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DOE/CS/4048-2

WEST CHESTER WORK CENTER CONSTRUCTION REPORT

MASTER

May 1979

Work Performed Under Contract No. EY-76-C-02-4048

Bell Telephone Company of Pennsylvania
Philadelphia, Pennsylvania

U.S. Department of Energy

Solar Energy

DISCLAIMER

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West Chester Work Center
Solar Space Heating Demonstration Project

Under Contract No. EY-76-C-02-4048

Construction Report
May 1979

Bell Telephone Company of Pennsylvania
One Parkway
Philadelphia, Pennsylvania 19102

Prepared for
U.S. Department of Energy

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ABSTRACT

This document reports on the construction stage of a solar space heating demonstration project. It describes an integrated system providing solar energy space heating for a 9982 sq. ft., newly built, one-story building. The building is located at 966 Matlack Street, West Goshen Township, Chester County, Pennsylvania. Functionally, the building consists of two sections: An Office and a Storeroom. The Office section is heated by solar-assisted water-to-air heat pump units. The Storeroom section is heated by an air-handling unit, containing a water-to-air coil. Solar energy is expected to provide 62% of the heating load, with the balance provided by a back-up electric boiler. The system includes 1900 active (2112 gross) square feet of flat-plate solar collectors, and a 6000 gallon above-ground indoor storage tank. Freeze protection is provided by a gravity drain-down scheme combined with nitrogen pressurization in a closed circuit.

The major subcontractors for the installation of this system were selected in July-August, 1976. After several schedule revisions, the installation was completed and the project was dedicated officially on October 25, 1977. Cost over-runs, which amounted to 45.6% above the estimate, can be attributed mainly to the fact that this was the first solar project experience for everyone involved.

1.0 INTRODUCTION

In June, 1976, the generic design of the solar space heating system for the West Chester Work Center was completed by InterTechnology Corporation (ITC) as part of their "Solar Heating & Cooling of Buildings - Phase I" contract with the U.S. Energy Research and Development Administration (ERDA). The basic scheme for building heating and the sizing of the solar components was optimized by ITC and presented by ERDA to Bell of Pennsylvania in a package consisting of generic drawings and specifications. Those drawings were included as Appendix A of Reference 6.1.

The solar heated building is one of two buildings situated on a five acre lot (Figure 1). It is T-shaped (Figure 2) with one axis running south to north. It consists of an Office section at the top of the T and a Storeroom section at the stem of the T. The building is used as the home base for telephone installers, repairmen and construction workers.

To maximize collection efficiency, the solar energy collection scheme selected by ITC was an open, gravity drain-down system rather than one using a glycol antifreeze solution in conjunction with a heat exchanger. With ERDA's concurrence, Bell of Pennsylvania modified the generic design to render the system pressurized instead of open. The reasons for the modifications are detailed in Section 3.0 of Reference 6.1. The generic drawings and specifications were revised to reflect engineering changes and additional detailing necessary for guidance of the HVAC subcontractor in the proper installation ofthe system as designed. The drawings used for construction of this project are included in Appendix A.

The major modifications to the generic design involved the addition of a separate holding tank (300 gallon capacity), to contain the nitrogen used for pressurizing the solar collection loop. This tank also serves as the container for water which is drained out of the collector and associated piping. The addition of the holding tank necessitated additional controls to provide for refilling the collectors prior to resumption of normal solar energy collection and storage.

Although this report is dated May, 1979, its contents apply only to work done through October, 1977, when the solar space heating system was placed in operation for the first time.

2.0 SYSTEM DESCRIPTION

2.1. Design Scheme:

The design drawings for this system are included in Appendix A. The main features of the system design are:

2.1.1. The Office section of the building (approximately 145 ft. X 43 ft.) is heated in the winter and cooled in the summer by 20 unitary heat pumps.

2.1.2. The Storeroom section of the building (approximately 82 ft. X 43 ft.) is heated by a conventional fan-coil unit which uses solar heated water, backed up by an electrical boiler as needed.

2.1.3. The heat source for the heat pumps during the heating season is water heated by solar energy, backed up by an electrical boiler as needed.

2.1.4. The heat sink for the heat pumps during the cooling season is water cooled by passing through a closed-circuit cooling tower.

2.1.5. The solar array consists of eighty-eight flat plate collector panels, arranged in two equal rows. The gross area is 2112 sq. ft. and the effective collection area is 1900 sq. ft. The panels are installed facing true South, tilted at 55° from horizontal.

2.1.6. Thermal energy storage is provided by a 6000 gallon capacity tank, installed above ground in the mechanical room.

2.1.7. Auxiliary heat is provided by an 80 kilowatt electric boiler, incorporating five elements of 16 kilowatts each.

2.1.8. Heat rejection during the cooling season is provided by a cooling tower located in the mechanical room, connected with outside air intake and discharge ducting.

2.2. System Components

Figure (3) is a simplified flow diagram of the solar heating system. There are three main loops which are built around the 6000 gallon water storage tank:

2.2.1. The solar collection loop circulates storage water through the collector panels, using the "Solar water pump". The 300 gallon "Holding tank" is used to store a mixture of nitrogen and water. In the solar collection mode of operation, most of the nitrogen will be in the holding tank. In the drain-down mode, water drained from the collectors and piping above the roof line will be in the holding tank. Prior to resumption of solar collection, this water is transferred to the collectors by the activation of the "Refill pump".

2.2.2. The Office heating loop circulates storage water through twenty water-to-air "Heat pump units", using the "HP units pump". During periods when the storage water temperature is below 70°F, the temperature of water fed to the heat pump units is regulated by a mixing valve which mixes water heated by the electric boiler with storage water to produce the 70°F minimum temperature required. The "Cooling tower" is activated during the cooling season to dissipate heat removed from the office space by the heat pumps.

2.2.3. The Storeroom heating loop circulates storage water through the "Fan-coil unit", using the "AHU pump". An auxiliary branch off this loop is used to supply hot water to four "forced flow heaters "FFH" located in the corridors of the office section at each entrance to the building, using the "FFH pump". The "Electric boiler" which straddles this loop is activated only when the water temperature leaving the boiler is below 105°F.

2.3 System Controls

Drawing M-5, Appendix A, describes the operation of the system controls, which consist of the following major elements:

2.3.1. Differential Temperature Controller: This is used to initiate the sequence for collection of solar energy whenever it senses a set temperature differential of 18°F between a typical absorber plate and water stored in the main tank. It will also act to shut down the solar water pump whenever the temperature differential drops below 3°F.

2.3.2. Four float switches: These are located just above the solar collectors and serve to shut down the refill pump and activate the solar water pump when they sense that all collectors have been refilled.

2.3.3. Low limit temperature sensor: Attached to a typical absorber plate, this sensor will act to initiate a drain cycle of the water to the holding tank whenever it senses a temperature below 40°F.

2.3.4. High limit temperature sensor: this sensor is located within the storage tank and acts to stop the collection of solar energy whenever it senses a temperature above 190°F.

2.3.5. Heat pump loop temperature sensor: This sensor acts to position an automatic valve that mixes heated water with return water, so that the temperature of the water supplied to the heat pump units is controlled at 70°F.

2.3.6. Heat pump units controls: Each of these units has its own integral thermostat to permit setting by the occupant of each office as desired.

2.3.7. Storeroom temperature controller: This is a wall-mounted thermostat used to position a three-way valve which supplies water to the coil in the air handling unit. It is also used to position outside air and return air dampers according to the season of the year.

2.3.8. Forced-flow heaters controls: Each forced-flow heater, used to heat the corridors of the building, is controlled by a wall-mounted thermostat which positions a three-way valve to provide the required flow of hot water to the unit.

2.4. Performance Monitoring

In consultation with IBM-Huntsville, the instrumentation required to monitor the performance of the system, in accordance with ERDA's document "SHC-1006: Instrumentation Installation Guidelines", was selected and incorporated into the design drawings. A list of the instrumentation appears in Table (1).

In addition to the ERDA instrumentation, Bell installed a parallel readout for 30 temperature measurements using thermocouples connected to "Series 400A Trendicators" manufactured by Doric Scientific Division of Emerson Electric Company.

3.0 CONSTRUCTION PROCEDURE

3.1 Consulting Engineering

Due to the need for an integrating contractor for this solar project, Bell of Pennsylvania commissioned Golz and Wick, Consulting Engineers of Philadelphia to do the following:

3.1.1. Modify and amplify the generic drawings and specifications.

3.1.2. Check the shop drawings.

3.1.3. Supervise the installation.

3.1.4. Prepare an operating and maintence manual.

3.1.5. Perform other related work as necessary for the successful completion of the project.

3.2. Construction Subcontracting:

The construction schedule for this building required that "Invitations to Bid" be issued by June 9, 1976, which was only a few days after receipt of the generic drawings. Knowing that the solar system drawings and specifications would undergo some significant changes, Bell of Pennslyvania decided to accept bids on the solar system on the basis of "Time and material", with a "Not-to-exceed" total sum. Each of six mechanical contract invitees was directed to state in his bid, the percentage factor for overhead and profit and his "Not-to-exceed" figure.

On July 2, 1976, the sealed bids were opened. The "Not-to-exceed" total sum ranged between $145,000 and $215,000 and the overhead and profit mark-up ranged between 6% and 15%. There was a discrepancy among the various bids in that the bid with the lowest mark-up was associated with the highest "Not-to-exceed" figure. Bell of Pennsylvania, reasoning that all bidders are equally capable of providing the labor and materials for approximately the same cost, decided to award the subcontract to the bidder with the lowest overhead and profit mark-up regardless of his high "Not-to-exceed" figure. Besides, this bidder, Hummel

Engineering Corporation, had a reputation of doing high quality work.

After Hummel Engineering was notified of being selected as the subcontractor for the solar system, the drawings and specifications were finalized and a solar collector panel manufactured by Heliotherm, Inc., was selected. The subcontractor was then asked to provide a breakdown of his estimated cost of various components of the system. This breakdown is listed in Table (2).

3.3. Project Cost Estimation

In negotiating the contract with ERDA, Bell of Pa. submitted the following cost estimate:

Total HVAC system estimated cost based on Table (2) breakdown	$201,300
Add 5% General Contractor's mark-up	10,065
Electric power wiring and conduit	29,700
Extra structural roof supports	11,000
Integrating contractor's fee	12,000
Service manual preparation	4,000
In-house engineering effort	5,000
Display board and brochures	5,000
Report preparation	9,000
Total	$287,065
Less cost of a conventional system	60,450
Incremental cost	$226,615

ERDA indicated a desire to award the contract to Bell on the basis of a fixed lump sum. At that time, it appeared that the financial risk to Bell by following that procedure was not great, in view of the "Not-to-exceed" protection incorporated into Bell's "Cost plus" subcontract with Hummel Engineering. The final outcome was that Bell had to bear the entire burden of a considerable cost over-run, which was necessitated by modification to the design and specifications undertaken during construction.

The contract between ERDA and Bell of Pennsylvania which was executed on September 30, 1976, was for a total sum of $201,429.00, being ERDA's share of the cost of this project.

3.4 Contract Data

Two main contracts were executed by Bell of Pennsylvania in connection with this project:

3.4.1. With Golz and Wick - Consulting Engineers
Architects Building
Philadelphia, Pa, 19103
Telephone: (215) 568-0661

This contract, dated June 28, 1976, commissioned Golz and Wick to provide engineering services in their capacity as the Integrating Contractor. Payment for these services were to be based on 2.5 times the payroll rate of technical employees involved, plus expenses for transportation, reproduction and postage without markup.

3.4.2 With R. Ranieri - General Contractor
One Maple Avenue
Hatboro, Pa., 19040
Telephone: (215) 672-1020
who, at Bell of Pennsylvania's direction, engaged:

Hummel Engineering Corporation-HVAC Subcontractor
1418 S. Front Street
Philadelphia, Pa., 19147
Telephone: (215) 468-8000

By this contract, dated January 10, 1977, the above parties agreed to furnish all labor and materials required for the installation of the heating ventilating and air conditioning system, including the solar heating portion. Payment for these services was to be based on cost plus a fixed fee of 6%, not to exceed

$202,046* to Hummel Engineering. With the addition of 5% fee due R. Ranieri, the guaranteed not to exceed cost was specified as $212,148.

3.5. Major Suppliers

Following is a summary list of major suppliers of various equipment and services on this project:

Architects	The Wright/Klett Association 433 York Road Jenkintown, Pa, 19046
Generic System Designer	InterTechnology Corporation 100 Main St. Warrenton, Virginia, 22186
Structural Engineers	Long & Tann, Inc. 115 S. 21 Street Philadelphia, Pa, 19103
Integrating Contractors	Golz & Wick Architects Building Philadelphia, Pa, 19103
General Contractor	R. Ranieri One Maple Avenue Hatboro, Pa, 19040
Mechanical Contractor	Hummel Engineering Corporation 1418 S. Front St. Philadelphia, Pa., 19147
Solar Collector Supplier	Heliotherm, Inc Lenni, Pa., 19052
Automatic Controls Supplier	Honeywell, Inc. P.O. Box 916 Valley Forge, Pa., 19481

* The excess of this figure over the sum of Table (2) is for four spare solar panels.

Heat Pumps Units	Walsh and Curley (Distributors for the Singer Co.) 42 Cassatt Ave. Berwyn, Pa, 19312
Thermal Storage Tanks	Adamson Co., Inc. 7 East 16th Street Richmond, Virginia, 23224
Panel Supports	Fisher Steel, Inc. W. Browning Road and Railroad Ave. Bellmawr, N.J., 08030

3.6. Schedules

Construction of the West Chester Work Center was started on August 13, 1976 and was initially projected for completion by December 31, 1976. It was soon realized that it was unrealistic to expect the solar heating system to be in operation in such a short time, because of the lead time needed for final selection of all the solar system components and the usual delays in delivery. What was thought to be a realistic schedule was developed in November, 1976, calling for completion of the building construction by March 15, 1977 and the solar heating system by April 15, 1977. Although the building was actually occupied by employees in late April, the completion of the solar heating system was not accomplished until October, 1977. Some of the reasons for the schedule slippage were:

3.6.1. Bad weather in early 1977.

3.6.2. Delays in finalizing the performance monitoring instrumentation and subsequent delivery of such sensors.

3.6.3. The need for making design changes while construction was going on.

3.6.4. Unfamiliarity of the subcontractor with the special requirements of a solar system.

3.6.5. Problems with material procurement.

3.7 Installation History

Most of the major equipment required for this project were ordered in October and November, 1976. Some of the hardware was delivered to the subcontractor in November and December, 1976. Installation of the indoor part of the system was commenced in January, 1977.

One of the problems encountered at this stage was caused by a delay in finalizing the selection and subsequent delivery of the ERDA flow sensors which are used for performance monitoring. This problem necessitated the installation of temporary spools in the piping at locations where the sensors were to be installed later. When the sensors arrived with detailed installation instructions, the contractor found it necessary to do some re-routing of the piping, to comply with the requirements of upstream and downstream distances. This problem caused not only some delay in the completion schedule, but also a substantial increase in labor cost.

Other problems encountered were caused by the incorporation of certain revisions to the drawings and specifications to provide additional details required for proper installation. The subcontractor construed these as engineering changes and charged extra for them. Among such items were the following:

3.7.1. Substitution of copper tubing with silver solder joints for the initially specified steel pipe with screwed fittings: This substitution was expected to result in enough reduction in labor cost to almost offset the additional cost of materials. As it turned out, both labor and materials were higher than the estimate.

3.7.2. The requirement to use Teflon hose with bronze wire braid reinforcement in the connection between each panel and the headers: This requirement was not clearly defined in the original specifications. The subcontractor's estimate was based on using plain rubber hose.

3.7.3. The requirement to install "Pete's plugs" and "Balvalve-indicators" at each panel's inlet: These devices, intended to permit measurement of pressures, temperatures and flow rates for each individual panel, were not clearly required in the original specifications. Consequently, they were not included in the estimate.

3.7.4. The requirement that all automatic valves be bubble-tight: This requirement was not clearly stated in the original specifications, but was later deemed necessary for successful performance of the system.

3.7.5. The addition of duplicate temperature and flow measurement devices: Because of uncertainty as to the timing of removal of the ERDA instrumentation, Bell felt a need to add a few venturis and thermocouple wells in the piping system to provide permanent monitoring capability. These were not included in the estimate.

3.7.6. The beefing-up of the panel structural supports: Our structural engineer redesigned the support structure to be made of 2 1/2" X 2 1/2" X 5/16" in lieu of 1 1/2" X 1 1/2" X 1/8". This necessitated employing iron workers in lieu of sheet metal workers, according to Union rules.

The above-mentioned items are only a few examples of type of changes that can run up the cost and delay the completion of a novel project such as this.

When the solar panels were ordered in November, 1976, a January delivery date was stipulated. However, while the manufacturer was prepared to expedite delivery, he was later told not to rush into production, since the subcontractor did not want to have to take delivery of the panels until he was ready to install them on the building roof. After several requested postponements, delivery of the panels was made in early June, 1977, directly to the job site. A crane and riggers were ready to take the panels to the roof and mount them on the support structure. This was accomplished efficiently within two days only. Appendix "B" includes some photographs which were taken during that operation.

Progress in completing the system installation was fairly slow during the summer of 1977. It was felt that since the system was not needed until the start of the heating season, there was no urgency to complete it before September, 1977. The subcontractor reduced his crew on this job whenever he had a need for utilizing his manpower elsewhere.

In complience with Bell's contract with ERDA, an on-site display room was provided which contains a professionally-produced exhibit for the benefit of visitors. The exhibit includes several charts explaining the operation of the solar system, a typical solar collector panel with a cut-out section and large size photographs of the panel installation procedure. In addition, slots were provided to distribute to visitors various brochures on solar energy, which were supplied to us by ERDA.

By early October, 1977, the system was at a stage of completion which allowed putting it into operation. A dedication ceremony, attended by the President and other higher management of Bell of Pennsylvania, several local dignitaries and a representative of ERDA, was conducted on October 25, 1977.

3.8. Cost Over-runs

By the time the solar system was placed in operation in October, 1977, Bell of Pennsylvania incurred the following over-runs over the estimated costs listed in paragraph 3.3:

3.8.1. Extra amount paid to the HVAC Subcontractor: $91,789.

3.8.2. Extra mark-up paid to the General Contractor: $4,589.

3.8.3. Extra amount paid to the Integrating Contractor: $10,618.

3.8.4. Extra amount paid for the Display Room: $2946.

The above sums do not include the extra time spent by in-house engineering on this project, which was considerable.

Table (3) lists the actual cost of the various items appearing in Table (2), with percentage increase of each item over the estimate. Table (3) also adds four items which were not included separately in the estimated breakdown of Table (2).

4.0 LESSONS LEARNED

Among the lessons learned on this project were the following:

4.1. Because of unfamiliarity of most installers with the peculiar requirements of a solar system, it is essential that more complete details be included in the design drawings and specifications than is customary with standard HVAC systems. These details should all be finalized prior to requesting bids from installation subcontractors.

4.2. To the extent possible, bids should be requested from only subcontractors who have had prior experience with solar systems.

4.3. Maximum effort should be exerted towards "Fixed lump sum" contracting in perference to "Cost plus fixed fee" type of contract, even if the latter include a "Not-to-exceed" clause.

4.4. Performance monitoring instrumentation should be finalized and detailed at an early stage to permit incorporation into the design drawings and specifications.

4.5 Ample time should be allowed for developing the engineering drawings and specifications and for the procurement of hardware.

4.6. It is a good idea to select one particular solar panel prior to completion of the detailed design of the system.

4.7. Delivery of needed hardware should be planned carefully in advance of the start of construction.

4.8. A thorough economic analysis should be undertaken to compare the cost effectiveness of drain-down systems with those using antifreeze in combination with a heat exchanger. This analysis should take into consideration such matters as the comparative maintenance costs caused by relative complexity of the controls. Also, in the case of drain-down systems, a thorough study of the relative merits of "open" versus "pressurized" systems should be undertaken.

4.9. The experience of the design engineer in solar technology is of vital importance.

5.0. CONCLUSION

In spite of the difficulties encountered, Bell of Pennsylvania is pleased to have co-operated with ERDA (now part of the U.S. Department of Energy) in executing this solar demonstration project. It has provided us, our consultants, suppliers and contractors with a unique opportunity to gain valuable experience in the design, construction and operation of a fairly complex solar space heating system. It is hoped that this report will be of benefit to future users of solar energy.

6.0 REFERENCE

6.1. "System Design Report", COO-4048-78-1, March, 1978.

FIGURE 1
PLOT PLAN

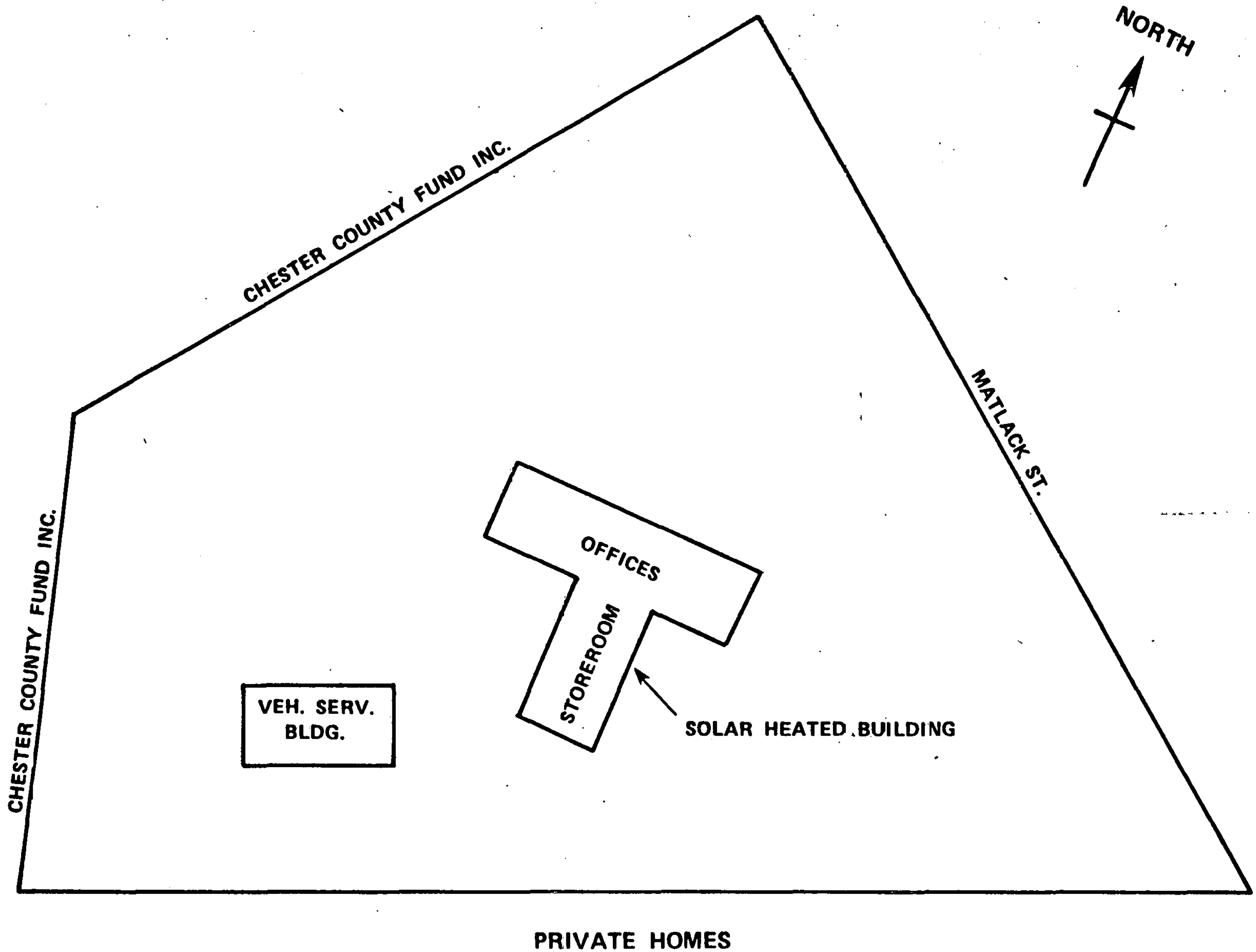


FIGURE 2

FLOOR PLAN

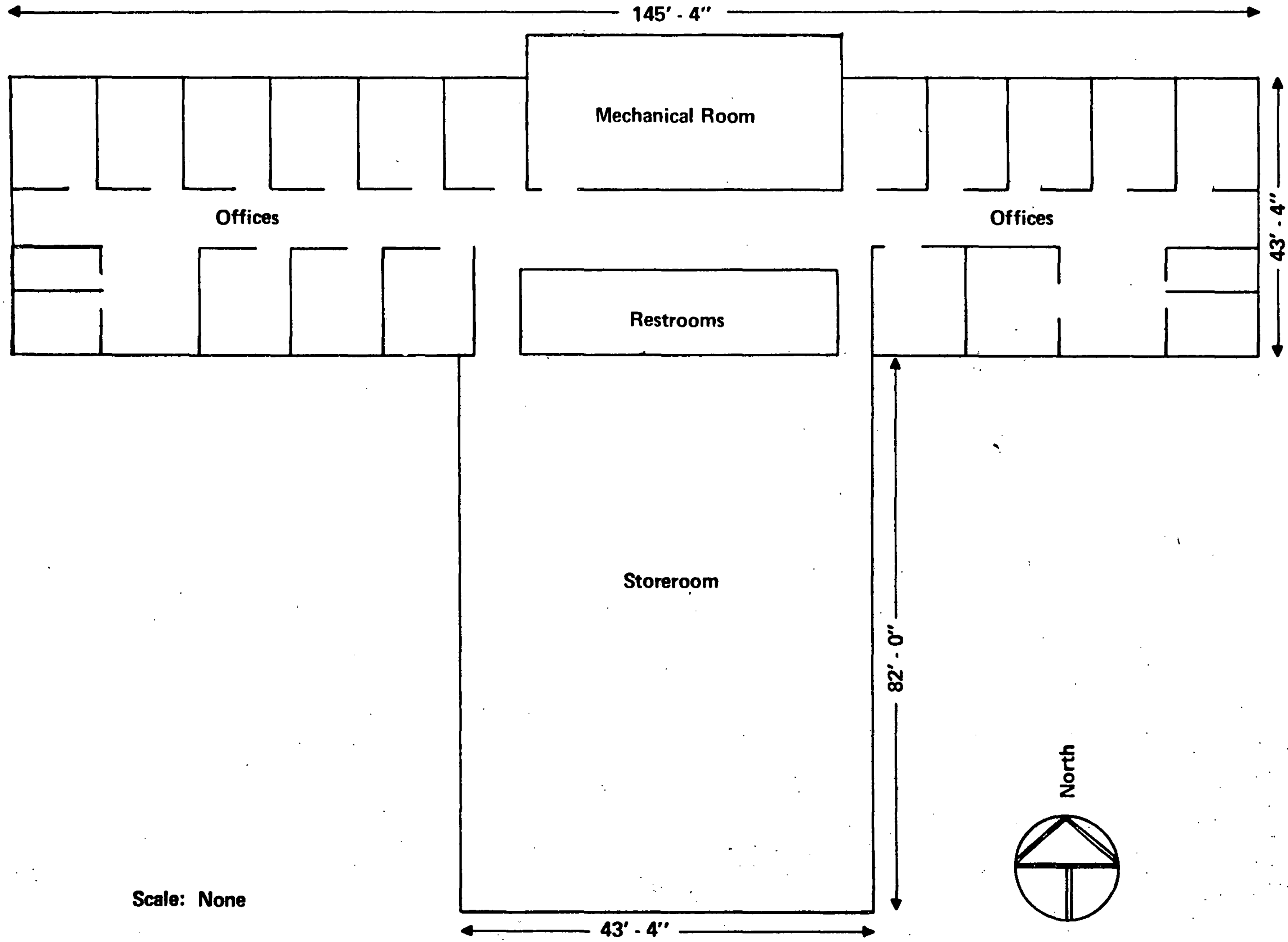
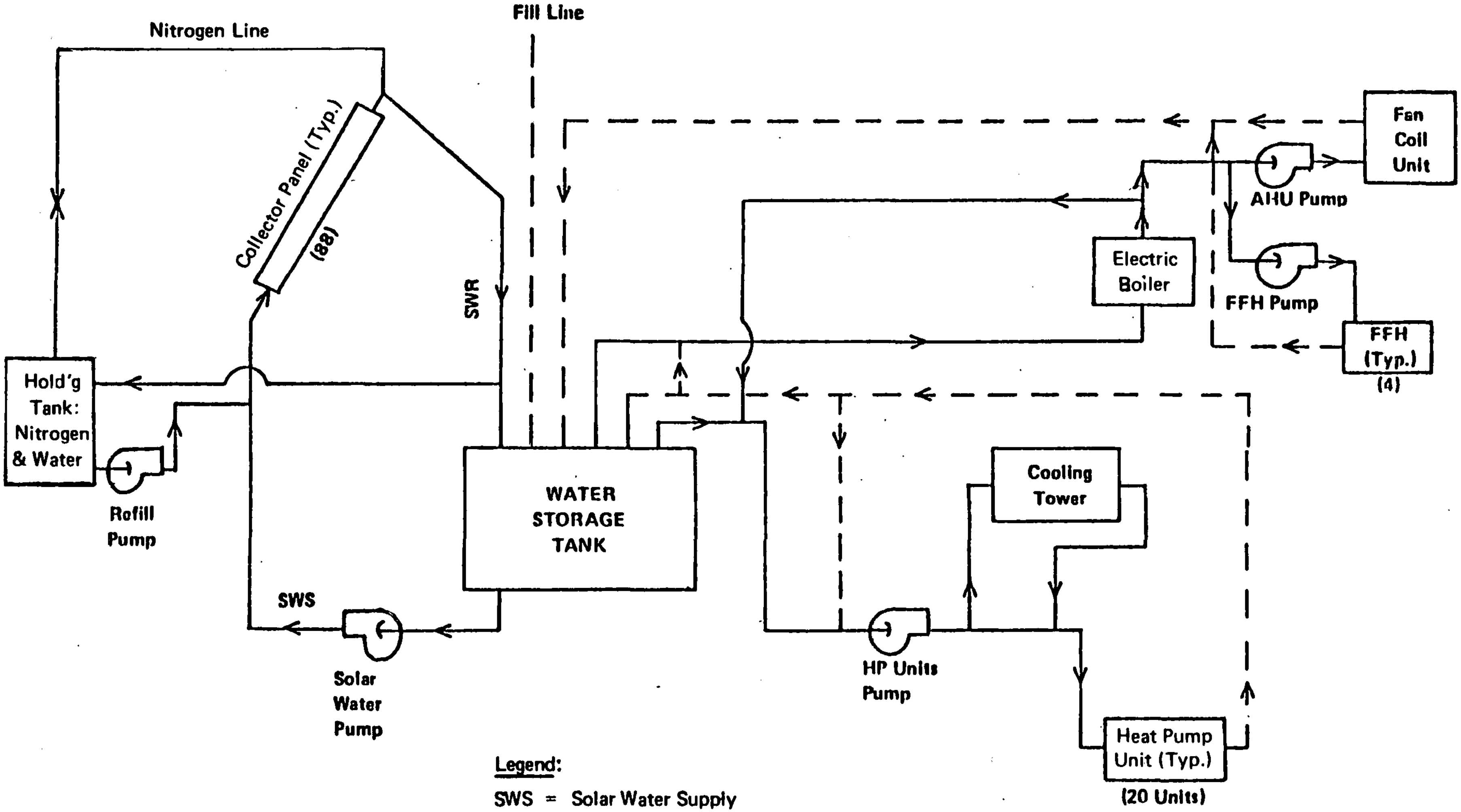


FIGURE 3

SIMPLIFIED FLOW DIAGRAM



<u>Legend:</u>

SWS = Solar Water Supply
SWR = Solar Water Return
AHU = Air Handling Unit
FFH = Forced Flow Heaters
HP = Heat Pump

Table 1
PERFORMANCE MONITORING INSTRUMENTATION

(a) Temperature Measurements

No.	Designation	Name	Range (oF) Min.	Range (oF) Max.	Thermowell Part No.	Probe Part No.
1	T029 (T-29)	Outside Ambient Air	-10	100	IS4	S53-P85Z36
2	T102 (T-1) (T-2)	Collector Array Inlet Water Temperature	40	180	F203U18	S57-P50Z36
3	TD102 (T-2A)	Collector Array Differential Water Temperature	0	75	F203U18	S53-P50Z36
4	T109 (T-9) (T-8)	Collector Array to Storage Tank Inlet Temperature	40	200	F203U18	S57-P50Z36
5	TD109 (T-9A)	Collector Array to Storage Tank Differential Temperature	0	75	F203U18	S53-P50Z36
6	T205 (T-5)	Storage Tank Top Water Temperature	40	200	F203U300	S53-P330
7	T206 (T-6)	Storage Tank Center Water Temperature	40	200	F203U300	S53-P330
8	T207 (T-7)	Storage Tank Bottom Water Temperature	40	200	F203U780	S53-P810
9	T421 (T-20) (T-21)	Storage Tank To FFH and AHU Loop Inlet Water Temperature	40	200	F203U18	S57-P50Z36
10	TD421 (T-21A)	Storage Tank to FFH and AHU Loop Differential Temperature	0	50	F203U18	S53-P50Z36
11	T423 (T-22) (T-23)	Storage Tank to HPU Loop Differential Temperature	40	200	F203U18	S57-P50Z36
12	TD423 (T23-A)	Storage Tank to HPU Loop Differential Temperature	0	15	F203U18	S53-P50Z36
13	TD411LO (T-11)	Lo Side Supplementary Heat (Boiler) Differential Temperature			F203U18	S53-P50Z36

No.	Designation		Name	Range (oF) Min.	Max.	Thermowell Part No.	Probe Part No.
14	TD411H1	(T-11A)	Hi Side Supplementary Heat (Boiler) Differential Temperature	-	-	F203U18	S53-P50Z36
15	TD427H1	(T-27)	Hi Side FFH Circ. Differential Water Temperature			F203U7	S53-P40Z36
16	TD427LO	(T-27A)	Lo Side FFH Circ. Differential Water Temperature	-	-	F203U7	S43-P40Z36
17	T425	(T-24) (T-25)	AHU Inlet Water Temperature	100	250	F203U18	S57-P50Z36
18	TD425	(T-25A)	AHU Differential Water Temperature	0	50	F20[illegible]18	S53-P50Z36
19	T413	(T-12) (T-13)	Heat Pump Loop Inlet Temperature (Heating) (Hi side)			F203U18	S57-P50Z36
20	TD413	(T-13A)	Heat Pump Loop Differential Temperature (Heating) (Lo side)			F203U18	S53-P50Z36
21	TD513*		Heat Pump Loop Differential (Cooling) (opposite of TD413)			*	*
22	TD519LO	(T-19)	Cooling Tower Differential Temperature (Lo side)			F203U18	S53-P50Z36
23	TD519H1	(T-19A)	Cooling Tower Differential Temperature (Hi side)			F203U18	S53-P50Z36
24	T628	(T-28)	Ambient Temperature Typical Office	50	85	-	S53-P85Z36

*NOTE: Measurement TD513 is the opposite sign of measurement TD413. No additional sensors are required. However, a separate channel is required in the SDAS for TD513.

(b) Flow Rate Measurements

No.	Designation	Name	Range (GPM) Min.	Design.	Max.	Model No.
25	W101 (F-1)	Collector Array Flow Rate	0	52	60	MKV-2 1/2-J01
26	W403 (F-3)	Supplementary Heat (Boiler) Flow Rate	0	97 or 45	100	MKV-2-J01
27	W410 (F-10)	Storage Tank from FFH and AHU Loop Flow Rate	25	45	55	MKV-2-J01
28	W411 (F-11)	Storage Tank from HPU Loop Flow Rate	0	52	60	MKV-2 1/2-J01
29	W412 (F-12)	Storage Tank to FFH and AHU Loop Flow Rate	0	97 or 45	100	MKV-2-J01
30	W413 (F-13)	Storage Tank to HPU Loop Flow Rate	0	52	60	MKV-2 1/2-J01
31	W408 (F-8)	Air Handling Unit Flow Rate	0	35 or Less	40	MKV-2-J01
32	W404 (F-4)	FFH Flow Rate	0	10	10	MKV-1-J01
33	W406 (F-6)	Heat Pump Loop Flow Rate	0	52	60	MKV-2 1/2-J01
34	W409 (F-9)	Cooling Tower Flow Rate	0	52	60	MKV-2 1/2-J01

(c) Power Measurements

No.	Designation	Name	Model No.
35	EP101 (KW-1)	Solar Collector Pump P-1 Power	PC5-14
36	EP105 (KW-5)	Solar Panel Refill Pump P-5 Power	PC5-14
37	EP403 (KW-3)	Forced Flow Heaters Circ. Pump P-3 Power	PC5-19
38	EP404 (KW-4)	Air Handling Unit Circ. Pump P-4 Power	PC5-5
39	EP408 (KW-8)	Air Handling Unit (AHU-1) Power	PC5-23
40	EP412	Forced Flow Heaters Total Fan Power (4 Units)	PC5-1
41	EP409 (KW-9)	Supplementary Heat Electric Boiler Power	PC5-80
42	EP402 (KW-2)	Heat Pump Units Circ. Pump P-2 Power	PC5-14
43	EP407 (KW-7)	Total Power to Heat Pump Units	PC5-62
44	EP510 (KW-10)	Cooling Tower Power Fan	PC5-53
45	EP511	Cooling Tower Pump Power	PC5-19
46	I001	Insolation	PSP

TABLE (2)

HVAC SUBCONTRACTORS ESTIMATE

		MATERIAL	LABOR	TOTAL
1)	SOLAR PANELS	$24,179.	$8,751.	$32,930.
2)	STORAGE TANK	9,730.	1,600.	11,330.
3)	ALL PIPING CONNECTING SOLAR PANELS WITH STORAGE TANK	12,360.	16,800.	29,160.
4)	AUTOMATIC CONTROLS FOR SOLAR COLLECTION	2,250.	4,200.	6,450.
5)	NITROGEN PRESSURIZATION EQUIPMENT	3,650.	3,500.	7,150.
6)	COOLING TOWER	6,280.	2,800.	9,080.
7)	AIR HANDLING UNIT	5,400.	3,800.	9,200.
8)	20 HEAT PUMP UNITS	12,920.	4,800.	17,720.
9)	ELECTRIC BOILER	2,650.	800.	3,450.
10)	ALL WATER PUMPS	6,250.	1,600.	7,850.
11)	ALL PIPING DOWNSTREAM OF STORAGE TANK	15,520.	22,200.	37,720.
12)	AUTOMATIC CONTROLS FOR HEATING EQUIPMENT	2,500.	4,500.	7,000.
13)	STRUCTURAL SUPPORTS FOR SOLAR PANELS	6,825.	5,425.	12,250.
14)	WATER TREATMENT	2,200.	920.	3,120.
15)	SHEET METAL EXHAUST	2,000.	3,300.	5,300.
16)	FORCE FLOW HEATERS	950.	640.	1,590.
	TOTALS	$115,664.	$85,636.	$201,300.

TABLE (3)

ACTUAL COSTS AND OVER-RUNS

	MATERIAL		LABOR		TOTAL	
	Actual Cost	% Increase	Actual Cost	% Increase	Actual Cost	% Increase
1) SOLAR PANELS	$24,521	1.4	$9,400	7.4	$33,921	3.0
2) STORAGE TANK	11,628	19.5	3,551	121.9	15,179	34.0
3) ALL PIPING CONNECTING SOLAR PANELS WITH STORAGE TANK	18,356	48.5	25,692	52.9	44,048	51.1
4) AUTOMATIC CONTROLS FOR SOLAR COLLECTION	5,565	147.3	7,070	68.3	12,635	95.9
5) NITROGEN PRESSURIZATION EQUIPMENT	4,425	21.2	4,796	37.0	9,221	29.0
6) COOLING TOWER	6,111	0	2,712	0	8,823	0
7) AIR HANDLING UNIT	5,250	0	3,821	0	9,071	0
8) 20 HEAT PUMP UNITS	15,978	23.7	7,208	50.2	23,186	30.8
9) ELECTRIC BOILER	2,521	0	981	22.6	3,502	1.5
10) ALL WATER PUMPS	6,370	1.9	2,300	43.8	8,670	10.4
11) ALL PIPING DOWNSTREAM OF STORAGE TANK	20,545	32.4	29,690	33.8	50,235	33.2
12) AUTOMATIC CONTROLS FOR HEATING EQUIP.	2,621	4.8	4,551	1.1	7,172	2.5
13) STRUCTURAL SUPPORTS FOR SOLAR PANELS	11,937	74.9	11,767	116.9	23,704	93.5
14) WATER TREATMENT	2,525	14.8	1,416	53.9	3,941	26.3

TABLE (3) (cont.)

ACTUAL COSTS AND OVER-RUNS

	MATERIAL		LABOR		TOTAL	
	Actual Cost	% Increase	Actual Cost	% Increase	Actual Cost	% Increase
15) SHEET METAL WORK	2,200	10.0	3,800	15.2	6,000	13.2
16) FORCE FLOW HEATERS	950	0	640	0	1,590	0
17) ERDA FLOW & TEMP. SENSORS	954	*	6,540	*	7,494	*
18) ERDA POWER SENSORS & J-BOX			3,200	*	3,200	*
19) BELL TEMP. MONITORING SYSTEM	1,950	*	501	*	2,451	*
20) ADDITIONAL ELEC. WORK	4,696	*	14,350	*	19,046	*
TOTALS	149,103	28.9	143,986	68.1	293,089	45.6

* Note: Items 17 to 20 were not identified as separate items in the original estimate (Table 2).

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Appendix A

Design Drawings

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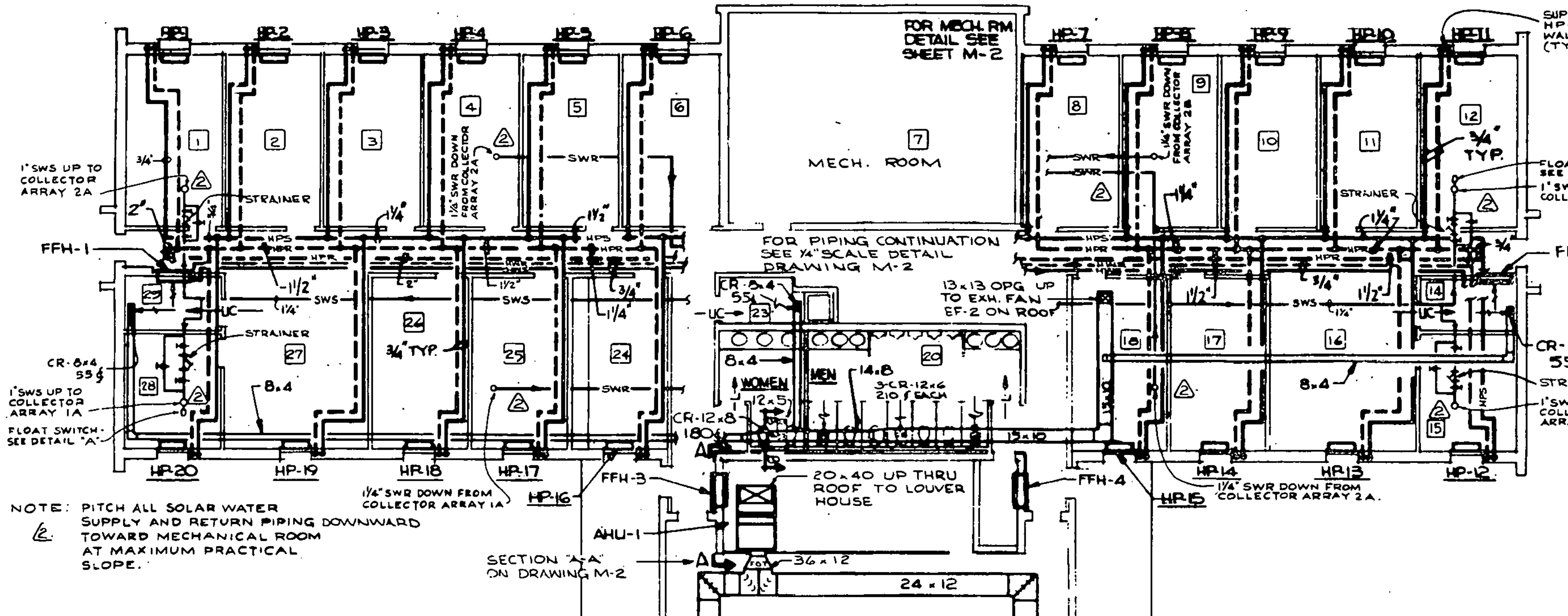
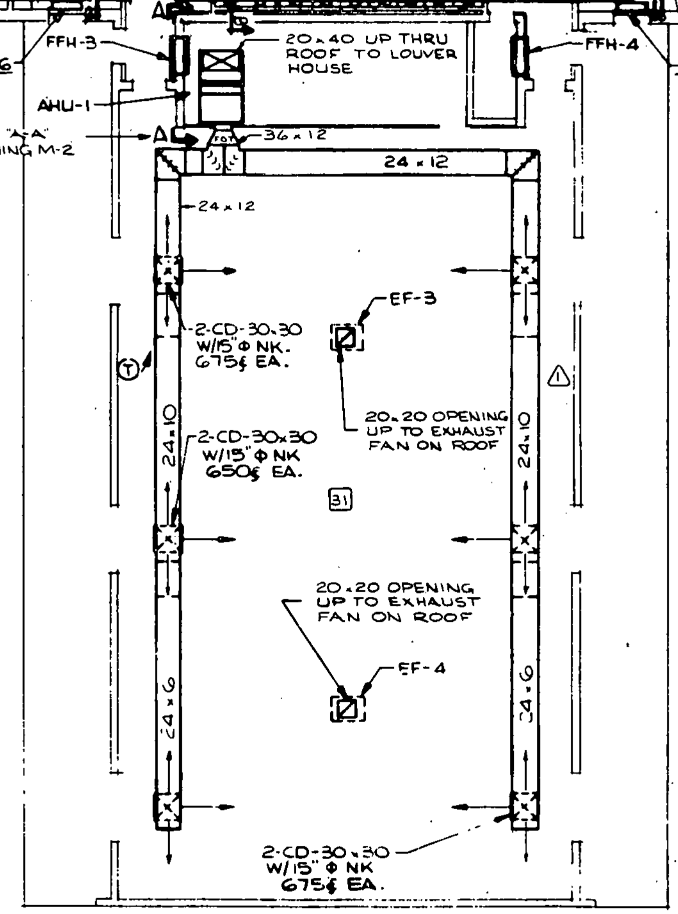
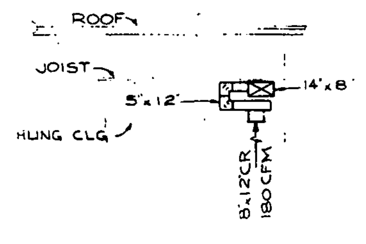


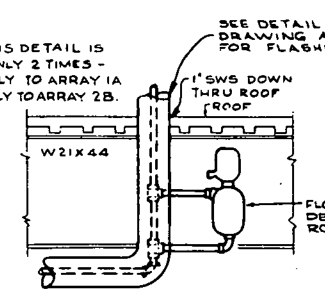


NOTE: PITCH ALL SOLAR WATER SUPPLY AND RETURN PIPING DOWNWARD TOWARD MECHANICAL ROOM AT MAXIMUM PRACTICAL SLOPE.



SECTION B-B

NOTE: ALL PLUMBING INDICATED ON THIS DRAWING IS SHOWN FOR WORK CO-ORDINATION ONLY AND IS NOT INTENDED TO BE A PART OF THE HVAC CONTRACT.



DETAIL "A"
SCALE: 3/4" = 1'-0"

FLOOR PLAN
SCALE: 1/8" = 1'-0"

SYMBOL LIST

DUCTWORK & PIPING

- SUPPLY DUCT
- RETURN OR EXH. DUCT
- RISE IN DUCTWORK
- ELBOW W/TURNING VANES
- GATE VALVE
- AUTO. 3-WAY VALVE
- AUTOMATIC VALVE
- BALANCING VALVE
- DIRECTION OF FLOW
- THERMOMETER W/WELL
- VOLUME DAMPER
- THERMOSTAT
- DIAMETER
- UNDERCUT
- LOUVER
- PRESSURE GAGE
- STRAINER
- CHECK VALVE
- GLOBE VALVE
- MANUAL AIR VENT
- AUTOMATIC AIR VENT (SARCO OR BAILEY)
- MOTOR
- METERING VENTURI

ABBREVIATIONS

CWS	CONDENSER WATER SUPPLY
CWR	CONDENSER WATER RETURN
HWS	HOT WATER SUPPLY
HWR	HOT WATER RETURN
SWS	SOLAR WATER SUPPLY
SWR	SOLAR WATER RETURN
CD	CEILING DIFFUSER
CG	CEILING GRILLE
CR	CEILING REGISTER
¢	CUBIC FEET PER MINUTE
AHU	AIR HANDLING UNIT
NK	NECK
HP	HEAT PUMP
BTU	BRITISH THERMAL UNIT
EWT	ENTERING WATER TEMP. °F
PD	PRESSURE DROP
GPM	GALLONS PER MINUTE
EDB	ENTERING DRY BULB TEMP °F
LDB	LEAVING DRY BULB TEMP °F
RPM	REVOLUTIONS PER MINUTE
SP	STATIC PRESSURE
TDH	TOTAL DYNAMIC HEAD
BHP	BRAKE HORSE POWER
MHP	MOTOR HORSE POWER
ROT	ROTATION
DIS	DISCHARGE
FPM	FEET PER MINUTE
OV	OUTLET VELOCITY
PDV	PRESSURE DIFFERENTIAL VALVE
FFH	FORCE FLOW HEATER
TS	TIP SPEED
HPS	HEAT PUMP SUPPLY
HPR	HEAT PUMP RETURN
N.C.	NORMALLY CLOSED
N.O.	NORMALLY OPEN
C.A.	COMPRESSED AIR

GENERAL NOTES

1. HEAT PUMP UNIT CONDENSATE DRAINS SHALL BE PIPED TO FITTING PROVIDED. SEE PLUMBING DRAWING.
2. DUCT CONSTRUCTION AND SUPPORT SHALL BE AS PER LATEST SMACNA GUIDE FOR LOW PRESSURE DUCTWORK
3. CO-ORDINATE EXACT DIFFUSER LOCATIONS WITH ELECTRICAL AND ARCHITECTURAL DRAWINGS

WALTER K. PLATT — PROFESSIONAL ENGINEER — PENNSYLVANIA

REV.	DESCRIPTION	DATE
1	GENERAL REVISIONS AND REVISIONS TO BULLETINS 1 THRU 5	8-17-76
2	REVISED PER BULLETIN No 6	11-12-76

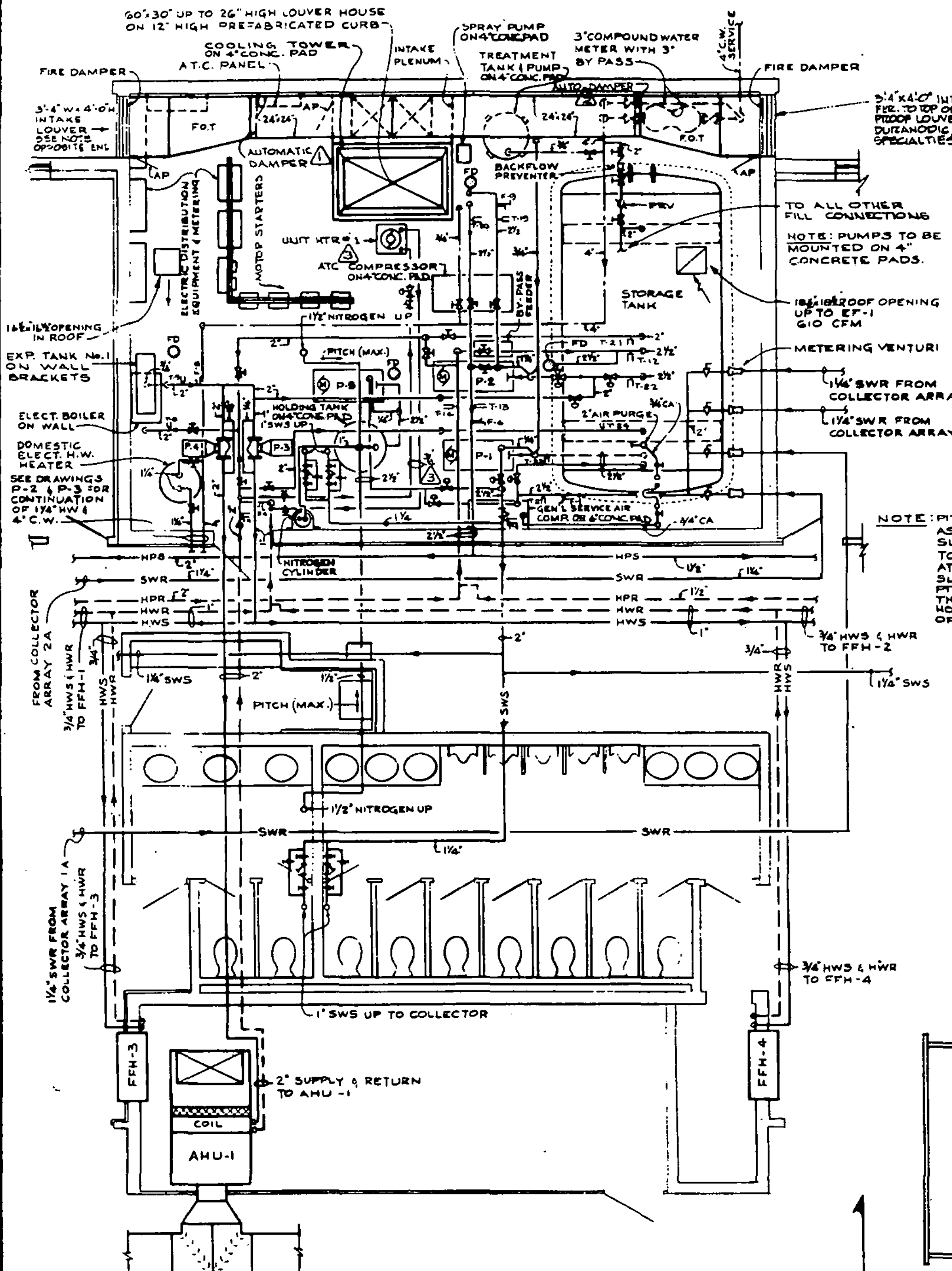
SHEET TITLE: MECHANICAL FLOOR PLAN & SYMBOL LIST

DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

WEST CHESTER WORK CENTER
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

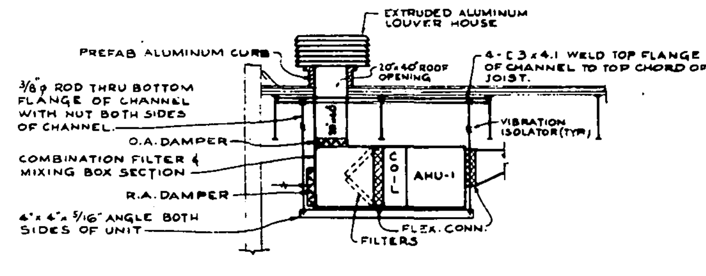
A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SHEET NO. M-1
JOB NO. C2009-5

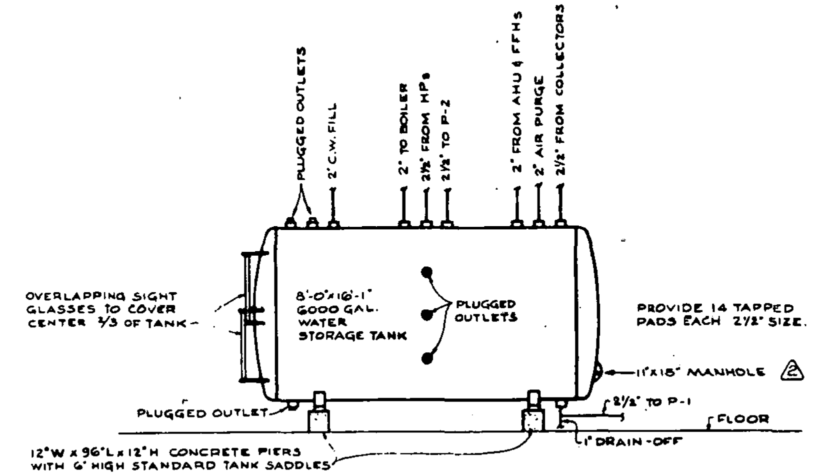


NOTE: PITCH ALL NITROGEN PIPING AS WELL AS SOLAR WATER SUPPLY AND RETURN PIPING TOWARD MECHANICAL ROOM AT THE MAXIMUM PRACTICAL SLOPE. NITROGEN PIPING MUST PITCH CONTINUOUSLY DOWN TO THE CONNECTION AT THE HOLDING TANK AND BE FREE OF ALL TRAPS.

PART FLOOR PLAN △2
SCALE: 1/4" = 1'-0"

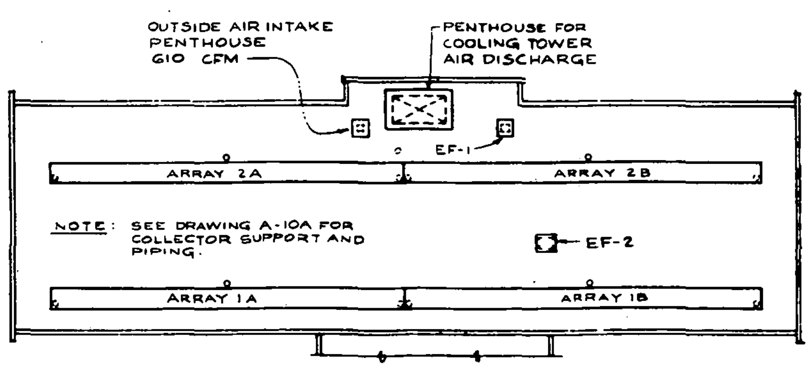


SECTION "A"-"A"
SCALE: 1/4" = 1'-0"



STORAGE TANK DETAIL
SCALE: 1/4" = 1'-0"

NOTE 1. EXTEND TANK FITTINGS TO CLEAR TANK INSULATION.
2. TANK SHALL BE WATER TIGHT, ALL STEEL CONSTRUCTION IN ACCORDANCE WITH APPLICABLE LOCAL CODE AND SHALL BE BUILT FOR 50 PSI WORKING PRESSURE AND SHALL BEAR ASME LABEL.



NOTE: SEE DRAWING A-10A FOR COLLECTOR SUPPORT AND PIPING.

ROOF PLAN △2
SCALE: 1/16" = 1'-0"

NOTE:
ALL PLUMBING INDICATED ON THIS DRAWING IS SHOWN FOR CO-ORDINATION ONLY AND IS NOT INTENDED TO BE A PART OF THE HVAC CONTRACT.

WALTER K. PLATT
DAVID A. WICK, JR.

REV	DESCRIPTION	DATE
△1	GENERAL REVISIONS PLUS REVISIONS TO BULLETINS 1 THRU 5	8-17-76
△2	REVISED PER BULLETIN #6	11-12-76
△3	ADDED UNIT HEATER # 1	1-31-77

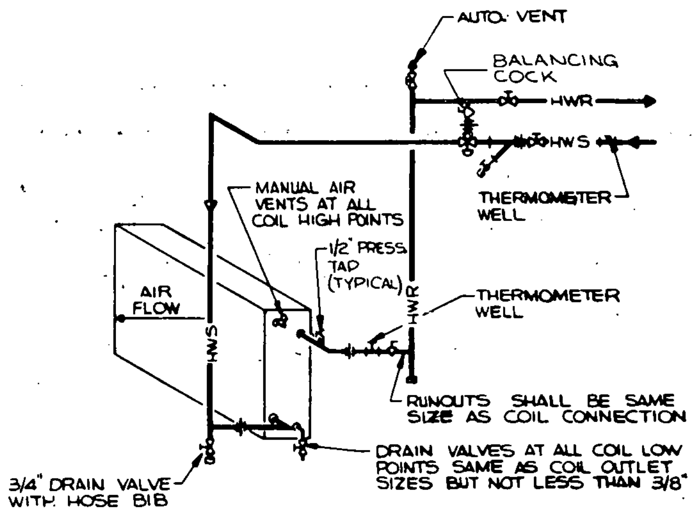
SHEET TITLE: MECHANICAL ROOM PLAN AND SECTIONS

DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

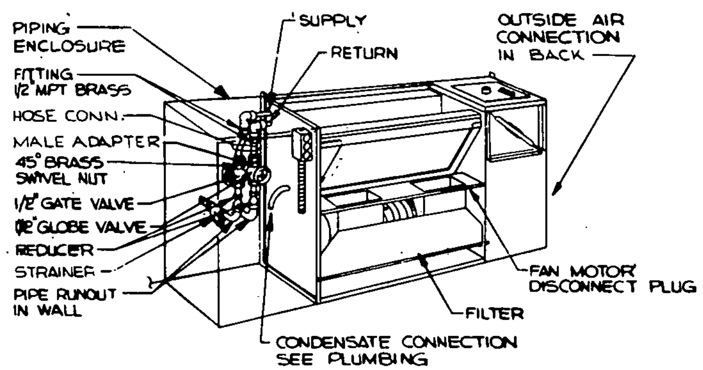
WEST CHESTER WORK CENTER
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SHEET NO. M-2
JOB NO. 00009-5

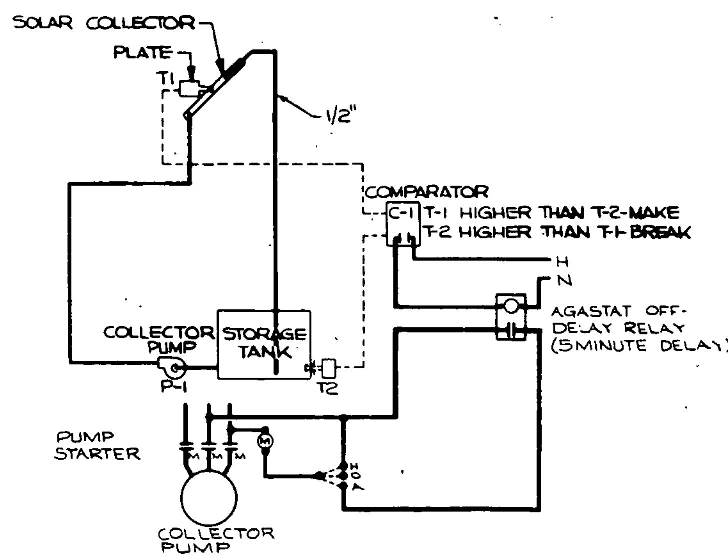


HOT WATER HEATING COIL CONNECTIONS
NO SCALE

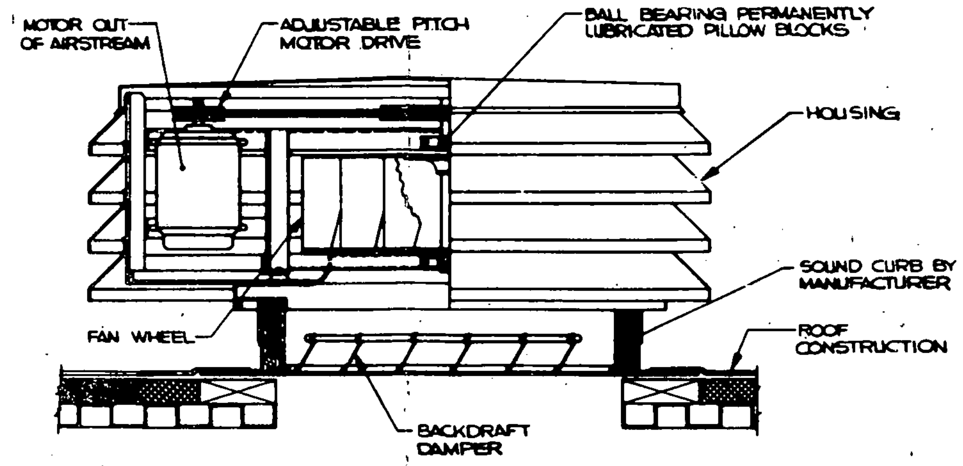


NOTE: PROVIDE DUCT CONNECTIONS TO LOUVER FOR OUTSIDE AIR INTAKE.

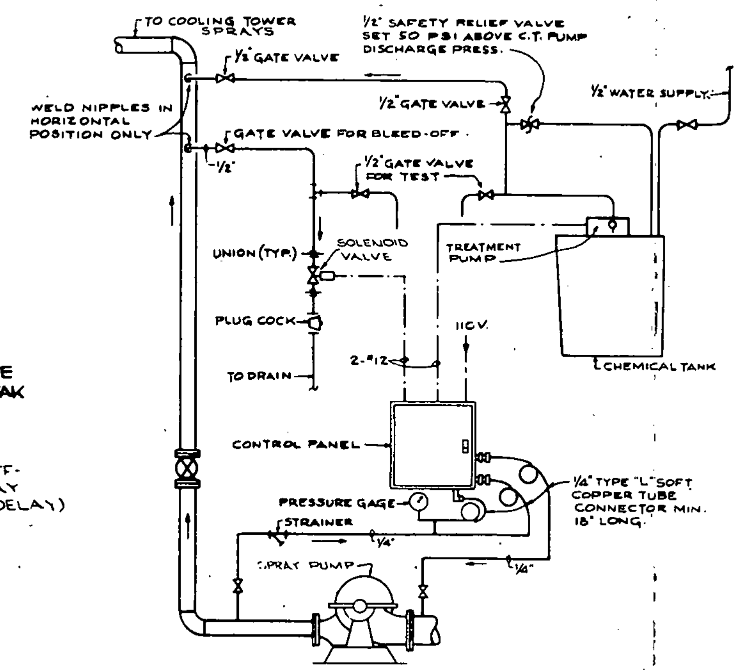
HEAT PUMP DETAIL
NO SCALE



STORAGE TANK PUMP CONTROL DETAIL
NO SCALE



EXHAUST FAN DETAIL
INTAKE PENTHOUSE SIMILAR
NO SCALE



COOLING TOWER SPRAY
CHEMICAL FEED SYSTEM WITH CONDUCTIVITY CONTROLLED BLEED-OFF
△2 NO SCALE

NOTE:
ALL PLUMBING INDICATED ON THI DRAWING IS SHOWN FOI WORK COORDINATION ONLY AND IS NOT INTENDED TO BE A PART OF THE HVAC CONTRACT.

REV.	DESCRIPTION	DATE
△1	GENERAL REVISIONS AND REVISIONS TO BULLETINS 1 THRU 5	8-17-76
△2	REVISED PER BULLETIN #6	11-12-76

SHEET TITLE: DETAILS

DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

WEST CHESTER WORK CENTER
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SHEET NO. M-3
JOB NO. 00009-5

FACTORY FABRICATED AIR HANDLING UNIT SCHEDULE

UNIT NO.	FAN DATA: CFM	S.P.	MAX. O.V. FPM	BHP	MAX. FAN WHEELS	MOT. DATA: MHP		HEATING COIL DATA: AIR S.P.	AIR EDB	AIR LDB	WATER GPM	WATER PD MAX.	WATER EWT	MAX. FACE VELOCITY	REMARKS	FILTERS TYPE
AHU-1	4000	2½"	1455	2.74	1	3		1/2"	50	85	31	1'	110	533	—	2" THROW AWAY

NOTE: STATIC DEFLECTION TO BE 1."

HEAT PUMP SCHEDULE

PUMP NO.	SERVICE	NOM CFM	OUTSIDE AIR C.F.M	GPM	PD FT. H_2O	SUMMER: EWT °F	ENT. AIR TEMP DB	ENT. AIR TEMP WB	TOTAL COOLING CAP. (BTUH)	COMP INPUT KW	FAN KW	HEAT OF REJECTION	LWT °F	WINTER: EWT °F	EAT °F	HEATING CAP (BTUH)	COMP INPUT (KW)	FAN INPUT (KW)	HEAT OF ABSOR. (BTUH)	LWT °F
HP13,19	CLERICAL AREAS	420	70	3.5	5.6	92	82.5	69.1	14,231	1.77	.13	20,188	103	70	70	19,000	1.66	.13	12,930	62.6
HP2-10,12 14-18,20	ALL OTHER ROOMS	230	40	1.9	6.0	92	82.5	69.1	7,210	1.11	.09	11,088	103	70	70	10,800	1.10	.09	6740	62.9
HP1,11	2 EXT. ROOMS NORTH SIDE	270	40	2.3	6.2	92	82.5	69.1	9,769	1.24	.09	14,055	103	70	70	13,000	1.24	.09	8500	62.6

FAN SCHEDULE

FAN NO.	SERVICE	PERFORMANCE DATA: CFM	SP WG	TS FPM	RPM	BHP	CONSTRUCTION DATA: TYPE FAN				MOT. DATA: MHP	REMARKS	NOTES
EF-1	MECH. ROOM	610	.25	2850	750	—	CENTRIFUGAL ROOF EXHAUSTER				1/6	V-BELT DRIVE	
EF-2	TOILETS & JC	975	.375	3705	975	—	CENTRIFUGAL ROOF EXHAUSTER				1/4	V-BELT DRIVE	
EF-3	STORAGE	2155	.25	3165	605	—	CENTRIFUGAL ROOF EXHAUSTER				1/4	V-BELT DRIVE	
EF-4	STORAGE	2155	.25	3165	605	—	CENTRIFUGAL ROOF EXHAUSTER				1/4	V-BELT DRIVE	

COOLING TOWER SCHEDULE ⚠4

LOCATION	AMBIENT WB °F	GPM	EWT	LWT	P.D. PSI	FAN MOTOR H.P.	PUMP MOTOR H.P.	MAXIMUM OPERATING WEIGHT, LBS
ROOF	78	52	103	92	.2	5	1/3	3000

TANKS

EACH OF THE FOLLOWING SHALL BE A.S.M.E. CONSTRUCTED FOR 50 PSI WORKING PRESSURE AND SHALL BEAR THE A.S.M.E. LABEL. TANKS SHALL HAVE GAUGE GLASSES AS REQUIRED TO COVER THE CENTER 2/3 OF EACH TANK.

EXPANSION TANK N°1 – NOMINAL 18 GAL. HORIZONTAL, 12" DIA. x 36" LONG.

HOLDING TANK – NOMINAL 300 GAL. VERTICAL, 30" DIA. x 96" HIGH.

GEN'L SERVICE AIR COMPRESSOR

AIR COMPRESSOR SHALL BE EQUAL TO GARDNER-DENVER MODEL ACA 2 x 2½, 4 CU. FT. PER MIN. AT 150 PSI, 888 RPM 3/4 HP MOTOR, V-BELT DRIVE WITH BELT GUARD.

PUMP SCHEDULE ⚠4

PUMP NO.	SERVICE	PERFORMANCE DATA: GPM	TDH FT.	RPM	BHP	CONSTRUCTION DATA: TYPE PUMP	DESIGN PRESSURE	MOT. DATA: MHP	REMARKS
P-1	SOLAR COLLECTOR	52	46	1750	—	CENTRIFUGAL END SECTION	—	2	
P-2	HEAT PUMPS	52	46	1750	—	CENTRIFUGAL END SUCTION	—	2	
P-3	FORCED FLOW HEATERS	10	20	1750	—	INLINE CIRCULATOR	—	1/3	
P-4	AIR HANDLING UNIT	35	20	1750	—	INLINE CIRCULATOR	—	1/2	
P-5	REFILL PUMP	48	50	1750	—	CENTRIFUGAL END SUCTION	—	2	

⚠5 UNIT HEATER N°1 – TRANE MODEL 'P' SIZE 80, 1/15 H.P. MOTOR, 120V.-1Φ, 1150 RPM NOMINAL RATING OF 38.5 MBH WITH 200F WATER ON 20 TD DROP 3.97 GPM WILL OPERATE WITH 110F WATER ON REDUCED OUTPUT.

FORCED FLOW HEATERS SCHEDULE

UNIT NO.	FAN DATA: CFM NOMINAL	EXT. S.P.	RPM MAX.	AIR-ON COIL EDB	HEATING WATER: GPM	P.D. FT.	EWT	CAPACITY (BTU/HR.) APPROX.	MOTOR WATTS	REMARKS
FFH-1	200	—	1100	60°	1	0.24	110	6000	85	—
FFH-2	200	—	1100	60°	1	0.24	110	6000	85	—
FFH-3	200	—	1100	60°	1	0.24	110	6000	85	—
FFH-4	200	—	1100	60°	1	0.24	110	6000	85	—

⚠5

NOTE 1 – IN ADDITION TO THE PROVISION FOR THERMOWELL AND PROBE AT EACH OF THESE INDICATED POSITIONS PROVIDE A THERMOMETER MOUNTED IN A SEPARABLE WELL AS SPECIFIED.

NOTE 2 – IN ADDITION TO THE PROVISION FOR FLOWMETER, NEARBY EACH OF THESE INDICATED POSITIONS BUT PROPERLY SEPARATED PROVIDE A BARCO OR EQUAL FLOW VENTURI AS SPECIFIED.

NOTE 3 – PROVISIONS FOR THERMOWELLS AND FLOWMETERS SHALL BE AS SPECIFIED IN INSTRUMENTATION INSTALLATION GUIDELINES AS PREPARED BY ERDA.

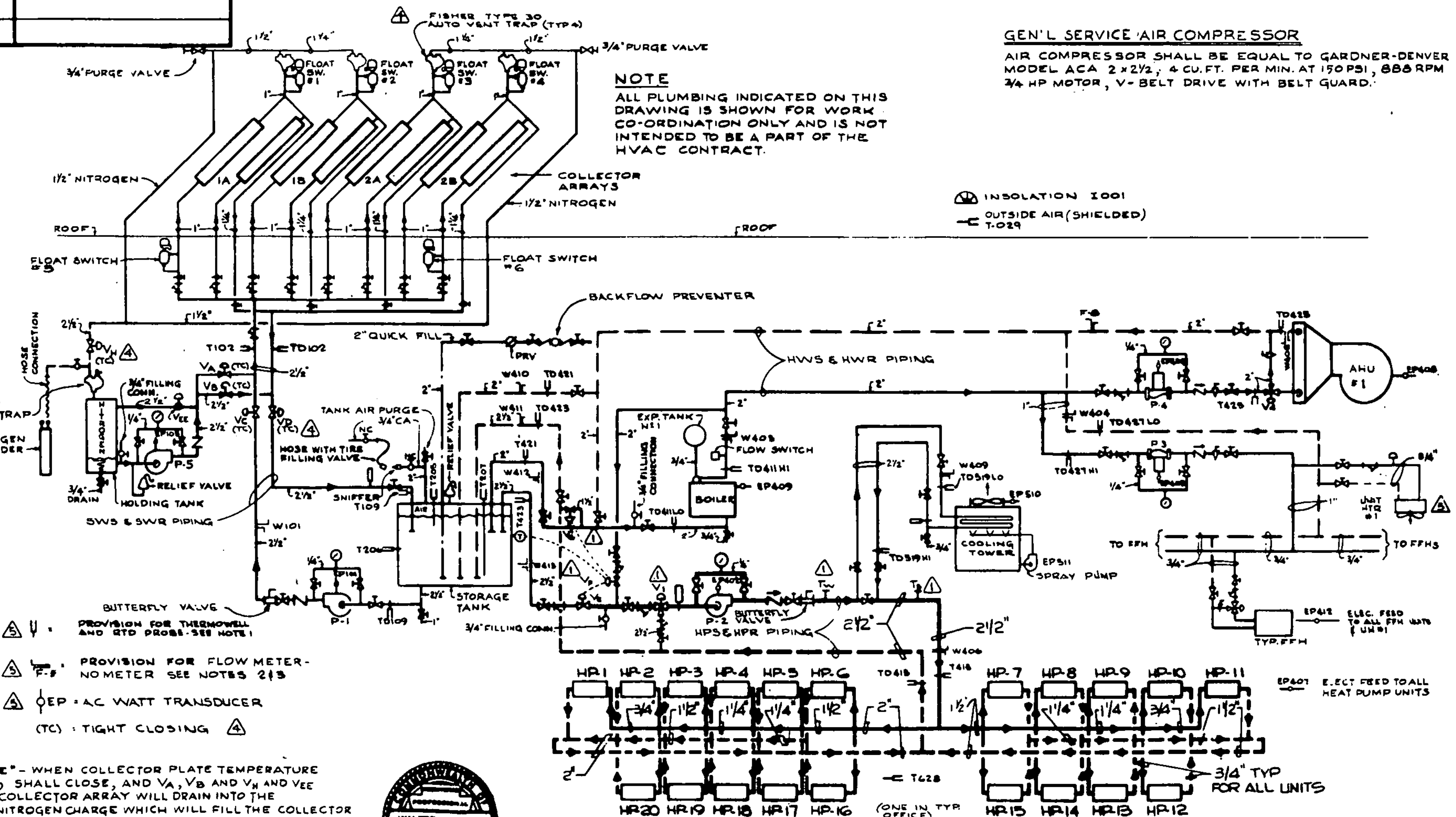
⚠5 : PROVISION FOR THERMOWELL AND RTD PROBE - SEE NOTE 1

⚠5 F-#: PROVISION FOR FLOW METER - NO METER SEE NOTES 2 & 3

⚠5 EP : AC WATT TRANSDUCER

(TC) : TIGHT CLOSING ⚠4

⚠4 ⚠2 NOTE:
"AUTOMATIC ARRAY DRAINAGE" – WHEN COLLECTOR PLATE TEMPERATURE IS 40F OR BELOW, V_C AND V_D SHALL CLOSE, AND V_A, V_B AND V_H AND V_{EE} SHALL OPEN WHEREUPON THE COLLECTOR ARRAY WILL DRAIN INTO THE HOLDING TANK DISPLACING THE NITROGEN CHARGE WHICH WILL FILL THE COLLECTOR ARRAY AND THE PIPING ABOVE THE ROOF. WHEN THE COLLECTOR PLATE TEMPERATURE RISES ABOVE THE STORAGE TANK TEMPERATURE, VALVE V_{EE} SHALL CLOSE AND THEN THE REFILL PUMP SHALL BE STARTED AND SHALL RUN UNTIL STOPPED BY FLOAT SWITCHES NUMBERED 1, 2, 3 AND 4, AT WHICH TIME VALVES V_A, V_B AND V_E SHALL CLOSE AND VALVES V_C AND V_D SHALL OPEN. FLOAT SWITCHES 1 THRU 4 TO BE WIRED IN SERIES.



⚠5 ⚠3 ⚠2 FLOW DIAGRAM
NO SCALE

NOTE: IN ALL PIPING BUT AUTOMATICALLY DRAINED SOLAR COLLECTOR PIPING, PROVIDE AUTO. AIR VENTS ON ALL HIGH POINTS AND WHERE INDICATED ON DRAWINGS. PROVIDE DRAIN-OFFS AT ALL LOW POINTS.

REV.	DESCRIPTION	DATE
1	GENERAL REVISIONS AND REVISED TO BULLETINS 1 THRU 5	8-17-76
2	REVISED PER BULLETIN #6	11-12-76
3	REVISED INSTRUMENTATION LAYOUT	12-8-76
4	ADDED VENT TRAPS, GEN. REVISIONS	1-5-77
5	REVISED INSTRUMENTATION PER ERDA, ADDED UNIT HEATER #1	1-31-77

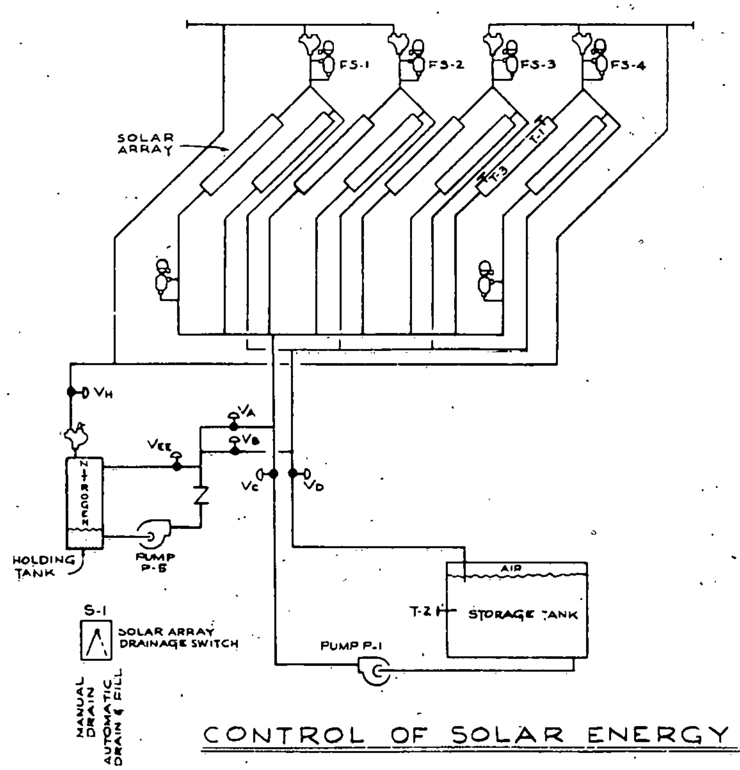
SHEET TITLE: EQUIPMENT SCHEDULES & FLOW DIAGRAM

DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

WEST CHESTER WORK CENTER
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SHEET NO. M-4
JOB NO. 00009-5



WITH SWITCH S-1 INDEXED TO "MANUAL DRAIN"

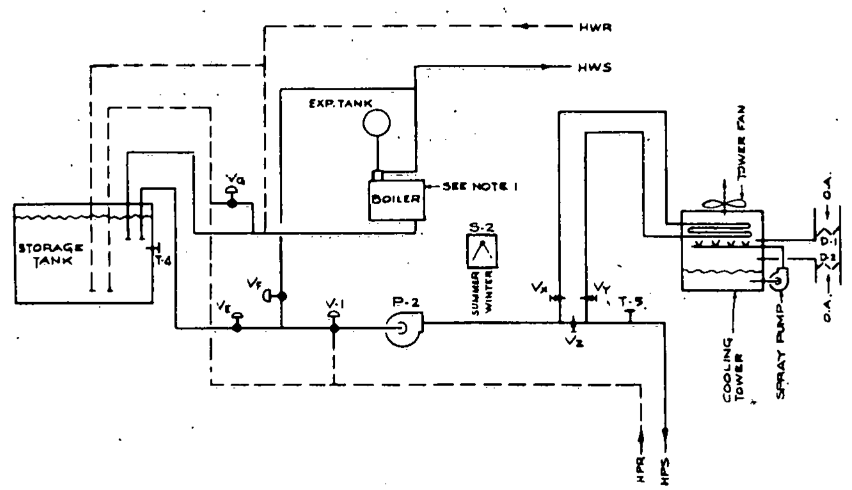
1. VALVES V_C AND V_D SHALL BE HELD CLOSED, VALVES V_A, V_B, V_{EE} AND V_H SHALL BE HELD OPEN.
2. PUMPS P-1 AND P-5 SHALL BE INOPERABLE.

WITH SWITCH S-1 INDEXED TO "AUTOMATIC DRAIN AND FILL"

ASSUMING ARRAY TO BE DRY, DRAINED INTO HOLDING TANK, VALVES V_C AND V_D HELD CLOSED, VALVES V_A, V_B, V_{EE} AND V_H HELD OPEN, SUBSEQUENT OPERATION SHALL BE AS FOLLOWS:

3. WHEN ARRAY TEMPERATURE SENSED BY T-1 RISES ABOVE STORAGE TANK TEMPERATURE SENSED BY T-2 BY AN ESTABLISHED DIFFERENTIAL (18° OR AS LATER SELECTED), VALVE V_{EE} SHALL CLOSE AND PUMP P-5 SHALL START. WHEN SOLAR ARRAY IS COMPLETELY FILLED AS SENSED BY FLOAT SWITCHES FS1 THRU FS4 PUMP P-5 SHALL BE STOPPED AND VALVES V_A, V_B AND V_H SHALL BE CLOSED AND VALVES V_C AND V_D SHALL BE OPENED. VALVE V_{EE} SHALL BE HELD CLOSED WHILE VALVES V_A AND V_B ARE CLOSING; AFTER V_A AND V_B ARE CLOSED VALVE V_{EE} SHALL OPEN.
4. WHEN ARRAY IS COMPLETELY FILLED AS SENSED BY FLOAT SWITCHES FS1 THRU FS4 PUMP P-1 SHALL BE OPERABLE
5. WHENEVER ARRAY TEMPERATURE SENSED BY T-1 IS GREATER THAN STORAGE TANK TEMPERATURE SENSED BY T-2 BY AN ESTABLISHED DIFFERENTIAL (18° OR AS LATER SELECTED), PUMP P-1 SHALL START.
6. WHENEVER DIFFERENTIAL SENSED BY T-1 AND T-2 (T-1 BEING THE HIGHER) FALLS BELOW AN ESTABLISHED DIFFERENTIAL (3° OR AS LATER SELECTED), PUMP P-1 SHALL STOP
7. WHENEVER STORAGE TANK TEMPERATURE RISES ABOVE 190F. PUMP P-1 SHALL NOT OPERATE
8. WHEN ARRAY TEMPERATURE SENSED BY T-3 DROPS TO 40F OR AS LATER SELECTED, VALVES V_C AND V_D SHALL BE CLOSED, VALVES V_A, V_B, V_H AND V_{EE} SHALL BE OPENED WHICH WILL CAUSE ARRAY TO DRAIN BY GRAVITY INTO HOLDING TANK. PUMPS P-1 AND P-5 SHALL BE HELD OFF.

CONTROL OF SOLAR ENERGY COLLECTION SYSTEM



YEAR-ROUND OPERATION

1. SWITCH S-2 INDEXES SYSTEM TO "SUMMER" OR "WINTER" OPERATION.
2. WHEN THE STORAGE TANK TEMPERATURE DROPS TO 70 F. OR AS LATER SELECTED (SENSED BY T-4), VALVES V_F AND V_G SHALL OPEN AND VALVE V_E SHALL CLOSE THEREBY PERMITTING BOILER TO BE HEAT SOURCE.
3. VALVES V_X, V_Y AND V_Z ARE MANUALLY POSITIONED.
4. VALVE V-1 SHALL BE POSITIONED FULL OPEN TO HEAT PUMP RETURN WATER WHENEVER PUMP P-2 IS NOT RUNNING.

WITH S-2 INDEXED TO "SUMMER"

5. COOLING TOWER OUTSIDE AIR DAMPERS D-1 AND D-2 SHALL OPEN.
6. MANUAL VALVES V_X AND V_Y SHALL BE OPENED, V_Z SHALL BE CLOSED.
7. COOLING TOWER SPRAY PUMP AND FAN ARE MADE OPERABLE.
8. ON A RISE IN TEMPERATURE TO 85F T-5 SHALL START COOLING TOWER SPRAY PUMP, ON A FURTHER RISE TO 90F T-5 SHALL START COOLING TOWER FAN.
9. V-1 SHALL BE HELD POSITIONED TO FULL FLOW FROM HEAT PUMP RETURN LINE (CLOSED TO HEAT SOURCES OF STORAGE TANK & BOILER).

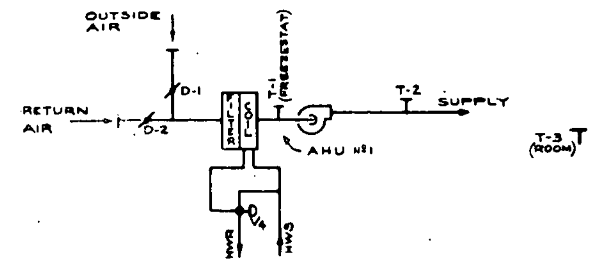
WITH S-2 INDEXED TO "WINTER"

10. COOLING TOWER OUTSIDE AIR DAMPERS D-1 AND D-2 SHALL BE HELD CLOSED.
11. MANUAL VALVES V_X AND V_Y SHALL BE CLOSED, V_Z SHALL BE OPEN.
12. COOLING TOWER SPRAY PUMP AND FAN SHALL BE HELD OFF.
13. ON A FALLING TEMPERATURE T-5 (SET 75F OR AS LATER SELECTED) SHALL GRADUALLY POSITION V-1 TO PASS HEAT SOURCE WATER (STORAGE TANK OR BOILER) TO PUMP P-2.

NOTE 1:

BOILER CONTROLS, INCLUDING LEAVING WATER TEMPERATURE, ARE FACTORY INSTALLED INTEGRAL WITH THE BOILER.

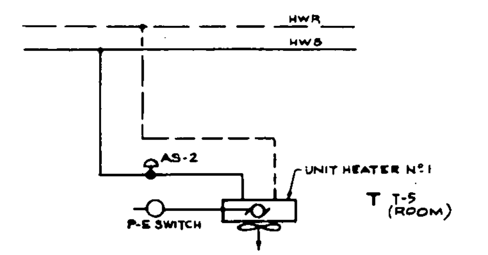
CONTROL OF HEAT PUMP LOOP SUPPLY AND RETURN



YEAR-ROUND OPERATION

1. ON A RISING TEMPERATURE T-3 GRADUALLY CLOSES V-4 TO THE COIL. ON A FURTHER RISE, AND AFTER V-4 IS FULLY CLOSED TO THE COIL, T-3 SHALL GRADUALLY OPEN D-1 SIMULTANEOUSLY GRADUALLY CLOSING D-2. T-2 SHALL OVERRIDE T-3 TO PROVIDE A LOW LIMIT ON AIR LEAVING UNIT.
2. WITH AHU Nº1 NOT RUNNING, D-1 SHALL BE HELD CLOSED, D-2 HELD OPEN, AND V-4 SHALL BE POSITIONED TO PASS HWS THRU THE COIL.
3. T-1, ON LOW TEMPERATURE, SHALL STOP AHU Nº1, CLOSE D-1, OPEN D-2 AND POSITION V-4 TO PASS HWS THRU THE COIL.

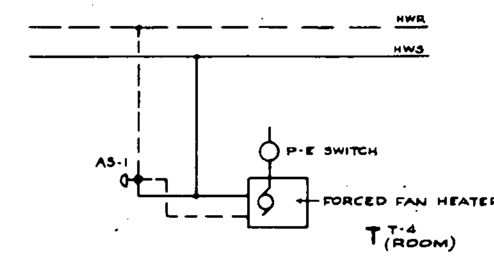
CONTROL OF AHU Nº1



YEAR-ROUND OPERATION

1. ON A FALLING TEMPERATURE T-5 SHALL START UNIT HEATER FAN MOTOR AND FULLY OPEN VALVE AS-2.

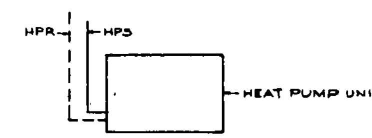
CONTROL OF UNIT HEATER Nº1



YEAR-ROUND OPERATION

1. ON A RISING TEMPERATURE T-4 SHALL GRADUALLY POSITION AS-1 TO BYPASS COIL. WHEN AS-1 IS FULLY CLOSED UNIT FAN SHALL STOP.

CONTROL OF FORCED FLOW HEATERS FF1 THRU 4



EACH HEAT PUMP UNIT SHALL HAVE FACTORY INSTALLED INTEGRAL THERMOSTAT, AUTOMATIC HEATING/COOLING CHANGEOVER FEATURE, OFF-HI-LOW SPEED SWITCH AND PROVISION FOR RANDOM STARTING OF THE UNITS. AFTER THE OCCUPANT HAS SELECTED THE DESIRED SETTING ON THE THERMOSTAT, THE UNIT WILL PROVIDE HEATING OR COOLING AS NEEDED TO MAINTAIN THE SET POINT.

HEAT PUMP UNIT CONTROL

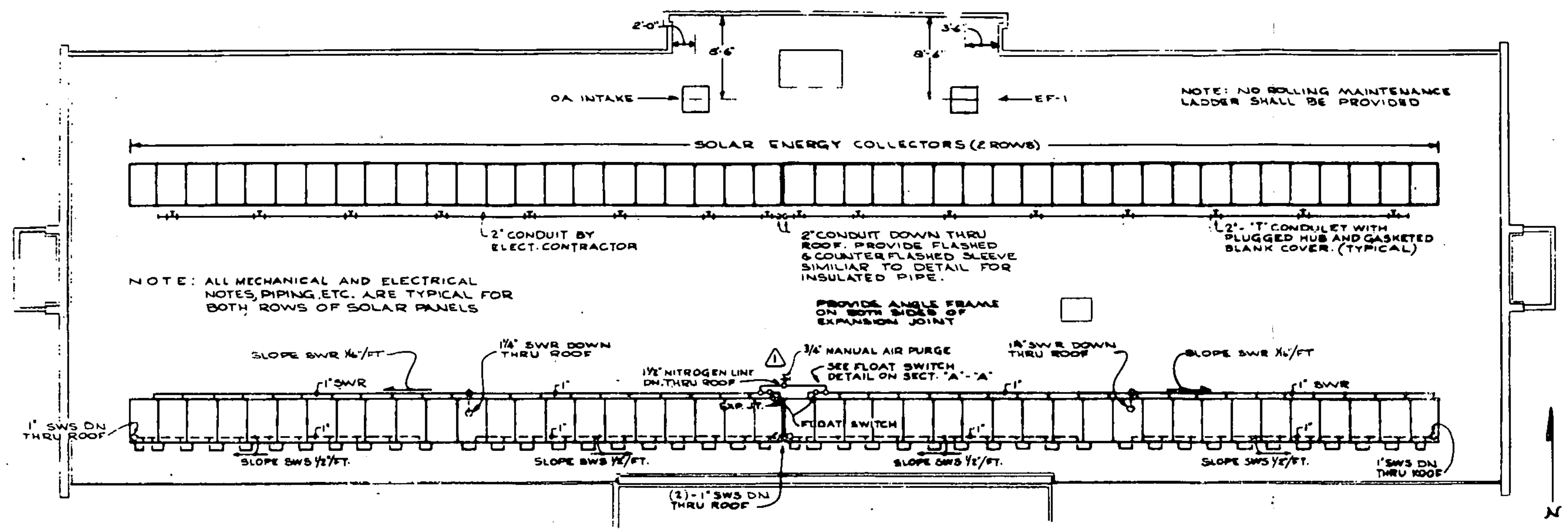
REV.	DESCRIPTION	DATE	SHEET TITLE
			TEMPERATURE CONTROL DIAGRAMS

DATE APRIL 22, 1977
SCALE NONE
DRAWN BY G & W

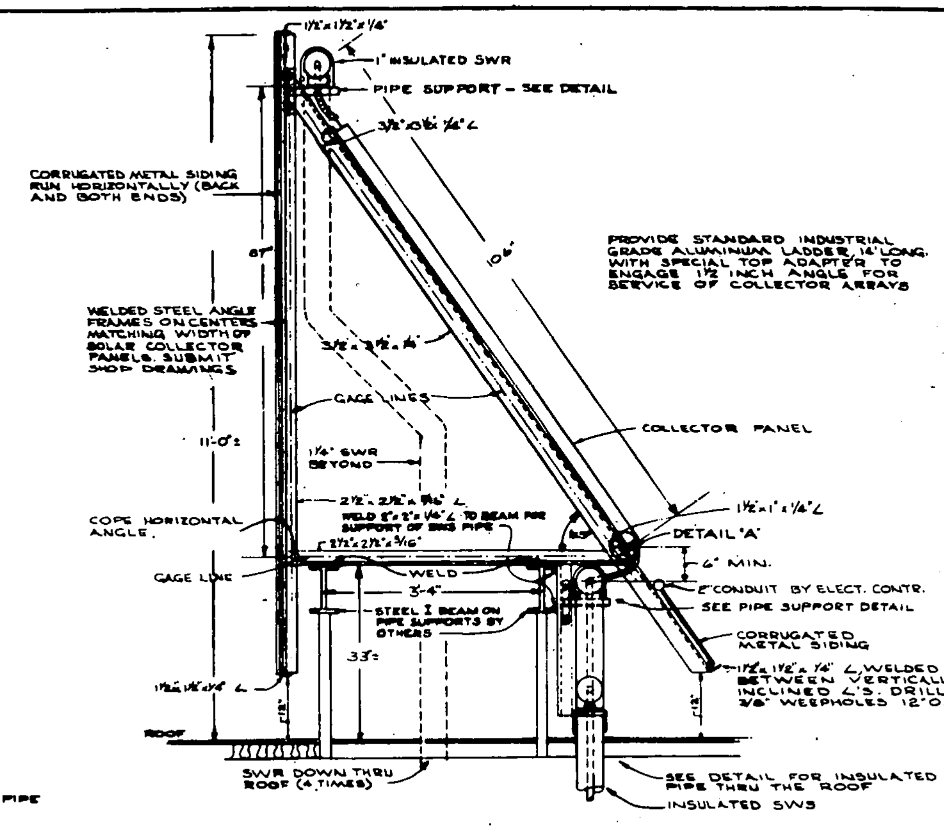
WEST CHESTER WORK CENTER.
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

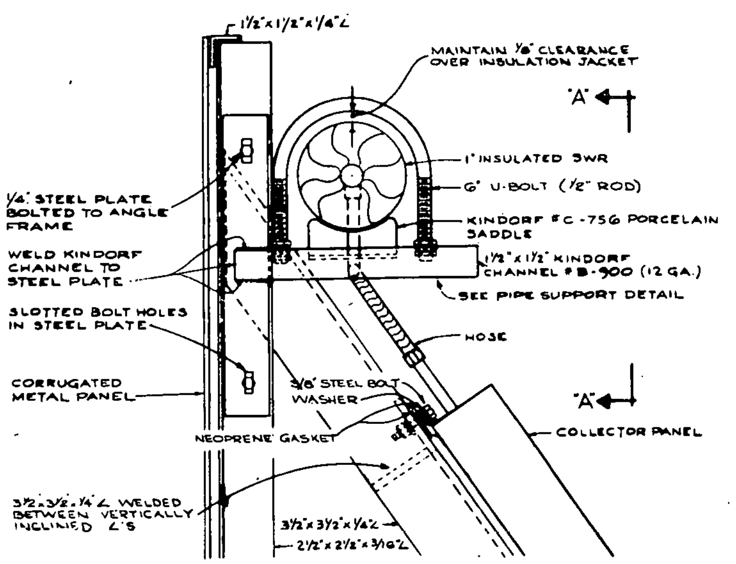
SHEET NO. M-5
JOB NO. 00009-5



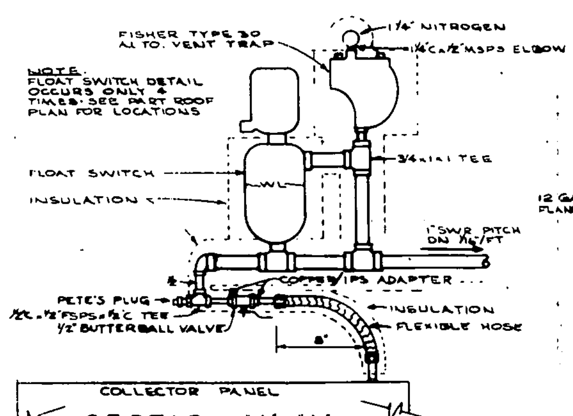
PART ROOF PLAN
SCALE: 1/8"=1'0"



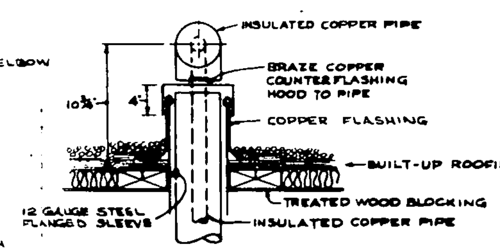
COLLECTOR PANEL DETAIL
SCALE: 3/4"=1'0"



TYPICAL RETURN CONNECTION AND PIPE SUPPORT
SCALE: 3"=1'-0"



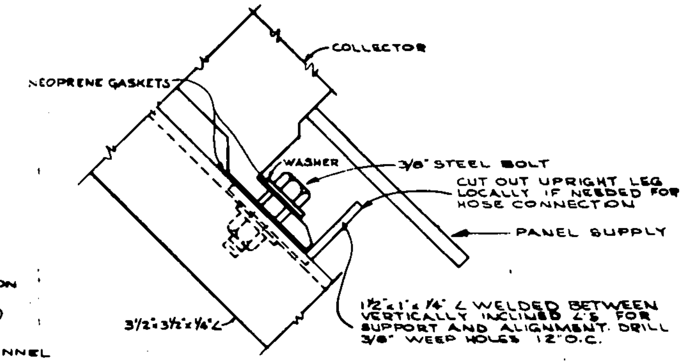
SECTION "A"-"A"
SCALE: 1 1/2"=1'-0"



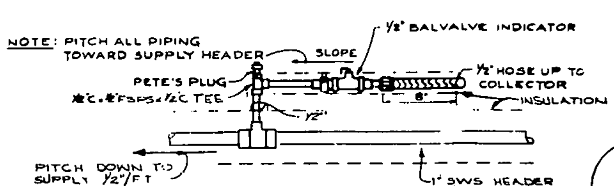
DETAIL OF INSULATED PIPE THRU THE ROOF
NO SCALE

NOTES:

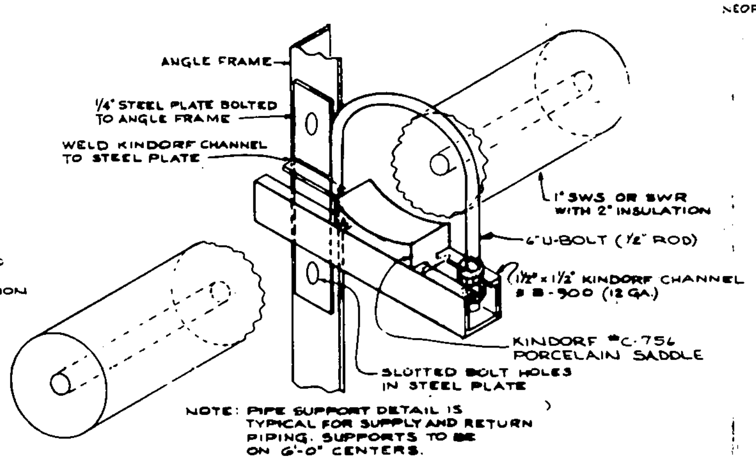
1. CORRUGATED METAL SIDING MUST BE PROVIDED AND ATTACHED TO VERTICAL AND HORIZONTAL MEMBERS. SIDING TO BE RUN IN HORIZONTAL DIRECTION.
2. PAINT CORRUGATED METAL SIDING AND ALL EXPOSED METAL AND PIPING ABOVE THE ROOF WITH ONE COAT PRIMER AND TWO COATS MAB #4-5M FLAXSEED ENAMEL.
3. ALL BOLTS ARE 3/8" Φ ASTM A307 WITH NUTS.
4. STRUCTURAL STEEL: ASTM A36
5. CONSTRUCTION:
   a) ANGLE FRAME TO BE ERECTED PLUMB
   b) TEMPORARY BRACING IN LONGITUDINAL DIRECTION SHALL BE PROVIDED PRIOR TO INSTALLATION OF METAL SIDING.
   c) CONSTRUCTION SHALL CONFORM TO A.I.S.C. 7th ED.



DETAIL "A"
NO SCALE



TYPICAL SUPPLY CONNECTION
SCALE: 1 1/2"=1'-0"



NOTE: PIPE SUPPORT DETAIL IS TYPICAL FOR SUPPLY AND RETURN PIPING. SUPPORTS TO BE ON 6'-0" CENTERS.

PIPE SUPPORT DETAIL
NO SCALE

GOLZ & WICK
CONSULTING ENGINEERS
PHILADELPHIA, PENNSYLVANIA

REVISED SECTION A-A

WEST CHESTER WORK CENTER
MATLACK ST. WESTGOSHEN TWP. CHESTER CO. PENNA
THE WRIGHT/KLETT ASSOCIATION · ARCHITECTS
OFFICE & STORAGE BUILDING
PART ROOF PLAN COLLECTOR DETAILS
SCALE AS NOTED DRAWN GEW DATE 11-12-76
BT-17
A-10A (PART OF BULLETIN #6)

Appendix B

Construction Photographs

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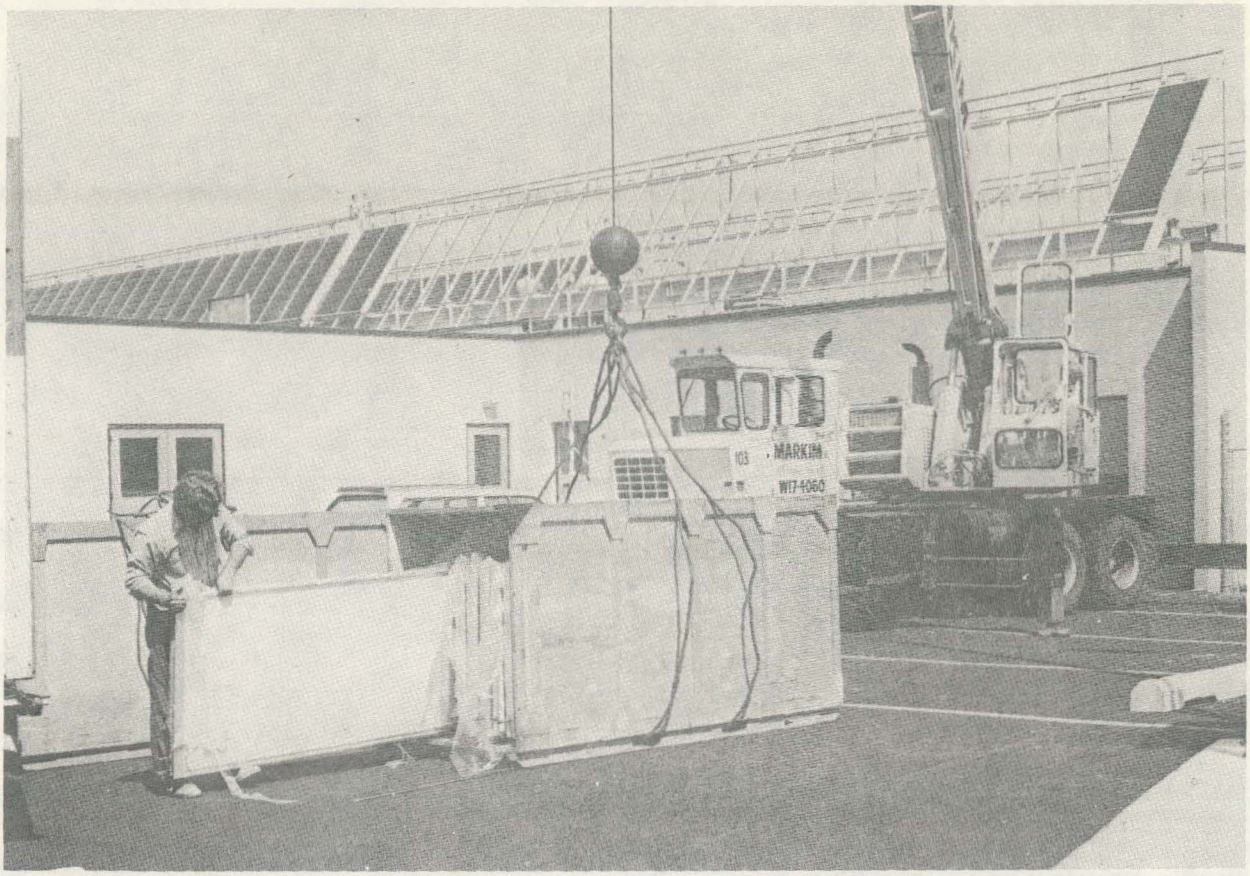
103
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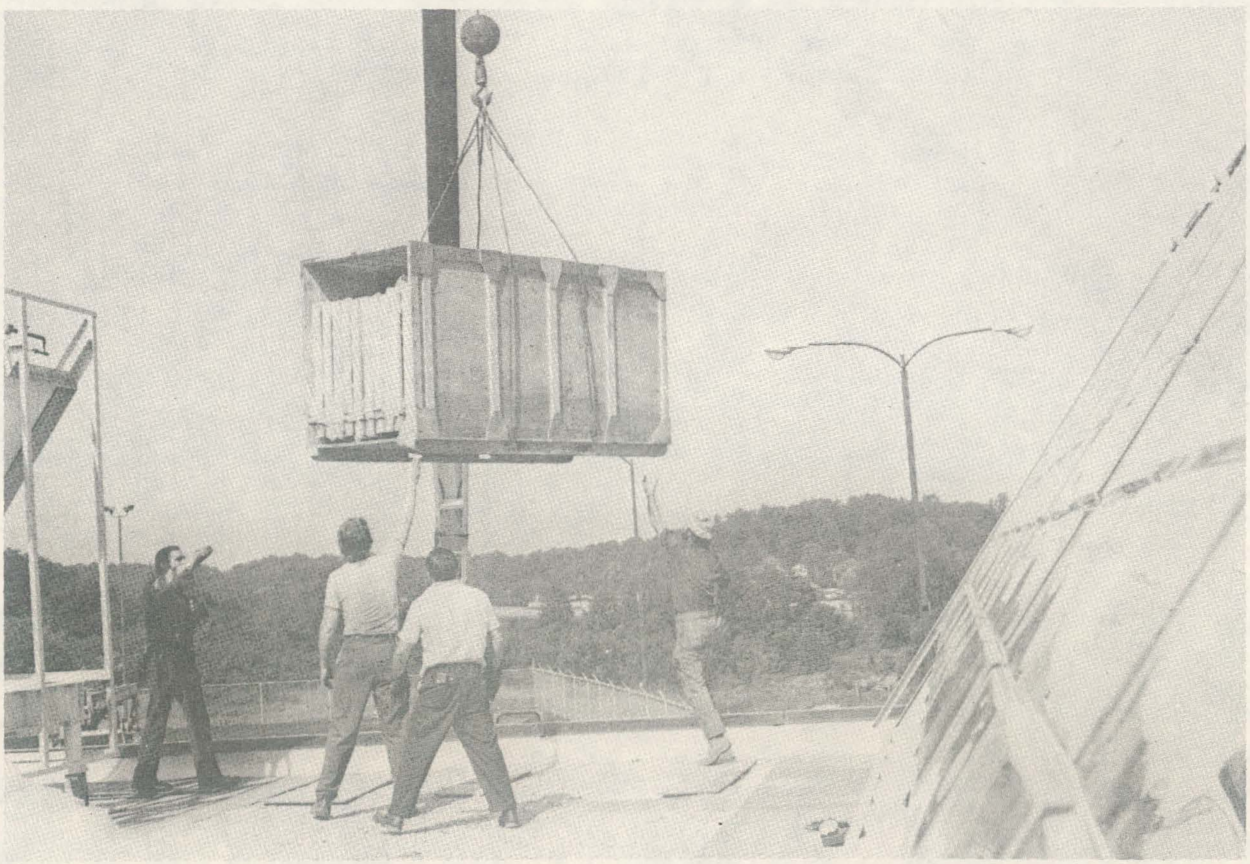

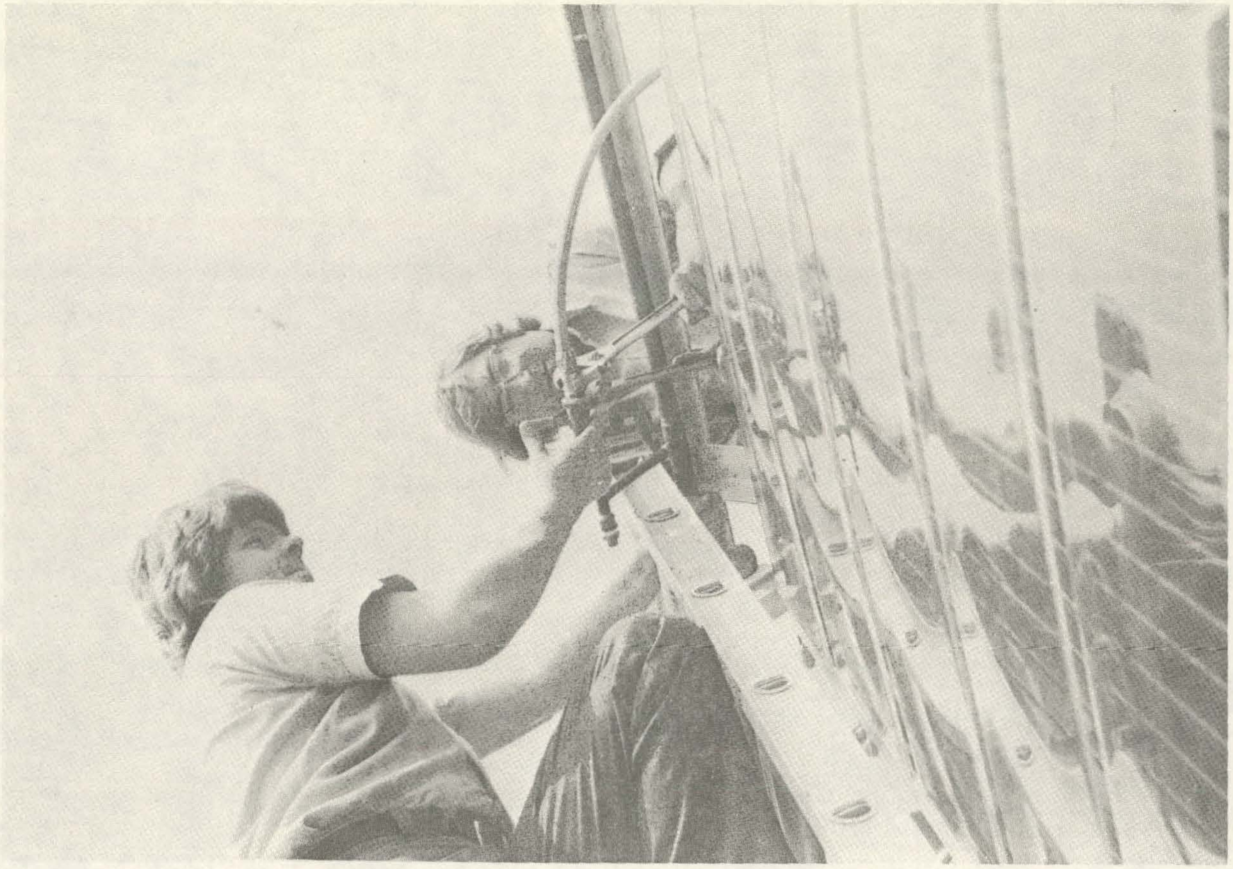

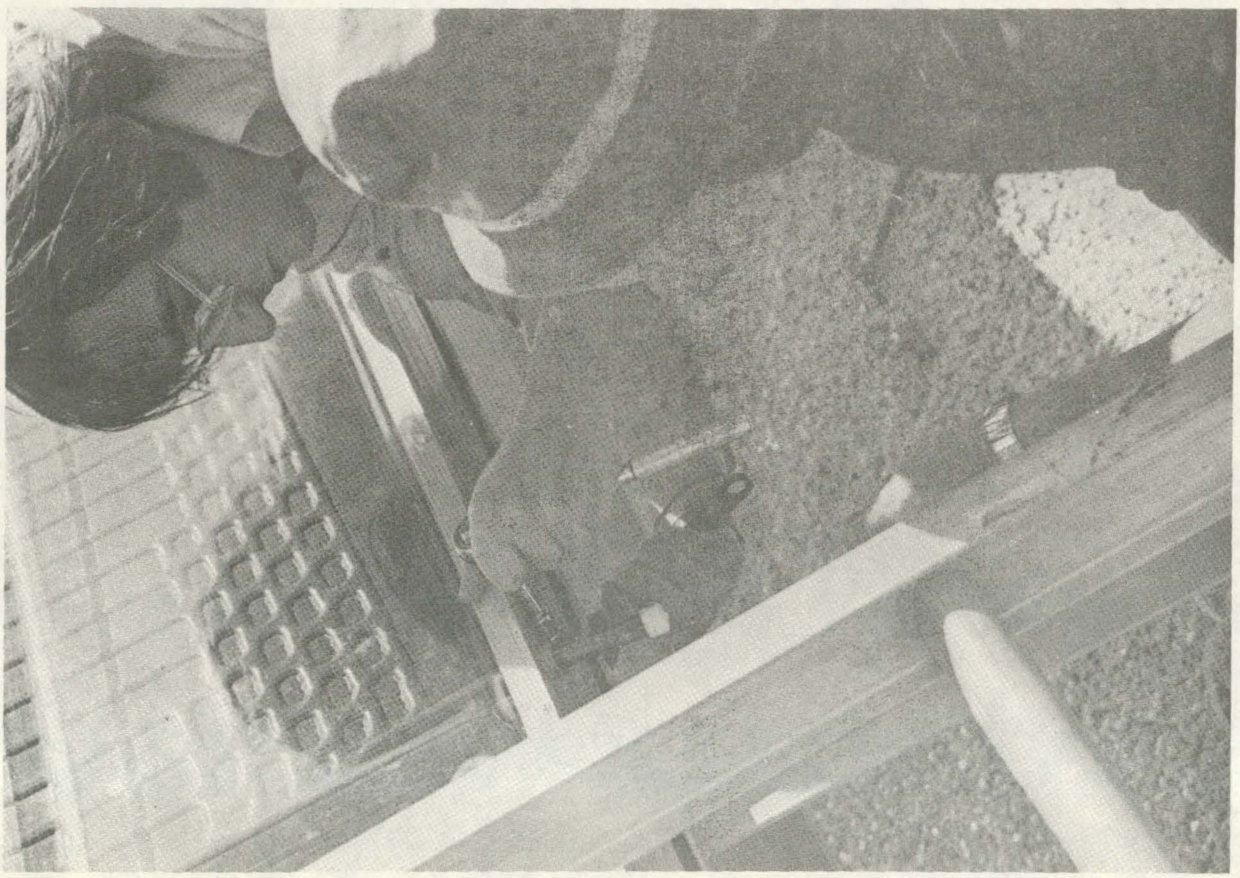

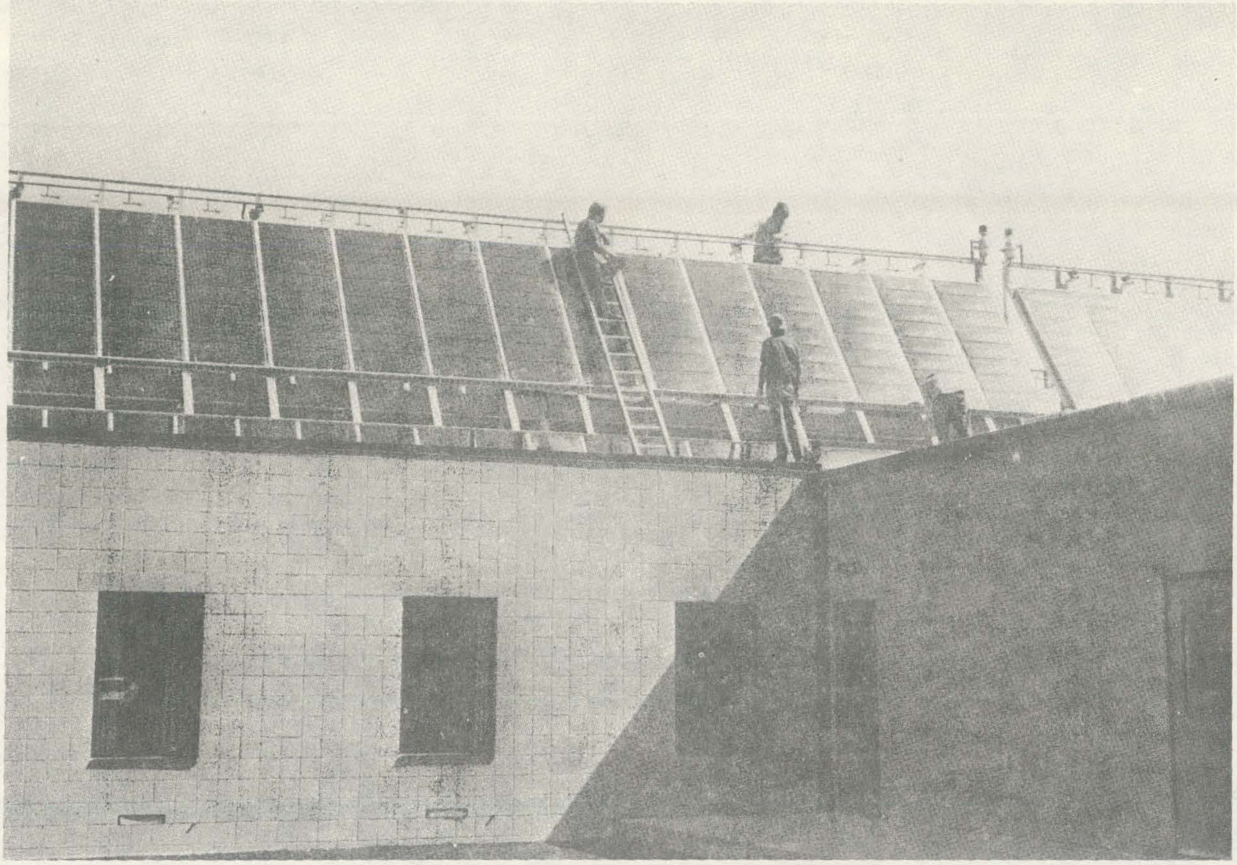

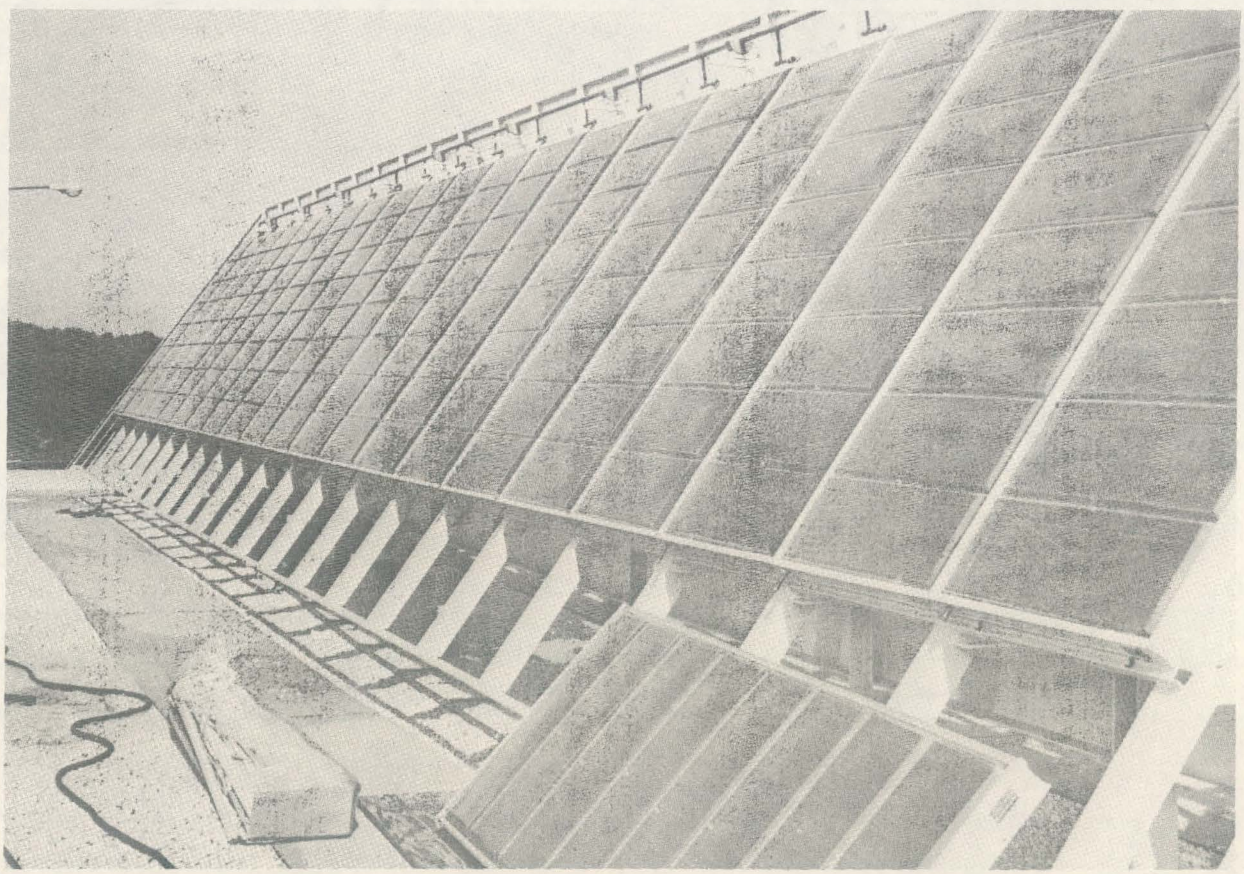

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