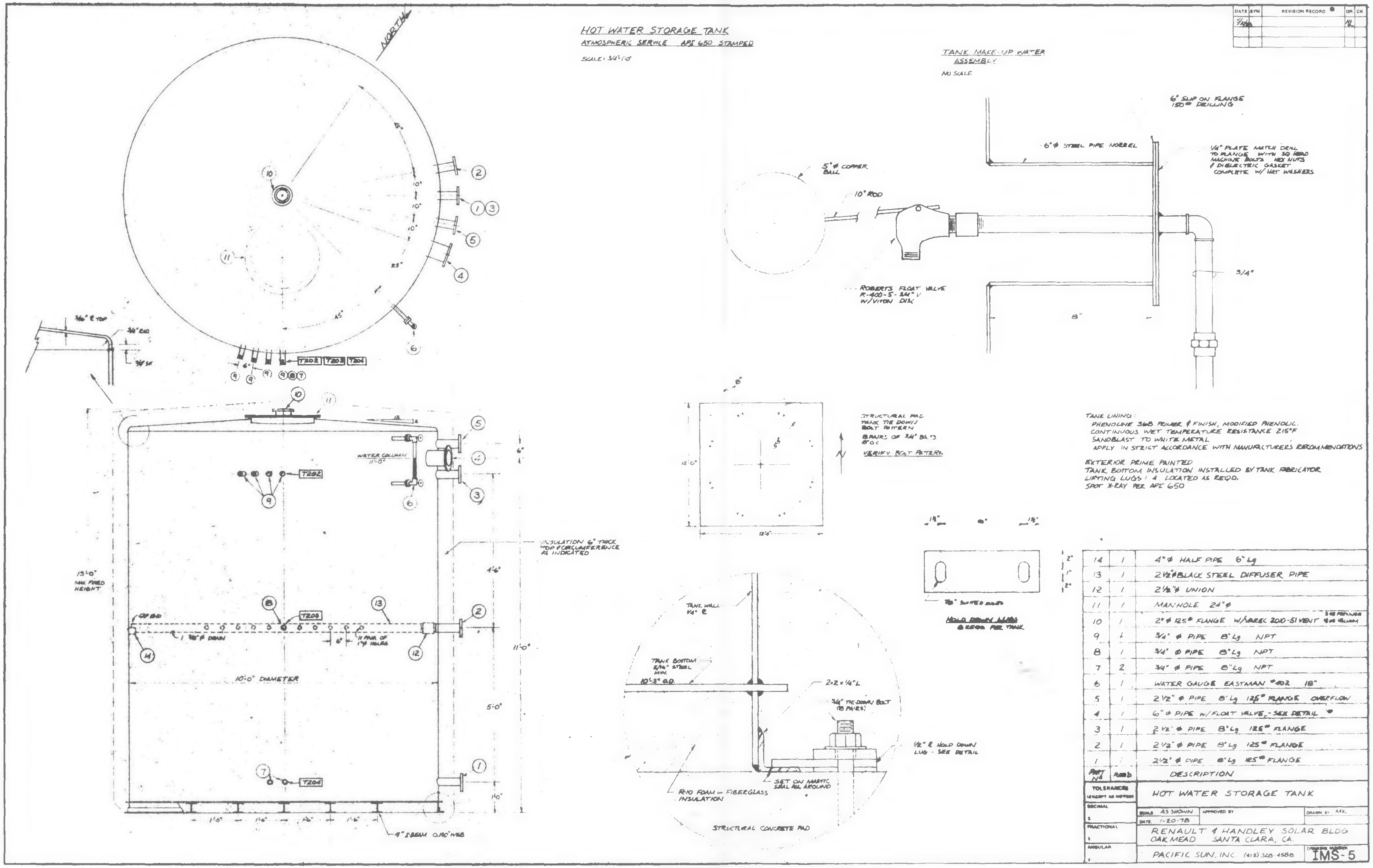


Figure B-10. Hot Water Storage Tank
Oakmead Industries

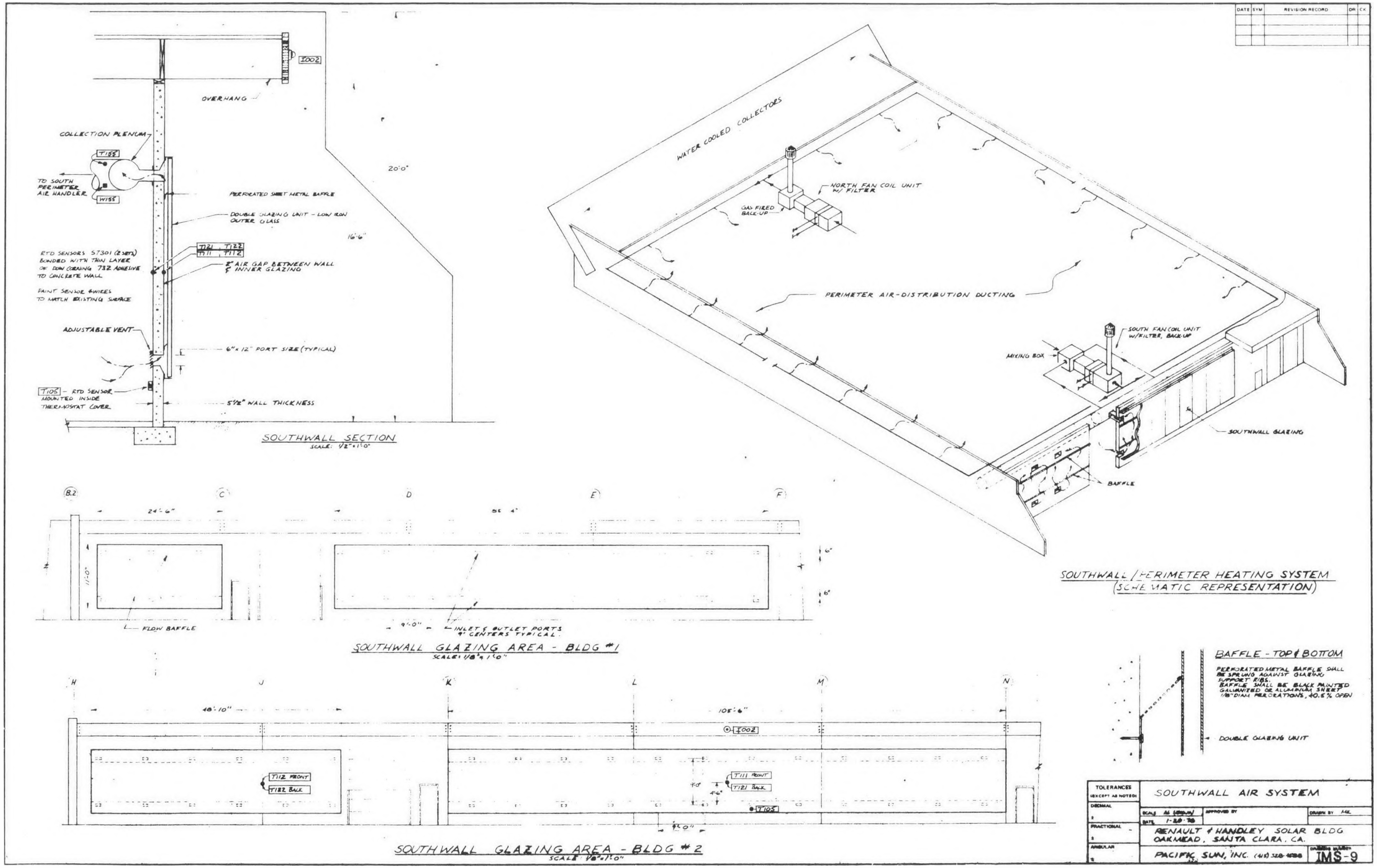


Figure B-11. South Wall Air System
Oakmead Industries

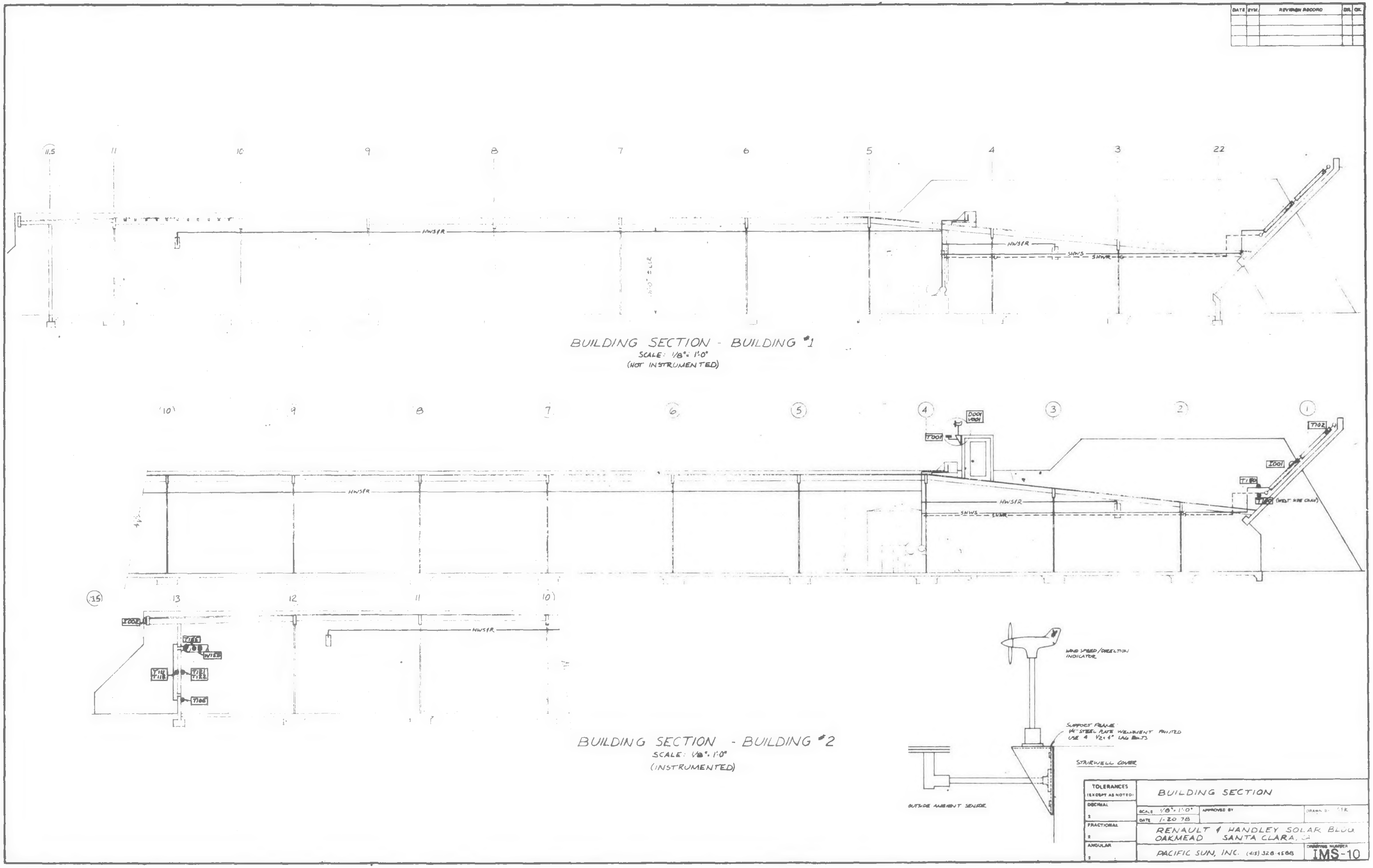


Figure B-12. Building Section
Oakmead Industries

TEMPERATURE MEASUREMENT INSTRUMENTATION

NO.	DESIGNATION	NUMBER J-BOX	NUMBER SDAS	NAME	S/N	RANGE (°F) MIN	RANGE (°F) MAX	PIPE TYPE	PIPE SIZE	TUBE SIZE	METHOD	REF FIG NO.	THERMOWELL PART NO.	PROBE PART NO.
1	T001			OUTSIDE AMBIENT		-20	120					I	SPECIAL	P/N 553-P
2	T100			COLLECTOR ARRAY INLET		30	230	CU		2-1/2		A	F203U15	553-P40236
3	T150			COLLECTOR ARRAY OUTLET		30	330	CU		2-1/2		"	"	"
4	T101			HX SHELL INLET		30	330	CU		2-1/2		"	"	"
5	T151			HX SHELL OUTLET		30	330	CU		21/2		"	"	"
6	T102			ABSORBER PLATE SURFACE		30	450	SURFACE MOUNT			BOND	H	DC732	S7301
7	T111			SOUTHWALL OUTER SURFACE (EAST)		30	230	SURFACE MOUNT			BOND	E	DC732	S7301
8	T112			SOUTHWALL OUTER SURFACE (WEST)		30	230		"		"	"	"	"
9	T121			SOUTHWALL INNER SURFACE (EAST)		30	230		"		"	"	"	"
10	T122			SOUTHWALL INNER SURFACE (WEST)		30	230		"		"	"	"	"
11	T105			SOUTHWALL INLET		30	160	WALL MOUNT				D	SPECIAL	553-P30236
12	T155			SOUTHWALL OUTLET (EAST)		30	230	18"⌀ DUCT				G	F132	553-P30236
13	T156			SOUTHWALL OUTLET (WEST)		30	230	"				"	"	"
14	T200			CONTROL LOOP, HX OUTLET		30	230	CU		2-1/2		A	F203U15	553-P40236
15	T250			CONTROL LOOP, HX INLET		30	230	CU		2-1/2		"	"	"
16	T201			STORAGE TANK INLET		30	230	CU		2-1/2		"	"	"
17	T251			STORAGE TANK OUTLET		30	230	CU		2-1/2		"	"	"
18	T202			STORAGE TANK TOP		30	230				TANK PROBE	C	F203U155	553-P180236
19	T203			STORAGE TANK MIDDLE		30	230				"	"	"	"
20	T204			STORAGE TANK BOTTOM		30	230				"	"	"	"
21	T300			DHW MAKE-UP WATER		30	160	CU		1		A	F203U15	553-P40236
22	T301			DHW PREHEAT TANK OUTLET							BOND	B	DC732	S7301
23	T350			DHW BACK-UP TANK OUTLET							BOND	B	DC732	S7301
24	T302			DHW HX INLET		30	230	CU		3/4		A	F203U04	553-P30236
25	T352			DHW HX OUTLET		30	230	CU		3/4		"	"	"
26	T353			DHW SUPPLY		30	230	CU		1		A	F203U15	553-P40236
27	T400			HOT WATER SUPPLY TO LOAD		30	230	CU		1-1/2		A	F203U15	553-P40236
28	T450			HOT WATER RETURN - NORTH		30	230	CU		1-1/2		"	"	"
29	T451			HOT WATER RETURN - SOUTH		30	230	CU		1-1/2		"	"	"
30	T600			NORTH ZONE		-20	120					D	N/A	553-P40236
31	T601			SOUTH ZONE		-20	120					"	"	"

COMMENTS:

1. Length of extension shall be selected to allow thermowell immersion in fluid stream between wall and centerline of tube/pipe.
2. Weather proof head shall be oriented to minimize accidental damage.
3. Material selection shall be galvanically compatible to the system design.
4. Dow Corning DC-342 heat transfer grease shall be applied to the bottom of the RTD probe prior to insertion into the thermowell.
5. Standard conduit 3/4" - 14 NPT internal pipe threads. Installation optional unless required per local codes. Rigid conduit shall be terminated at the sensor end with flexible conduit. All connections shall be watertight.
6. If installation of thermowell(s) degrades the design or operational integrity of the fluid transport system, other methods shall be investigated for this application. ERDA shall provide and/or approve the design change.
7. Pipe thread sealing compound may be used in accordance with local codes.
8. In areas where mixing of fluid is necessary to provide meaningful temperature results, the RTD shall be located 10 diameters for a pipe smaller than 1" or 20 diameters for pipe greater than 11/4" from the mixing intersection.
9. ERDA supplied part to site contractor.
10. Source: Minco Products, Inc., Minneapolis, Minnesota or equivalent.

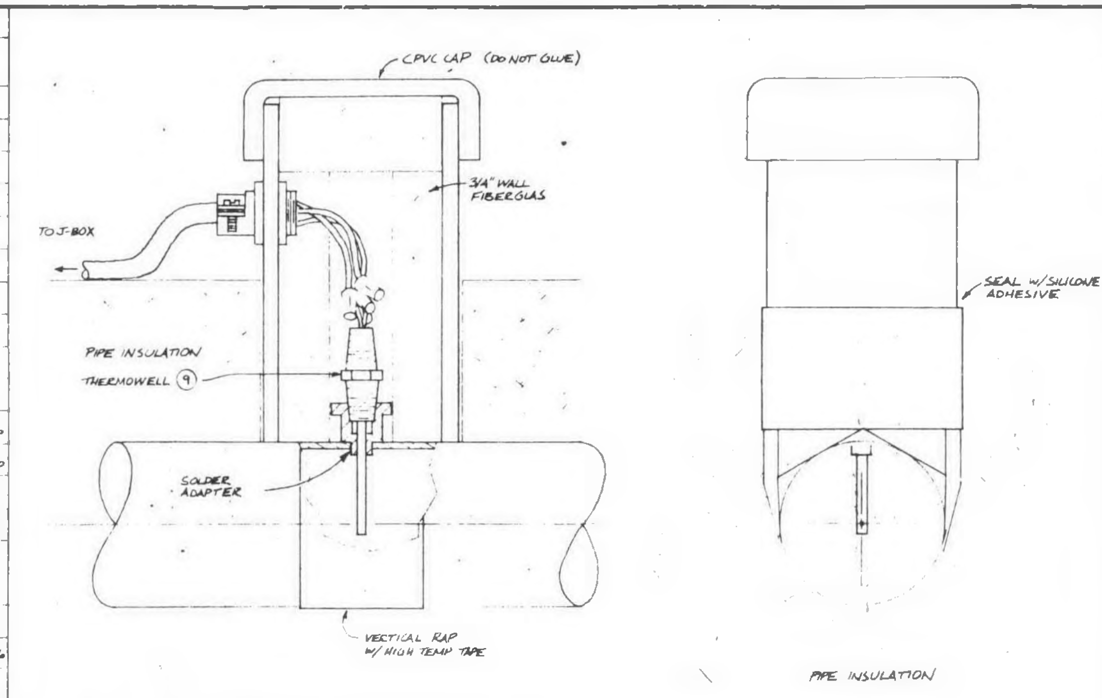
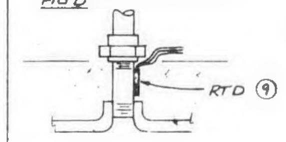


FIG A SOLDER ADAPTER PIPE SENSOR
NOTE: ON RUNS SMALLER THAN 1"⌀ USE C×C×F TEE. ON OUTSIDE PROBES, MOUNT HEAD ON SIDE OF PIPE

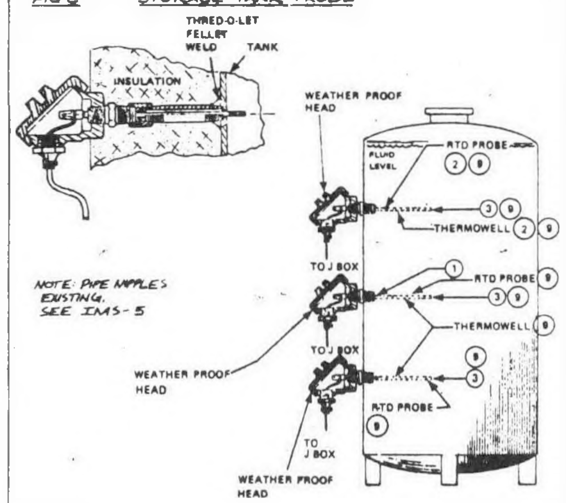
DHW TANK OUTLET
FIG B



DHW TANK CONSTRUCTION REQUIRES RTD SURFACE PROBE FOR OUTLET TEMP MEASUREMENT. MOUNT AS CLOSE TO BRASS NIPPLE/TANK CONNECTION AS POSSIBLE. WRAP w/ 3/4" WALL ARMAFLEX

DATE	SYM	REVISION RECORD	DR	CK

FIG C STORAGE TANK PROBE



NOTE: PIPE NIPPLES EXISTING. SEE IMS-5

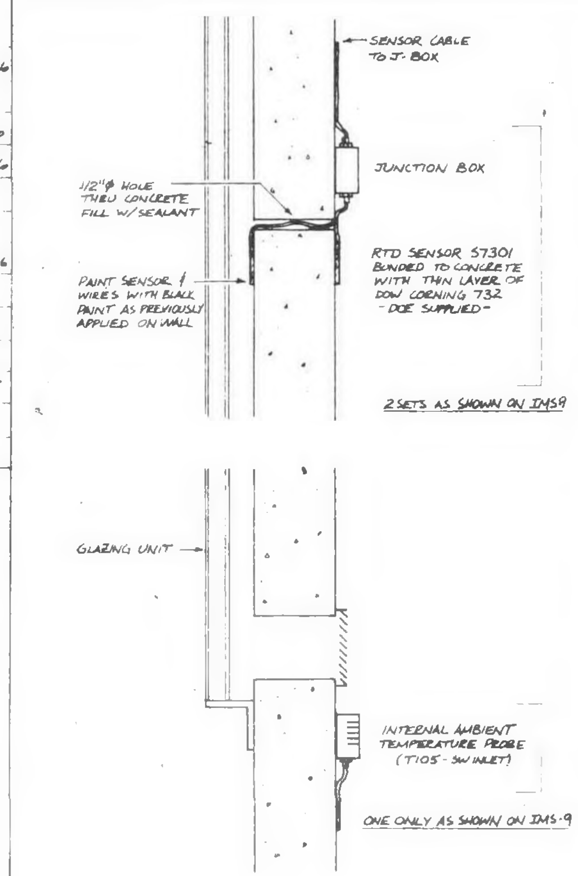


FIG E SOUTHWALL

FIG F RTD ELEMENT WIRING
P/N 553-P

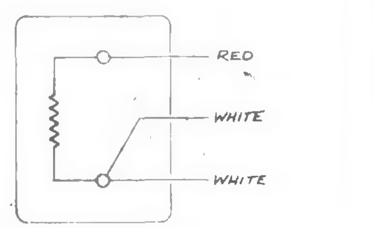


FIG G

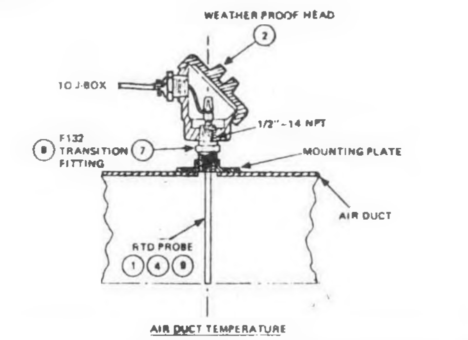
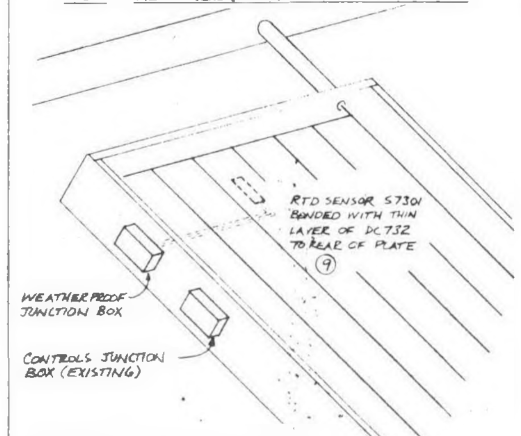
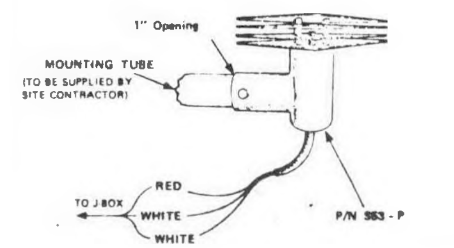


FIG H ABSORBER PLATE TEMPERATURE

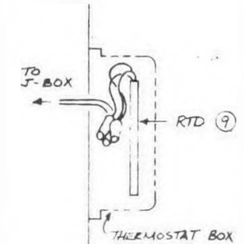


NOTE: MATL BY DOE & CONTRACTOR INSTALLATION BY PACIFIC SUN, INC.

FIG I OUTSIDE AMBIENT
SEE IMS-10



ZONE TEMPERATURE
FIG D



MOUNT ON WALL NEAR PLACEMENT OF TYP NORTH & SOUTH ZONE THERMOSTATS

TOLERANCES (EXCEPT AS NOTED)	TEMPERATURE MEASUREMENT DETAILS		
DECIMAL	SCALE AS SHOWN	APPROVED BY	DRAWN BY MAK
FRACTIONAL	DATE 6/28/78		
ANGULAR	RENAULT & HANDLEY SOLAR BLDG #2 OAKMEAD SANTA CLARA, CA		
	PACIFIC SUN, INC. (415) 328-4588	DRAWING NUMBER	IMS-A

Figure B-13. Temperature Measurement Details
Oakmead Industries

DATE	SYM	REVISION RECORD	DR	CK

FLOW RATE INSTRUMENTATION

	NUMBER J-BOX	NUMBER SCAS	NAME	S/N	RANGE (GPM/CFM) MIN	RANGE DESIGN	RANGE MAX	LIQUID PIPE TYPE	FLOW PIPE SIZE	AIR FLOW DUCT DIMENSIONS (IN) L	W	T	MODEL NUMBER
32	W100		COLLECTOR LOOP FLOW RATE		7	50	70	CU	2-1/2				MKV-2-1/2
33	W155		SOUTHWALL AIR FLOW, EAST		0	1000	1500				16"ϕ		
34	W156		SOUTHWALL AIR FLOW, WEST		0	1000	1500				16"ϕ		
35	W200		CONTROL LOOP FLOW		7	50	70	CU	2-1/2				MKV-2-1/2
36	W201		TANK CHARGE / DISCHARGE FLOW		7	50	70	CU	2-1/2				MKV-2-1/2
37	W300		DHW MAKE-UP, TOTALIZER		0*		25	CU	1"				BADGER
38	W302		DHW HX FLOW RATE		1	2.5	10	CU	3/4"				MKV-3/4
39	W400		NORTH COIL FLOW		3.5	25	35	CU	1 1/2"				MKV-1-1/2
40	W401		SOUTH COIL FLOW		3.5	25	35	CU	1 1/2"				MKV-1-1/2
41	F400		NORTH AUX FURNACE NAT. GAS										AL425
42	F401		SOUTH AUX. FURNACE NAT. GAS										AL425

COMMENTS:

(1) Two inch (2") size flowmeters or less shall be preceded by a minimum of ten (10) diameters, followed by six (6) diameters of uninterrupted flow line and should not contain flexible lines.

Two and one-half inch (2-1/2") size flowmeters or larger shall be preceded by a minimum of twenty (20) diameters and followed by ten (10) diameters of uninterupted flow line and should not contain flexible lines.

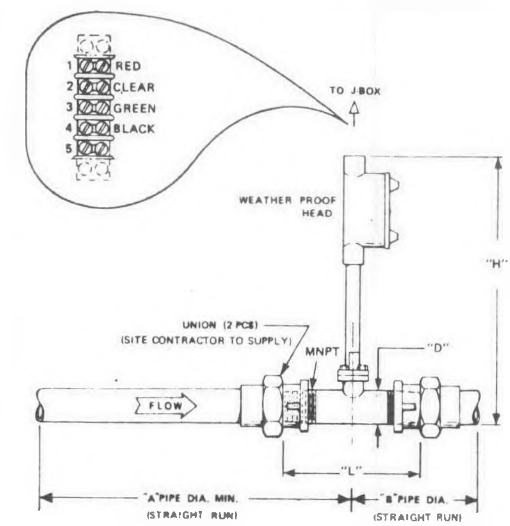
(2) Flowmeters shall be located in the horizontal position if possible.

(3) Material selection shall be galvanically compatible to the system design.

(4) Pipe thread sealing cumpound may be used on all pipe threads in accordance with local codes.

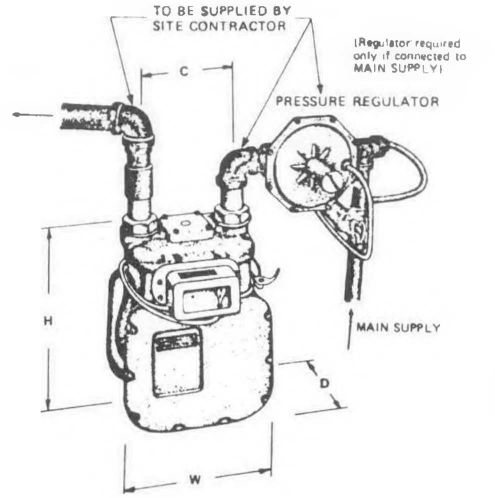
(5) Flowmeter by-pass (isolation) optional depending on the criticality of circuit and is required only if the system must be operational during flowmeter maintenance or repair. In areas where the fluid cannot be drained, isolation valves must be provided to prevent excessive loss of transport fluid.

(6) Standard conduit 1/2" - 14 NPT internal pipe threads. Installation optional unless required per local codes. Rigid conduit shall be terminated at the sensor end with flexible conduit.

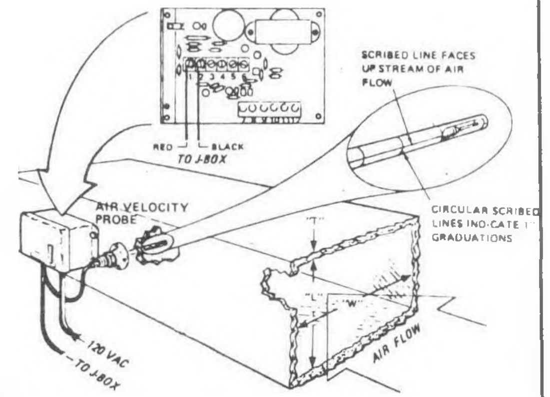


SMALL PIPE FLOWMETER DIMENSIONS

PIPE SIZE (IN)	"D" (IN)	"L" (IN)	"H" (IN)	MODEL NUMBER	PIPE STRAIGHT RUN LENGTH (UPSTREAM) ("A")	PIPE STRAIGHT RUN LENGTH (DOWNSTREAM) ("B")
1/2	.840	4.0	11.938	MKV-1/2	10	6
3/4	1.050	4.0	12.125	MKV-3/4	10	6
1	1.315	5.0	12.438	MKV-1	10	6
1 1/4	1.66	6.0	12.750	MKV-1 1/4	10	6
1-1/2	1.9	6.0	13.0	MKV-1-1/2	10	6
2	2.375	8.0	13.5	MKV-2	10	6
2-1/2	2.875	9.0	14.0	MKV-2-1/2	20	10
3	3.500	9.0	15.125	MKV-3	20	10

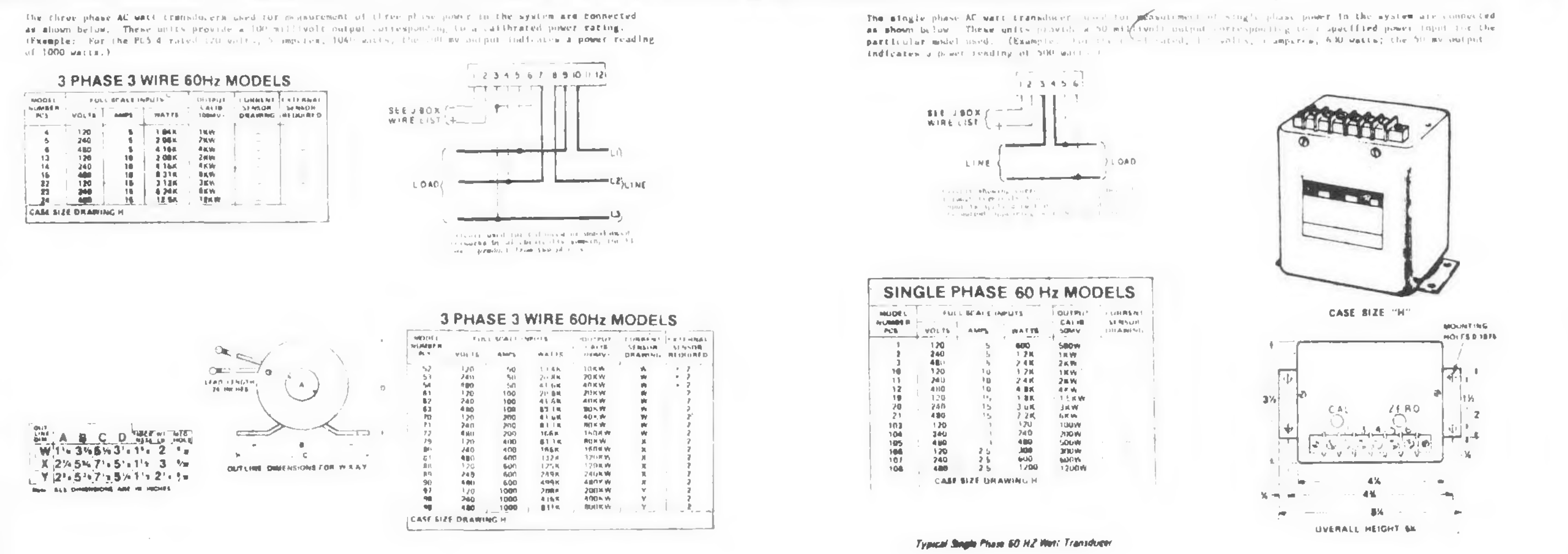


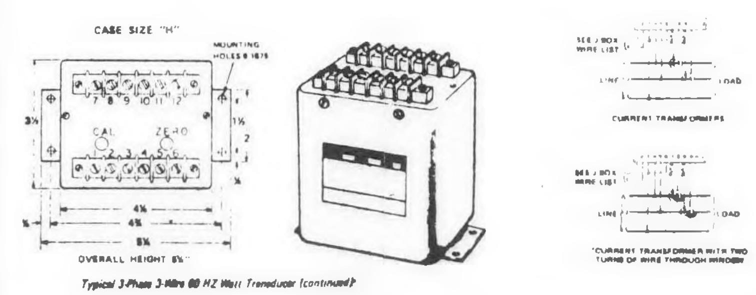
MODEL NO	MAX PRESS (PSIG)	CONNECTION PIPE	MC/PLG	DIMENSIONS C	D	E	H	S	W	INDEX TYPE	CAPACITY AT 1 2" H_2O (CFH)
AC 80	5	1/2		11 1/4	7		11		7/8	FRONT	80
AL 175	5	3/4	1 1/4 MC	6	7		11 3/4		8	FRONT	175
AC 175	5	3/4	1	6	7		11 3/4		8	FRONT	175
AL 250	5	3/4	1 1/4 MC	6	8 1/2		13 7/8		9 5/8	FRONT	250
AL 425	100 RJS		1 1/4	8 1/2	10		14 7/8		10 3/4	FRONT	425



POWER INSTRUMENTATION

NO.	DESIGNATION	NUMBER J-BOX	NUMBER SDAS	NAME (MEASUREMENTS)	PHASE	CONFIGURATION 3 OR 4 WIRE	FULL SCALE INPUTS VOLTS	AMPS	POWER (KW)	MODEL
43	EP100			COLLECTOR PUMP POWER P1	3	3	240	4	1.0	PC5-5
44	EP101			HEAT DUMP BLOWER POWER	3	3	240	3	.75	PC5-5
45	EP200			CONTROL LOOP PUMP POWER, P3	3	3	240	3	.75	PC5-5
46	EP301			DHW HEAT EXCHANGER PUMP, P4	1	2	120	2	.25	PC5-106
47	EP400			HEATING COIL CIRCULATING PUMP, P2	3	3	240	3	.75	PC5-5
48	EP600			NORTH PERIMETER AHU	3		TO BE DETERMINED			
49	EP601			SOUTH PERIMETER AHU	3		TO BE DETERMINED			
50	EP302			DHW BACK-UP TANK ELEMENT	3	3	240	75	18	PC5-62





Typical 3-Phase 3-Wire 60 HZ Watt Transducer (continued)

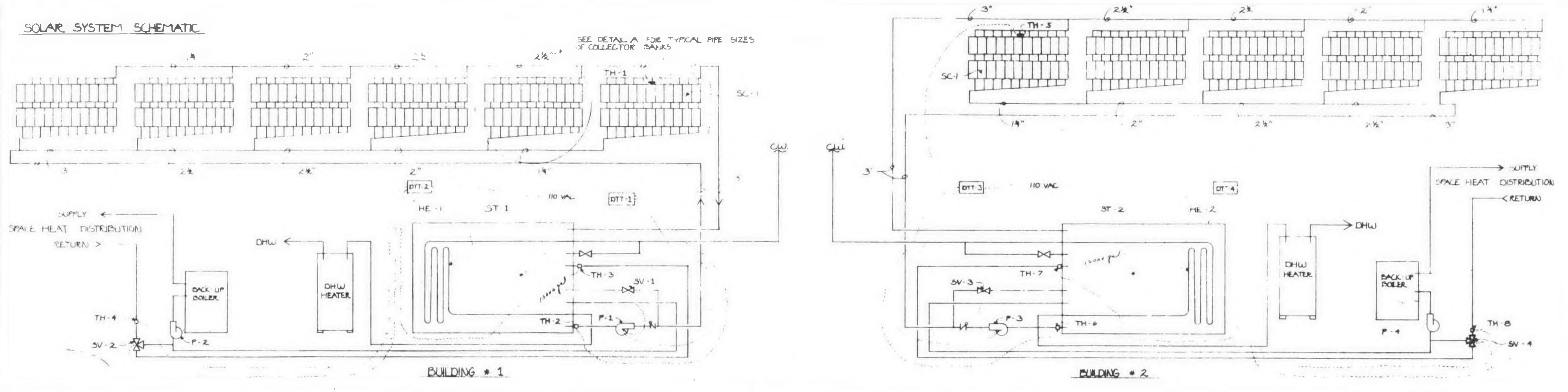
SPECIAL INSTRUMENTATION

NO.	DESIGNATION	NUMBER J-BOX	NUMBER SDAS	NAME (MEASUREMENTS)	MODEL NO.	COMMENTS	
51	I001			TOTAL RADIATION	PSP	COLLECTORS, 45° TILT	SEE IMS-3,4
52	I002			SOUTHWALL TOTAL RADIATION	PSP	SOUTHWALL, VERTICAL PLANE	SEE IMS-9
53	V001			WIND VELOCITY	SINGLE UNIT W101-P-DC/540	SEE IMS-10	
54	D001			WIND DIRECTION			

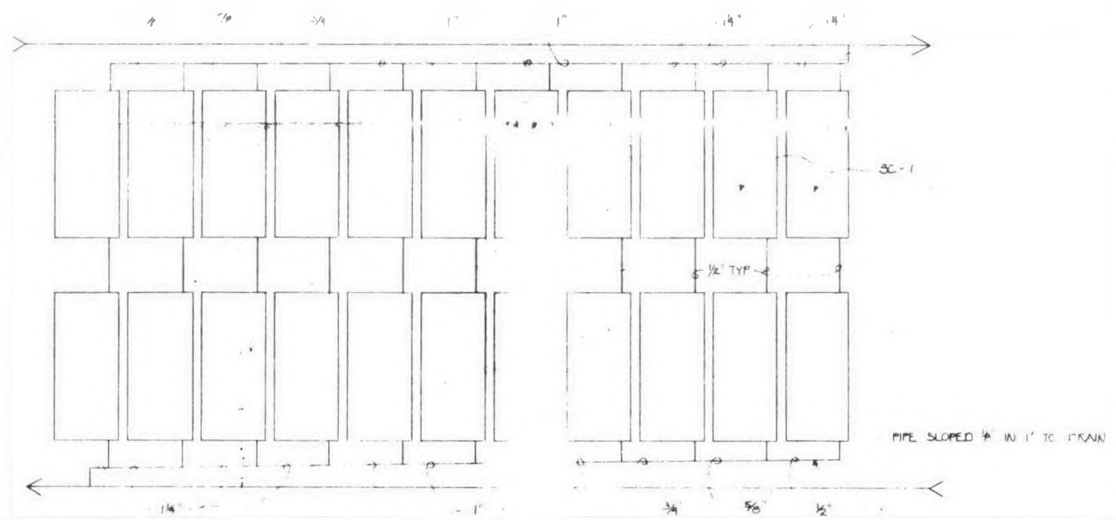
TOLERANCES (EXCEPT AS NOTED)	FLOWRATE, POWER AND SPECIAL INSTRUMENTATION DETAILS		
DECIMAL	SCALE AS SHOWN	APPROVED BY	DRAWN BY MAK
FRACTIONAL	DATE 6/28/78		
ANGULAR	RENAULT & HANDLEY SOLAR BLDG #2 OAKMEAD, SANTA CLARA, CA		
	PACIFIC SUN, INC. (415) 328-4588		IMS-B

Figure B-14. Flow Rate, Power and Special Instrumentation Details Oakmead Industries

SOLAR SYSTEM SCHEMATIC



DETAIL A



EQUIPMENT SCHEDULE

SC-1, SOLAR COLLECTORS

SOLERA #3492 TYPE C COLLECTORS, ALUMINUM MILL FINISH
BUILDING NO. 1, TO HAVE 132 COLLECTORS
BUILDING NO. 2, TO HAVE 110 COLLECTORS

ST-1, ST-2, STORAGE TANKS

NEVADA TANK AND CASING CYLINDRICAL WARM WATER STORAGE TANKS LINED WITH FARBERTITE COAL TAR EMULSION
ST-1 TO BE 95" DIA. x 304" 12000 GAL. STEEL TANK
ST-2 TO BE 95" DIA. x 327" 10000 GAL. STEEL TANK
EACH TANK TO BE INSULATED ON SITE WITH SPRAY ON POLYURETHANE FOAM TO A THICKNESS EQUIVALENT TO R-25.

HE-1, HE-2 HEAT EXCHANGERS

WATER TO WATER COPPER TUBE HEAT EXCHANGERS TO BE SPECIFIED WHEN OCCUPANCY LEVEL OF BUILDING IS ESTABLISHED.

P-1, P-3, SOLAR PUMPS

BELL & GOSSETT CENTRIFUGAL PUMPS, MODEL 1531 2AB 8½" BRONZE FITTED PUMP WITH 2HP, 230/460 VAC, 1750 RPM MOTOR.

P-2, P-4, DISTRIBUTION PUMPS

SPACE HEATING SYSTEM CIRCULATING PUMPS. TO BE SPECIFIED WHEN HEATING SYSTEM FINALIZED

DTT-1, DTT-2, DTT-3, DTT-4, DIFFERENTIAL TEMPERATURE THERMOSTATS

HAMPSHIRE CONTROLS CORPORATION, TEMTITE 224 DIFFERENTIAL TEMPERATURE CONTROLS

TH-1, TH-2, TH-3, TH-4, TH-5, TH-6, TH-7, TH-8, THERMISTORS

HAMPSHIRE CONTROLS CORPORATION, TT300 SENSOR PROBES
TH-2, TH-3, TH-6, TH-5 TO BE LOW TEMPERATURE SENSORS
TH-1, TH-4, TH-5, TH-8 TO BE HIGH TEMPERATURE SENSORS

SV-1, SV-2, SV-3, SV-4, SOLENOID VALVES

SV-1, AND SV-3 TO BE HYDRO-RAIN MODEL 101-2FC NORMALLY OPEN ELECTRIC VALVE WITH FLOW CONTROL AND 24 VAC SOLENOID.
SV-2 AND SV-4 TO BE HYDRO-RAIN 102 SERIES 3-WAY ELECTRIC VALVE WITH FLOW CONTROL AND 24 VAC SOLENOIDS.
EXACT SIZE TO BE SPECIFIED WHEN HEATING SYSTEM IS FINALIZED.

INSTALLATION NOTES

SOLAR CONTROL SYSTEM

DIFFERENTIAL THERMOSTATS, PUMPS, AND SOLENOID VALVES FOR EACH SOLAR SYSTEM TO BE MOUNTED IN RESPECTIVE SYSTEMS MECHANICAL ROOM. THERMISTORS TH-1 AND TH-5 TO BE MOUNTED ON SOLAR COLLECTOR AS CLOSE TO RUBBER GROMMET [illegible] STORAGE TANK TO SOLAR COLLECTORS AS CLOSE TO TANK AS IS POSSIBLE. THERMISTORS TH-3 AND TH-7 TO BE MOUNTED ON PIPE LEAVING STORAGE TANK TO SPACE HEAT CIRCULATING SYSTEM AS CLOSE TO STORAGE TANK AS IS POSSIBLE. THERMISTORS TH-4 AND TH-8 TO BE MOUNTED ON SPACE HEATING CIRCULATING SYSTEM RETURN PIPE IN MECHANICAL ROOM. ALL THERMISTORS TO BE WRAPPED WITH INSULATION AND WATERPROOF TAPE.

PIPING NOTES

USE COPPER PIPE THROUGHOUT. ALL COPPER PIPE TO BE INSULATED WITH 3/4" JACKET TYPE INSULATION OR EQUIVALENT. ALL JOINTS TO BE SWEAT SOLDERED.

SOLAR COLLECTOR MOUNTING

SOLAR COLLECTORS TO BE MOUNTED TO REDWOOD RUNNERS WITH NO. 8 x 3/4" ROUND HEAD WOOD SCREWS AS PER FLANGE ON SOLAR COLLECTOR FRAME.

john brooks boyd associates

BUILDINGS FOR
RENAULT & HANDLEY — 2500 EL CAMINO — PALO ALTO, CALIF.
OAKMEAD VILLAGE — SCOTT BLVD. — SANTA CLARA, CALIF.

SCALE: NONE
DATE: NOV 2, '76

SOLAR · MECHANICAL SYSTEM

SHEET SM 1
1 OF 5

Figure B-15. Solar Mechanical System Drawing #1
Oakmead Industries

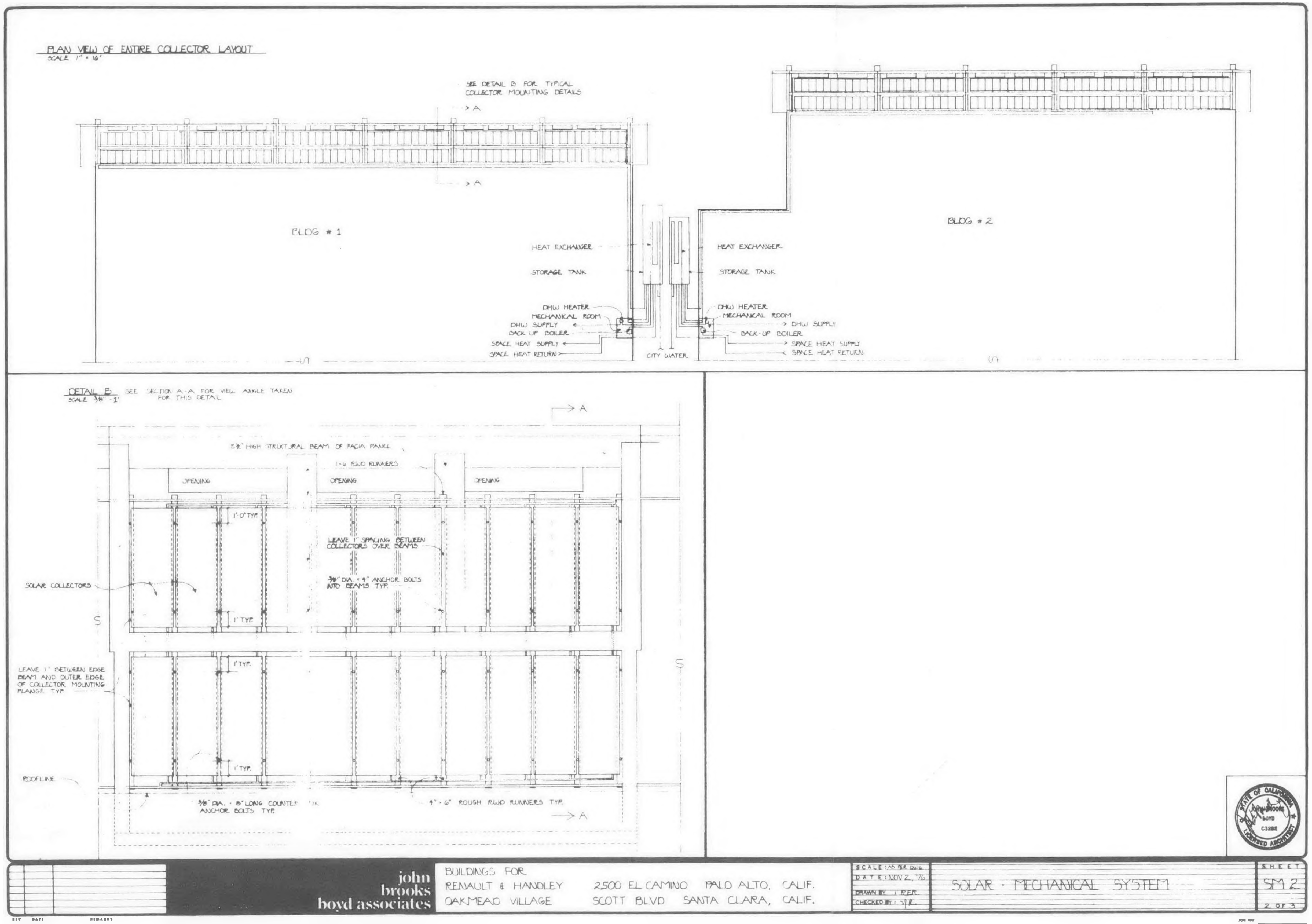
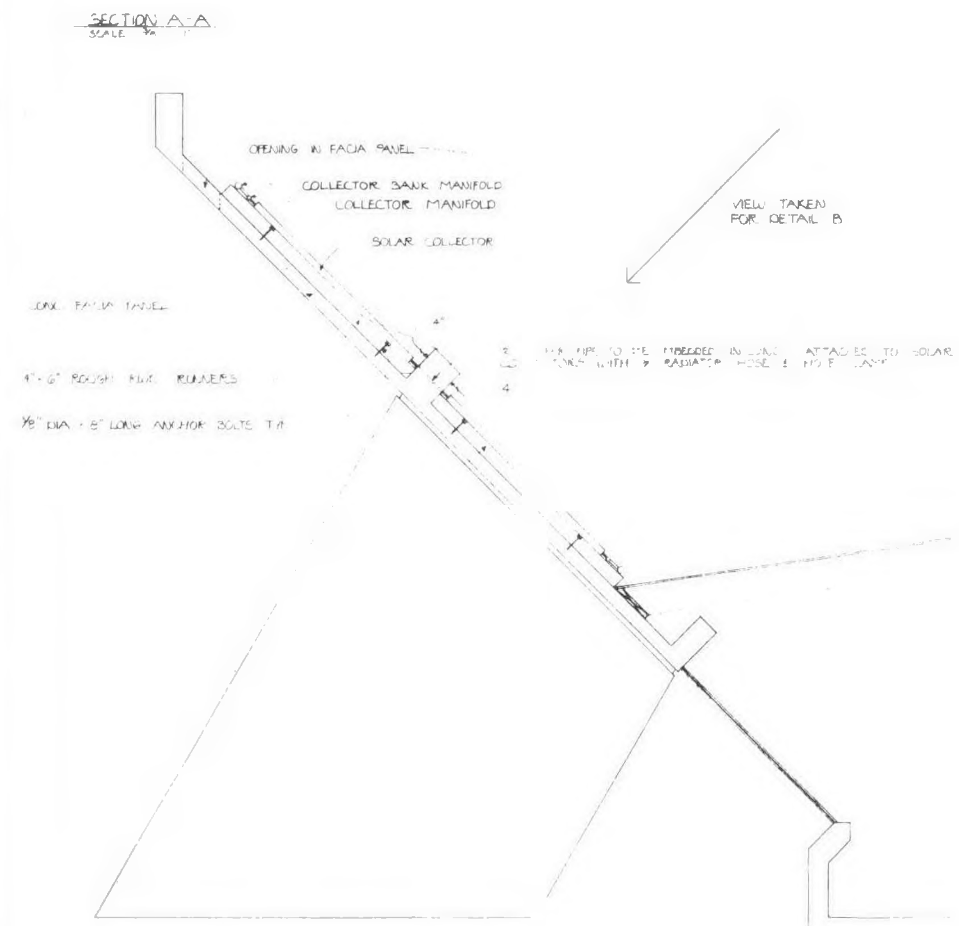


Figure B-16. Solar Mechanical System
Drawing #2
Oakmead Industries



HVAC SYSTEM

WALLIS MECHANICAL ENGINEERING
1775 So. 1st St. Bldg. 66
San Jose, California 95112
408*288-8770

HEATING, VENTILATING AND AIR CONDITIONING

DESIGN CONSIDERATIONS

These major considerations were involved in the configuration selected for heating, ventilating and air conditioning this project:

1. Provision must be made for maximum utilization of available solar energy without resorting to reheat cycles or contrived "tack on" configurations.
2. System must permit maximum flexibility of internal arrangement to accomodate modification of tenant's processes without major redesign.
3. Cost of system must not exceed conventional systems for this class of construction by any significant sum.
4. Owning cost of system must be consistant with other systems in this class of construction.
5. Solar energy utilization cannot be advanced to the detriment of other energy conserving design features.

H.V.A.C. - SYSTEM CONFIGURATION

System shall consist of a modular arrangement of roof top package air conditioning units with an energy efficiency rating (A.R.I.) of 7.8 or better. Each unit will be rated 90,000 BTUH total cooling. Units will be equipped with multi-row low pressure drop 67.5MBH hot water heating coil and economizer cycle. Unit zone size will be ± 2700 square feet.

Heating hot water will be circulated to unit coils from solar storage tank. Solar heat will be backed up with a gas/oil fired boiler, 1,125MBH for Building No. 1, 1,500 MBH for Building No. 2, boilers selected for low standby loss and conversion efficiency above 80%. Water circulating pumps will be selected so that horsepower is proportional to water flow.

Units along South wall will obtain preheated ventilation air from the air solar energy system, as required.

H.V.A.C. - SYSTEM CONTROL

Each zone/module shall have two modes of control, occupied and unoccupied. When lights in a zone are off, unit fan will be cycled under control of a night setback thermostat, with no outside air introduced. When zone lights are on, fan will operate continuously with thermostat controlling heating, "economy" cycle and cooling in accordance with zone demand.

Hot water will be circulated in response to zone demand, with backup boiler brought on line upon depletion of stored heat.

At South zones, air from air solar heat recovery system will be utilized to the maximum extent available before demand is placed on hot water system.

H.V.A.C. - MODULAR SYSTEM ADVANTAGES

1. Simplified duct work permits lower fan horsepower, lower duct work cost.
2. Discrete zones permit maximum advantage to be taken of diversity of load, eliminate need for reheat, and reduce impact of individual unit failure.
3. Discrete zones make partial building utilization move economical.
4. Maximum use is made of economy cycle through ability to respond to individual zone requirements.

john brooks boyd associates

BUILDINGS FOR
RENAULT & HANDLEY — 2500 EL CAMINO — PALO ALTO, CALIF.
OAKMEAD VILLAGE — SCOTT BLVD. — SANTA CLARA, CALIF.

SCALE
DATE NOV 2
DRAWN BY R.E.R.
CHECKED BY

SOLAR · MECHANICAL SYSTEM

SHEET SM3
3 OF 3

REV DATE REMARKS

Figure B-17. Solar Mechanical System
Drawing #3
Oakmead Industries

APPENDIX C

SOLAR TERMINOLOGY

APPENDIX C

SOLAR TERMINOLOGY

Absorptivity	The ratio of radiation absorbed by a surface to the total radiated energy incident on that surface.
Active Solar System	A system in which a transfer fluid (liquid or air) is circulated (by pump or fan) through a solar collector.
Air Conditioning	Popularly defined as space cooling; more precisely, the process of treating indoor air by controlling the temperature, humidity, and distribution to maintain specified comfort conditions.
Ambient Temperature	The surrounding air temperature.
Array	An assembly of a number of collector elements, or panels, into the solar collector for a solar energy system.
Auxiliary Energy	In solar energy terminology, the energy supplied to the heating or cooling load from other than the solar source, usually from a conventional heating or cooling system. Excluded are operating energy, and energy which may be supplemental in nature but does not have the auxiliary system as an origin; e.g., energy supplied to the space heating load from the external environment by a heat pump.
Auxiliary Energy Subsystem	In solar energy terminology, the auxiliary energy system is the conventional heating and/or cooling equipment used as a supplement or backup to the solar system.
Backflow	Reverse flow.
Backflow Preventer	A valve or damper installed in a pipe or duct to prevent reverse flow of the fluid.
Beam Radiation	Radiated energy received directly, not from scattering or reflecting sources.

Collected Solar Energy	The thermal energy added to the heat transfer fluid by the solar collector.
Collection Subsystem	The assembly of components that absorbs incident solar energy and transfers the absorbed thermal energy to a heat transfer fluid.
Collector Array Efficiency	Same as Collector Conversion Efficiency. Ratio of the collected solar energy to the incident solar energy. (See also Operational Collector Efficiency.)
Collector Conversion Efficiency	Ratio of thermal energy output to solar energy incident on the collector array.
Concentrating Solar Collector	A solar collector that concentrates the energy from a larger area onto an absorbing element of smaller area.
Conditioned Space	The space in a building in which the air is heated or cooled to maintain a desired temperature range.
Control System or Subsystem	The assembly of electric, pneumatic, or hydraulic, sensing, and actuating devices used to control the operating equipment in a system.
Cooling Degree-Days	The sum over a specified period of time of the number of degrees the mean daily temperature is <u>above</u> 65°F.
Cooling Tower	A heat exchanger that transfers waste heat to outside ambient air.
Diffuse Radiation	Solar radiation which is scattered by air molecules, dust, or water droplets and incapable of being focused.
Drainback	Automatic draining of the collector array and piping to storage each time the collector pump shuts off.
Draindown	A system equipped with automatic or manual valves which drain the solar collectors and collector piping to prevent freezing in the event of cold weather.

Duct Heating Coil	A liquid-to-air heat exchanger in the duct distribution system.
Effective Heat Transfer Coefficient	The heat transfer coefficient, per unit plate area of a collector, which is a measure of the total heat losses per unit area from all sides, top, back, and edges.
Energy Gain	The thermal energy gained by the collector transfer fluid. The thermal energy output of the collector.
Energy Savings	The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.
Expansion Tank	A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as the system heat transfer fluid expands and contracts to prevent excessive pressure from developing and causing damage.
F-Chart	A computer program developed by the University of Wisconsin Solar Energy Laboratory, which calculates solar heating system performance and economics.
Fixed Collector	A solar collector that is fixed in position and cannot be rotated to follow the sun daily or seasonably.
Flat-Plate Collector	A solar energy collecting device consisting of a relatively thin panel of absorbing material. A container with insulated bottom and sides and covered with one or more covers transparent to visible solar energy and relatively opaque to infrared energy. Visible energy from the sun enters through the transparent cover and raises the temperature of the absorbing panel. The infrared energy reradiated from the panel is trapped within the collector

Flat-Plate Collector (Continued)	because it cannot pass through the cover. Glass is an effective cover material (see Selective Surface).
Focusing Collector	A concentrating type collector using parabolic mirrors or optical lenses to focus the energy from a large area onto a small absorbing area.
Fossil Fuel	Petroleum, coal, and natural gas derived fuels.
Glazing	In solar energy terminology, the transparent covers used to reduce energy losses from a collector panel.
Heat Exchanger	A device used to transfer energy from one heat transfer fluid to another while maintaining physical segregation of the fluids. Normally used in systems to provide an interface between two different heat transfer fluids.
Heat Transfer Fluid	The fluid circulated through a heat source (solar collector) or heat exchanger that transports the thermal energy by virtue of its temperature.
Heating Degree-Days	The sum over a specified period of time of the number of degrees the mean daily temperature is <u>below</u> 65^{o}F.
Incidence Angle	The angle between the line to a radiating source (the sun) and a line normal to the plane of the surface being irradiated.
Incident Solar Energy	The amount of solar energy irradiating a surface taking into account the angle of incidence. The effective area receiving energy is the product of the area of the surface times the cosine of the angle of incidence.
Insolation	Incoming solar radiation
Instantaneous Efficiency	The efficiency of a solar collector at one operating point, $\frac{Ti - Ta}{I}$, under steady-state conditions (see Operating Point).

Instantaneous Efficiency Curve	A plot of solar collector efficiency against operating point, $\frac{Ti - Ta}{I}$, (see Operating Point).
Load	That to which energy is supplied, such as space heating load or cooling load. The system load is the total solar and auxiliary energy required to satisfy the heating or cooling requirements.
Manifold	The piping that distributes the transport fluid to and from the individual panels of a collector array.
Microclimate	Highly localized weather features which may differ from long-term regional values due to the interaction of the local earth's surface with the atmosphere.
Nocturnal Radiation	The loss of thermal energy by the solar collector to the night sky.
Operating Energy	The amount of energy (usually electrical energy) required to operate the solar and auxiliary equipments and to transport the thermal energy to the point of use, and which is not intended to directly affect the thermal state of the system.
Operating Point	A solar energy system has a dynamic operating range due to changes in level of insolation (I), fluid input temperature (Ti), and outside ambient temperature (Ta). The operating point is defined as: $\frac{Ti - Ta}{I} \left(\frac{{}^{o}F \times hr \times ft^2}{BTU}\right)$
Operational Collector Efficiency	Ratio of collected solar energy to incident solar energy <u>only during the time the collector fluid is being circulated with the intention of delivering solar-source energy to the system.</u>
Outgassing	The emission of gas by materials and components, usually during exposure to elevated temperature, or reduced pressure.

Passive Solar System	A system which uses architectural components of the building to collect, distribute, and store solar energy.
Pebble Bed (Rock Bed)	A space filled with uniform-sized pebbles to store solar-source energy by raising the temperature of the pebbles.
Reflected Radiation	Insolation reflected from a surface, such as the ground or a reflecting element, onto the solar collector.
Rejected Energy	Energy intentionally rejected, dissipated, or dumped from the solar system.
Retrofit	The addition of a solar energy system to an existing structure.
Selective Surface	A surface that has the ability to readily absorb solar radiation, but reradiates little of it as thermal radiation.
Sensor	A device used to monitor a physical parameter of a system, such as temperature or flow rate, for the purpose of measurement or control.
Solar Conditioned Space	The area in a building that depends on solar energy to provide a fraction of the heating and cooling needs.
Solar Fraction	The fraction of the total load supplied by solar energy. The ratio of solar energy supplied to loads divided by total load. Often expressed as a percentage.
Solar Savings Ratio	The ratio of the solar energy supplied to the load minus the solar system operating energy, divided by the system load.
Storage Efficiency, η_s	Measure of effectiveness of transfer of energy through the storage subsystem taking into account system losses.
Storage Subsystem	The assembly of components used to store solar-source energy for use during periods of low insolation.

Stratification	A phenomenon that causes a distinct thermal gradient in a heat transfer fluid, in contrast to a thermally homogeneous fluid which results in the layering of the heat transfer fluid, with each layer at a different temperature. In solar energy systems, stratification can occur in liquid storage tanks or rock beds, and may even occur in pipes and ducts. The temperature gradient or layering may occur in a horizontal, vertical, or radial direction.
System Performance Factor	Ratio of system load to the total equivalent fossil energy expended or required to support the system load.
Ton of Refrigeration	The heat equivalent to the melting of one ton (2,000 pounds) of ice at 32°F in 24 hours. A ton of refrigeration will absorb 12,000 BTU/hr, or 288,000 BTU/day.
Tracking Collector	A solar collector that moves to point in the direction of the sun.
Zone	A portion of a conditioned space that is controlled to meet heating or cooling requirements separately from the other space or other zones.

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