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WEST CHESTER WORK CENTER. SOLAR SPACE HEATING DEMONSTRATION PROJECT

Final Technical Progress Report

August 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

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Bell Telephone Company of Pennsylvania

One Parkway

Philadelphia, Pennsylvania 19102

Prepared for

U.S. Department of Energy

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ABSTRACT

This document is the final technical report on 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. 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. The system design was based on solar energy providing 62% of the heating load, with the balance to be supplied by heat pump power and 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 overruns, 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.

System operation during two heating seasons disclosed the need for some major modifications to avoid freeze-ups and improve efficiency and reliability. These modifications were implemented during 1978 at a total cost of $38,382. In addition, the cost of repairing the damage caused by a 1977-78 freeze-up was $25,173. Solar energy collected during the 1978-79 heating season was only 77 million Btu's, less than half the design expectations. This can be attributed to the fact that the system was not operating at par until the modifications were completed in January, 1979.

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 10.1.

The solar heated building is one of two buildings situated on a five acre lot (Figure 1). It is located at 966 Matlack Street, West Goshen Township, Chester County, Pennsylvania. The building 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 10.1. 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 of the system as designed. The drawings used for construction of this project are included in Appendix A of this report. The specifications for the entire HVAC system are included in Appendix C of Reference 10.1.

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.

Following completion of the system installation, it was placed in operation for the first time in October, 1977. However, many difficulties were encountered, necessitating prolonged shutdowns during the 1977-78 heating season and the execution of major modifications over a period of several months. System operation during the 1978-79 heating season showed noticeable gradual improvement. Operation during February, 1979, which included a 15 day stretch of continuous subfreezing weather, was quite satisfactory.

This report encompasses the entire project. It summarizes information on the design, construction and operation of the system, which appeared in References 10.1, 10.2 and 10.3, respectively. Included in this report are details of our experience with the system during its first two heating seasons.

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 were 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 closed circuit 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 DESIGN SUMMARY

The design of the system, described in Chapter 2.0 of this report, evolved from the generic design drawings and specifications which were prepared by InterTechnology Corporation (ITC) and presented by ERDA to Bell of Pennsylvania in June, 1976. The main features of the design scheme developed by ITC was kept intact, except for changing the system from open to closed with nitrogen pressurization.

3.1. Modifications to the Generic Design:

With an open system, all the water contained in the piping and the components located above the water level in the storage tank would have drained into the tank every time the pumps were de-activated. This would have caused the introduction of air, which could not be easily vented when pumps were re-activated. Also, the introduction of air would have accelerated corrosion and scale-formation within the system, which includes components having small water passages that can get clogged easily.

With a pressurized system, no air is likely to be introduced because, except for the solar collection loop, water would remain in its place even when pumps are shut down. To permit draining of the water out of the collectors for the sake of freeze avoidance, a "Holding Tank" was added, to which water drained out of the collectors is diverted by automatic positioning of two pairs of valves. This holding tank is pressurized with nitrogen which, when displaced by water drained out of the collectors, is transferred upwards to fill the voids in the collectors and keep the system pressurized. In addition to the holding tank, a "Refill Pump" was added to accomplish the task of refilling the collectors prior to the resumption of normal solar energy collection into the main storage tank.

To accommodate the pressurization scheme, controls were modified by adding four float switches above the collectors, which serve to shut-down the refill pump, re-position several valves, and activate the solar collection pump. The detailed operation of all controls is described in drawing M-5, Appendix A. The latest version of the solar collection loop controls is described in Appendix B.

Other modifications to the generic design involved various revisions to the piping system, such as increasing the slope of the supply headers, increasing the number of risers from four to twelve and adding a branch off the collection loop connecting to the holding tank and refill pump.

The closed-circuit "Cooling Tower", needed for heat rejection from the "Heat Pump Units" during the cooling season, was moved from the roof to inside the mechanical room. Outside air ducts for supply and exhaust were connected to the cooling tower.

All of the modifications to the generic design are described in more detail in Chapter 3.0 of Reference 10.1.

3.2. Selection of Solar Collector Panels:

Back in 1976, there were very few collector manufacturers who could provide performance data on their products, certified by an independent testing agency. That situation made the task of selecting a collector panel for this project difficult and time consuming.

The procedure followed in panel selection was to invite thirteen manufacturers to submit bids, each including an efficiency plot generated in accordance with NBS1R 74-635: "Method of Testing for Rating Solar Collectors Based on Thermal Performance". Additional information requested from the bidders included materials used for panel components and the type of warranty offered.

In order to translate the bidders' submittals into Btu's per dollar, various values of efficiencies, read from the bidders' submittals, corresponding to the pertinent environmental parameters $\left(\frac{T_{fluid} - T_{ambient}}{Insolation}\right)$ were divided by the cost of an installed panel in dollars per square foot. These quotients become cost merit figures, by which it was possible to determine which panel offered the best return for the investment. This procedure is described in detail in Chapter 4.0 of Reference 10.1.

Based on cost merit figures and other considerations, the solar panel selected for this project was Heliotherm Model DC24SC. A brief description. a partial cross section and an efficiency plot of this solar collector appear in Table 2 and Figures 4 and 5, respectively. More details about this panel appear in Appendix D of Reference 10.1.

4.0. CONSTRUCTION SUMMARY

Following the selection of Golz and Wick, Consulting Engineers of Philadelphia, Pennsylvania, as the "Integrating contractors", six mechanical contractors were invited to bid on the building HVAC system, including the solar heating portion, on a "Time and Material" basis with a "Not-to-exceed" total sum. Out of the six bidders, Hummel Engineering Corporation of Philadelphia, Pennsylvania, was selected to furnish and install the system. The estimated incremental cost of the solar heating system was $226,615. On this basis, Bell of Pennsylvania negotiated its contract with ERDA for a fixed lump sum of $201,429. A listing of major suppliers for this project appears in paragraph 3.5 of Reference (10.2).

For reasons discussed in Reference (10.2), the completion of this installation took six months longer than originally planned and resulted in cost over-runs amounting to $109,942. Table 3 of Reference (10.2) contains an itemized breakdown of the cost over-runs.

The highest cost over-run (95.9%) was incurred in conjunction with the automatic controls for the solar collection loop. This item, which was subcontracted to Honeywell by Hummel Engineering, was grossly underestimated initially. The second highest cost over-run (93.5%) was incurred in conjunction with the solar panel structural supports. The reasons given for this cost increase were the use of heavier structural steel elements than originally estimated and the need to use iron workers in lieu of sheet metal workers. Other major cost over-runs, ranging from 34% to 66%, were incurred in conjunction with the piping, the storage tank, the Integrating Contractors' fees and the visitors' display room.

One of the items contributing to both schedule delays and cost increases had to do with the fact that the performance-monitoring sensors were not finalized and delivered to the installer early enough. Because the building had to be occupied by April, 1977, the HVAC subcontractor was told to proceed with the piping installation prior to receipt of the sensors, and found it necessary later-on to re-do some of the piping to accommodate flow-sensor requirements.

5.0 OPERATION SUMMARY

Upon completion of the construction stage, the solar system was activated in October, 1977. In the first few weeks of operation, when outdoor temperatures seldom fell below freezing, there were very few operational problems. However, with the advent of freezing weather, several deficiencies were discovered as a result of freeze-ups which occurred in late December, 1977, and late January,

1978. It became necessary to shut down the solar collection loop, pending the execution of the following modifications to both the controls and the hardware:

5.1. Solar Collection Loop Controls Modifications:

Among the control system modifications which had to be introduced were the following (See Flow Diagram, Drawing M-4, Appendix A):

5.1.1. Heat-tracing of the automatic vent traps: Four automatic vent traps located above the collector panels, and connecting the return headers to the holding tank to permit nitrogen flow between the panels and the tank, were getting stuck due to freeze-up of water vapor in their small ports. To remedy this situation, electrical resistance wire was wrapped around each of the four float switches and automatic vent traps. These assemblies were then enclosed within two insulated boxes to minimize any loss of heat to the cold outdoor air surrounding them. Thermostatic surface-contact elements were provided to energize the heaters as needed to maintain the vent valves at a minimum temperature of 45°F at all times.

5.1.2. Drain control modification: The original controls called for the cessation of solar energy collection when insolation drops below the level required to maintain a 3°F differential between the absorber plate surface and the storage water. This was accomplished by de-activation of the circulation pump, leaving the water in a stagnant condition within the collectors and outdoor piping until the absorber plate surface temperature drops below 40°F, thus initiating a drain-down. A risk inherent in this procedure is that some elements of the outdoor piping may freeze before the absorber plate temperature sensor has had a chance to drain the system. To minimize such risk, we proceeded to add an outdoor temperature sensor, which acts to drain the system whenever the solar collection pump is inactive while the outdoor temperature is below 45°F.

5.1.3. Valve sequence time delay: The solar collection loop controls include two sets of pneumatic valves: One set, V_A and V_B, connects the collectors to the Holding Tank and the other set, V_C and V_D, connects the collectors to the Storage Tank. The initial system control was such that while one set of valves is closing, the other set starts to open. That procedure created a situation where the two tanks become interconnected for a few seconds, resulting in some migration of water in one direction or another depending on which tank had a momentarily higher pressure. This situation was especially bad when it caused the water quantity in the Holding Tank to become inadequate to refill the collectors completely. Under those circumstances, the refill pump would never stop and normal solar collection cannot be initiated automatically. To remedy this situation, it became necessary to introduce an automatic time delay between the sequence of operation of the two different sets of valves.

5.1.4. Prevention of nitrogen trapping during refill: Initially, the refilling of the collectors was done through both supply and return risers. This was causing some nitrogen to be trapped momentarily within at least some of the collectors, giving a false signal to the float switches "FS-1,2,3 and 4" that the collectors had been completely filled. This signal would then switch the operation prematurely from "P5" to "P1", causing the two pumps to cycle back and forth. To correct this problem, the control was modified so that following the first "Collectors Full" signal which the float switches receive, valve "V_B" closes to allow any additional water required to enter the collectors from the bottom only, thus driving any trapped nitrogen out through the automatic vent traps. A time-delay relay was also installed to keep the refill pump running for five minutes after the first "Collectors Full" signal is received. During that interval, pump "P1" would start, but any water it pumps out of the Storage Tank would be blocked by valve "V_C" being in a closed position.

5.1.5. Prevention of refill pump cycling: It was discovered that valve "V_D" in the return line from the collectors to the Storage Tank opens a few seconds before valve "V_C", which connects the supply line from the storage tank to the collectors. This situation was causing the water level at float switches "FS-1,2,3 and 4" to drop momentarily, shutting down pump "P1" and re-starting pump "P5". To correct this dificiency, pneumatic restrictors were modified to slow down the opening of valve "V_D".

5.1.6. Drain malfunction alarm: Due to the fact that this system is left unattended most of the time, it was deemed advisable to be able to transmit an automatic alarm, around the clock, in case the system does not drain when it should. To accomplish this, it was necessary to provide water level sensors in six out of eight risers connecting the collectors with the holding tank. These sensors were installed to sense whether the water level has dropped below the roof when insolation became inadequate for collection of solar energy while the outdoor temperature was below 45°F. In the event that this has not occurred within thirty minutes, an alarm is transmitted to a remote station where there is an attendant available 24 hours a day, seven days a week. The receipt of such an alarm would cause a serviceman to be dispatched to the site, in order to do what is necessary to force the system to drain before it freezes.

5.1.7. Refill pump overtime alarm: When the system is operating normally, it takes about five to seven minutes of refill-pump operation to fill all of the collectors and the piping above the roof. Following this event, the refill pump shuts down automatically in preparation for the resumption of solar energy collection. There may be occasions when a system malfunction causes the refill pump to run overtime, either due to a blockage in the system or inadequate water quantity in the holding tank. Such a malfunction can be a prelude to a system freeze-up. It was deemed advisable to install a timer that would shut-down the refill pump automatically after fifteen minutes of operation, simultaneously transmitting a remote alarm similar to the one described in section 5.1.6 above.

5.2. Heat Utilization Loop Controls Modifications:

There are two circulation pumps "P3" and "P4", which supply hot water to the forced-flow heaters and the air-handling unit, respectively. These two pumps were set initially for continuous operation, regardless of the need for heat by the equipment served. It was later determined that by confining the activation of these two pumps to periods when the equipment served by them need heat, we would not only save pump operational energy, but also minimize the undesirable addition of electrical heat to the storage tank. Accordingly, the pump controls were so modified. Additionally, to guard against any possible freeze-up of stagnant water in the coil of the air handling unit, which may be caused by cold air leaking through the outside air damper, a temperature sensor attached to the surface of the coil was provided to start pump "P4" if the coil temperature drops below 40°F. The modification to pump "P3" control was to activate it whenever the outdoor temperature falls below 55°F.

5.3. Hardware Modifications:

5.3.1. Header to panel connections: As shown in the dotted lines of Figure 6, the connections between the supply headers and each solar panel were originally installed with a 90° elbow and included a flow measuring and adjustment device having a 3/16 inch orifice. It was determined that this arrangement had to be changed to avoid possible freeze-ups. All 88 connections between the supply headers and each panel were modified as shown by the solid lines of Figure 6.

5.3.2. Outside air damper improvement: The air handling unit serving the Storeroom had conventional outside and return air dampers. Such dampers, even in the closed position can have air leakage rates of 15 to 25%. In order to minimize heat loss from the heating coil to outside air, the original outside air damper was replaced with a tighter one, guaranteed to have no more than 2% leakage rate.

5.4 Collector Panel Repairs:

Early in 1978, it was discovered that approximately half the solar collector panels exhibited various degrees of warpage, some with slight ripples, others with out-of-plane warpage severe enough to have dislodged the plexiglas cover. In addition, seven panels developed leaks in the end waffle section. The collector manufacturer disclaimed any responsibility for the damage to the absorber plates, basing that on the occurrence of freeze-ups. An independent investigation, conducted later in September 1978 by the Franklin Institute Research Laboratory, attributed the warpage to both freezing and lack of adequate allowance for differential expansion. However, Bell of Pennsylvania did not press its case against Heliotherm on this matter.

Another defect discovered in the collector panels was relative shrinkage of the plexiglas covers, which resulted in gaps between them and their frames. Some of the gaps were so wide as to allow rain water to accumulate inside the panels. In this case, Heliotherm agreed to provide a better seal between each cover and its frame.

In order to render all the panels operable for the 1978-79 heating season, consideration was given to either straightening out the badly-warped plates or replacing them with new ones. Economic and schedule considerations resulted in a decision to straighten out most of the warped panels, while replacing the ones which were beyond repair.

5.5. Modification and Repair Costs:

The costs incurred in connection with the above modifications and repairs amounted to $63,555. A breakdown of these costs appears in Sections 4.10 and 5.0 of Reference 10.3.

6.0 SYSTEM PERFORMANCE

6.1. Historical Narrative:

Although data from 24 temperature sensors, 10 flow sensors and 12 power sensors were accumulated continuously since October, 1977, the first meaningful performance report to be issued by IBM-Huntsville was for November, 1978. The reasons for this delay were:

6.1.1. The system operation during the 1977-78 heating season was sporadic, punctuated by two lengthy shutdowns.

6.1.2. The accuracy of the data was not considered reliable by IBM during the first year of operation. The temperature probes were partially influenced by the ambient temperature, thus needing external insulation. Some of the flowmeter data, where the flow rates change abruptly, reflected inaccuracies caused by instantaneous sampling every five minutes. Correction of this deficiency had to be accomplished by adding totalizing devices for two flowmeters.

6.1.3. Temperature differential sensors originally installed were found to be not as accurate as absolute temperature sensors. Therefore, all temperature data had to be converted to absolute readings.

IBM completed the required modifications to the site data acquisition system (SDAS) on November 2, 1978. While no meaningful performance reports were generated until then, the SDAS was very useful in providing information for trouble shooting at times when the system was malfunctioning. Typical of such useful information was knowing the timing of activation of various pumps and the simultaneous insolation rates.

6.2. Performance Parameters:

Because of the unavailability of meaningful monthly performance reports prior to November, 1978, the discussion of system performance will be confined to only five months of the 1978-79 heating season. Table 3 represents a summary of significant performance parameters for each month. Most of the terms used in this Table are self explanatory and their values were taken directly from References 10.4 through 10.8. However, the values of the following parameters, appearing in the Table, differ from those listed in the IBM Monthly Performance Reports as discussed below:

6.2.1. Solar energy used: For the purpose of this report, this parameter has been computed as the collected solar energy during the month modified by any addition or removal of energy from storage, as the case may be. Because all of the system components are located within the confines of this building, any energy losses from storage are considered to have been utilized towards satisfying the space heating load. This procedure would not be accurate in a project where the storage tank is located underground or outside the main building, in which case losses from storage are real.

6.2.2. Space heating load: For the purpose of this report, this parameter has been computed as the sum of the solar energy used, auxiliary thermal energy and system operating energy. This computation differs from the values listed in Reference 10.4 through 10.8, which were computed from direct measurements of flow rates and temperature drops of the water circulating through the various heating devices. The logic behind the procedure followed in this report is that any heat lost from the uninsulated piping system is dissipated within the building space and therefore contributes towards satisfying the space heating load. Also, it is assumed that even the energy used to run the pumps and fans is converted into heat which gets dissipated within the building space.

6.2.3. Solar fraction: This parameter is simply the ratio of solar energy used to the space heating load. Due to the fact that values for these two parameters used in this report differ from those listed in References 10.4 through 10.8, it follows that the monthly solar fraction will also differ.

6.3. Observations:

A discussion of significant observations follows:

6.3.1. Solar collection and electrical savings: A glance at the numbers listed in Table 3 shows progressive improvement in the system performance. Especially noticeable are the month-by-month increases in solar collection efficiency and electrical energy savings. These improvements can be attributed to progress in the automatic operation of the system, which permitted taking better advantage of available solar energy.

There is room for further improvement in this regard, because the ratio of operational incident solar energy to total incident solar energy is still too low. This ratio is a direct measure of the fraction of the time when the collection pump is active while solar energy is available for collection. In February, when this ratio was the highest achieved, it was still only 0.71. This is an indication that solar collection time could be further improved. One way to increase this ratio is to re-adjust the differential temperature controller settings (between the absorber plate and storage water) so that there will be less frequent drain-and-refill cycles on partly-cloudy days and longer periods of solar collection on sunny days.

6.3.2. Space heating load: Monthly space heating loads are expected to be proportional to the difference between average building temperature and average ambient temperature for the month. Table 3 shows that the space heating loads for November and December were much higher than would be expected on the basis of the weather. This was caused mainly by a fault in the controls of the air handling unit, used to heat the Storeroom, which made the fan run all night, drawing outside air through a leaky damper and across the heating coil. This fault was later discovered and corrected by making the fan shut down at night and by replacing the conventional outside air damper with one having less than 2% leakage.

6.3.3. Daily solar collection: The IBM Monthly Performance Reports (Reference 10.4 through 10.8) include collector performance parameters on a daily basis. Examination of these parameters indicates vividly that on clear sunny days, when the system operation is not interrupted by drain-and-refill cycles caused by intermittent reductions in insolation, it is possible to collect up to 2.2 million BTU's per day, at an average daily collection efficiency as high as 47%. This is an indication that the system has a very good potential performance, which can be enhanced by taking the necessary measures to reduce unnecessary drain-and-refill cycling on partly-cloudy days.

6.3.4. Comparison with projected performance: Table 4 lists several parameters which are significant in comparing the 1978-79 solar collection with design expectations. It is important to note, by comparing lines (3) and (6), that the actual 1978-79 insolation was quite different from the historical long term values for each of the five months listed. However, since the solar collection efficiencies, actual and long term, are based on the respective insolation, it is valid to view those efficiencies as measures of how well the system performed. Thus, comparison of line (8) with line (5) indicates poor performance for the first three months listed, due to the fact that the collection loop was being operated in the manual mode while undergoing the improvements described in paragraph 4.9 of Reference 10.3. The actual collection efficiency for February, 1979, came close to prediction (32.5% versus 37.1%), indicating a considerable improvement in the operation of the collection loop. This improvement did not hold as well for March, 1979, mainly because March weather included several warm days, when solar collection was interrupted automatically due to the storage water temperature having approached its high limit of 190°F.

7.0 FUTURE IMPROVEMENTS

At the conclusion of the 1978-79 heating season, an appraisal was made of the system operation, with a view towards further performance improvement. This appraisal resulted in the following decisions:

7.1. Differential Temperature Controller:

The existing controller was a light duty residential model, which was suspected of somewhat erratic operation. It was therefore decided to replace it with a newer model (Honeywell No. R7412A) which has provisions for on-site re-adjustment of the differential settings. This will provide us with the capability to experiment with the differential settings in order to minimize the drain-and-refill cycles on partly cloudy days. New temperature sensors, compatible with the new differential controller, are to be installed at both the absorber plate and the storage tank. In addition, the sensor wiring, which currently runs through the same conduit as the power wiring for the heat-trace tape, will be replaced with shielded cables to avoid any possible interference with the true sensor signal.

7.2. Automatic Vent Traps:

There are four "Fisher Type 30" traps located above the level of the solar collectors, intended to prevent water from entering the nitrogen piping leading to the holding tank. These traps are expected to open automatically at the initiation of a drain operation, to permit the introduction of nitrogen from the holding tank into the solar collectors. There has been some suspicion that on some occasions, the traps did get stuck in the closed position, thus causing water to stagnate in the collectors. To remedy this problem, it is planned to replace these automatic vent traps with solenoid valves, which will open and close, as needed, in response to electrical signals originating at the float switches. The solenoids have the additional advantage of larger openings (3/4"), in lieu of the 3/16" ports in the vent traps.

Appendix B contains a narrative description and associated drawings of the solar collection controls, based on the incorporation of the above-mentioned improvements.

8.0 LESSONS LEARNED

The principal lesson learned on this project is that, to accomplish a successful solar project, there is no substitute for experience. Many of the mistakes that were made can be attributed to the novelty of such an undertaking. However, the mere fact that it is termed a demonstration project implies that changes are to be expected to accomplish progress. Some of the specific lessons learned were:

8.1 Although "Drain-down" solar systems are inherently more efficient than those using antifreeze combined with a heat-exchanger, they require more complex controls which render them less reliable and more troublesome.

8.2 "Pressurized drain-down" solar systems require even more complex controls than "Open drain-down" systems.

8.3 Prior to selection of the basic collection scheme, a thorough economic analysis should be undertaken to compare the cost effectiveness of drain-down systems with those using anti-freeze 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.

8.4. It is a good idea to select one particular solar panel prior to completion of the detailed design of the system. The selection of the panel should take into consideration not only thermal efficiency, but also structural integrity.

8.5. It would be highly desirable to purchase an entire solar system from a single source, if possible. Warranties on individual components purchased from several different sources have little value.

8.6. 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.

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

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

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

8.10. Advertised claims by control manufacturers should not be taken at face value.

8.11. Solar experience of both the consulting engineer and the installation subcontractor is vitally important.

9.0 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.

10.0 REFERENCES

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

10.2. "Construction Report", DOE/CS/4048-2, May, 1979.

10.3. "Interim Test and Evaluation Report", DOE/CS/4048-3, July, 1979.

10.4. "Monthly Performance Report", SOLAR/2012-78/11, November, 1978.

10.5. "Monthly Performance Report", SOLAR/2012-78/12, December, 1978.

10.6. "Monthly Performance Report", SOLAR/2012-79/01, January, 1979

10.6. "Monthly Performance Report", SOLAR/2012-79/02, February, 1979.

10.6. "Monthly Performance Report", SOLAR/2012-79/03, March, 1979.

FIGURE 1

PLOT PLAN

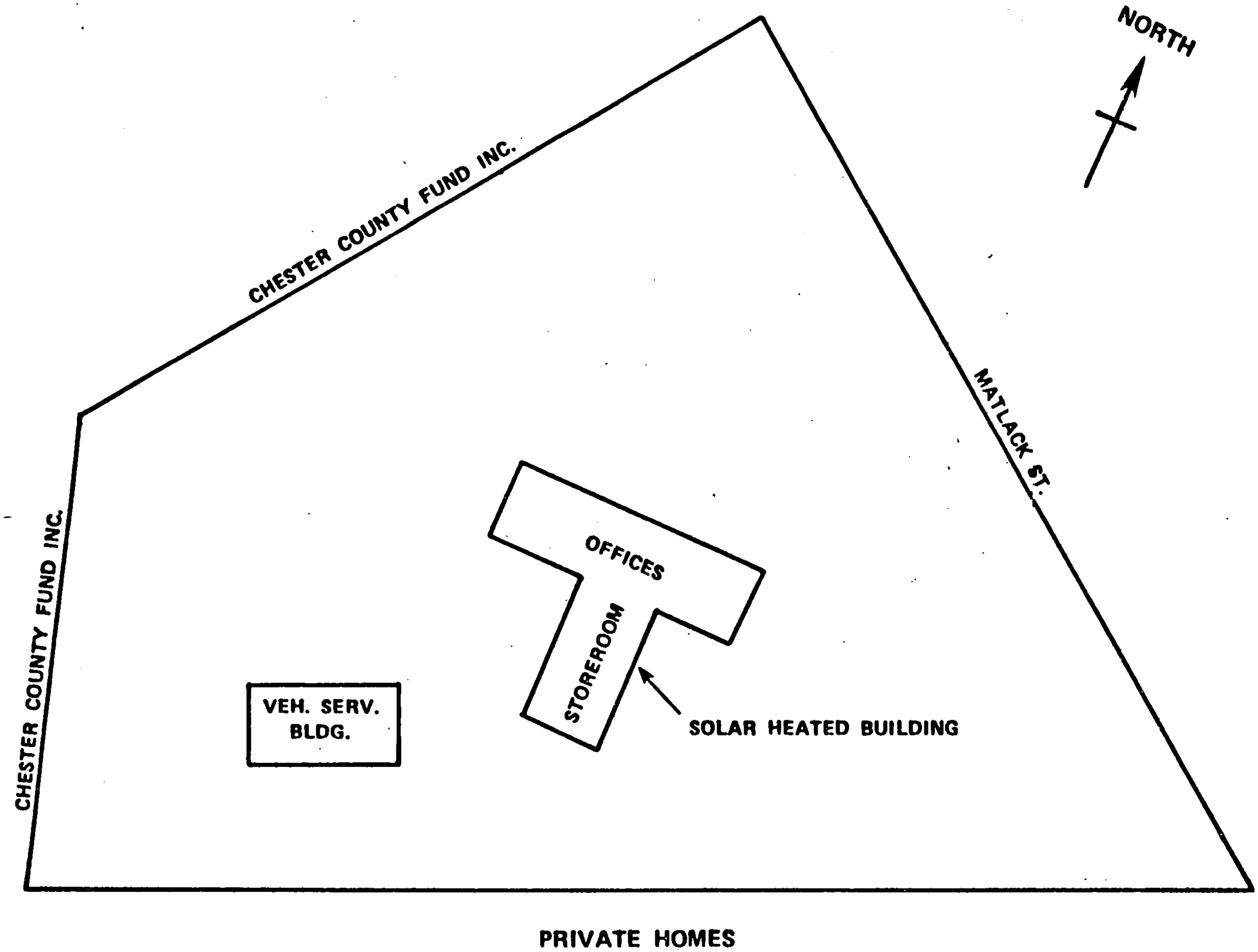


FIGURE (1)

FIGURE 2

FLOOR PLAN

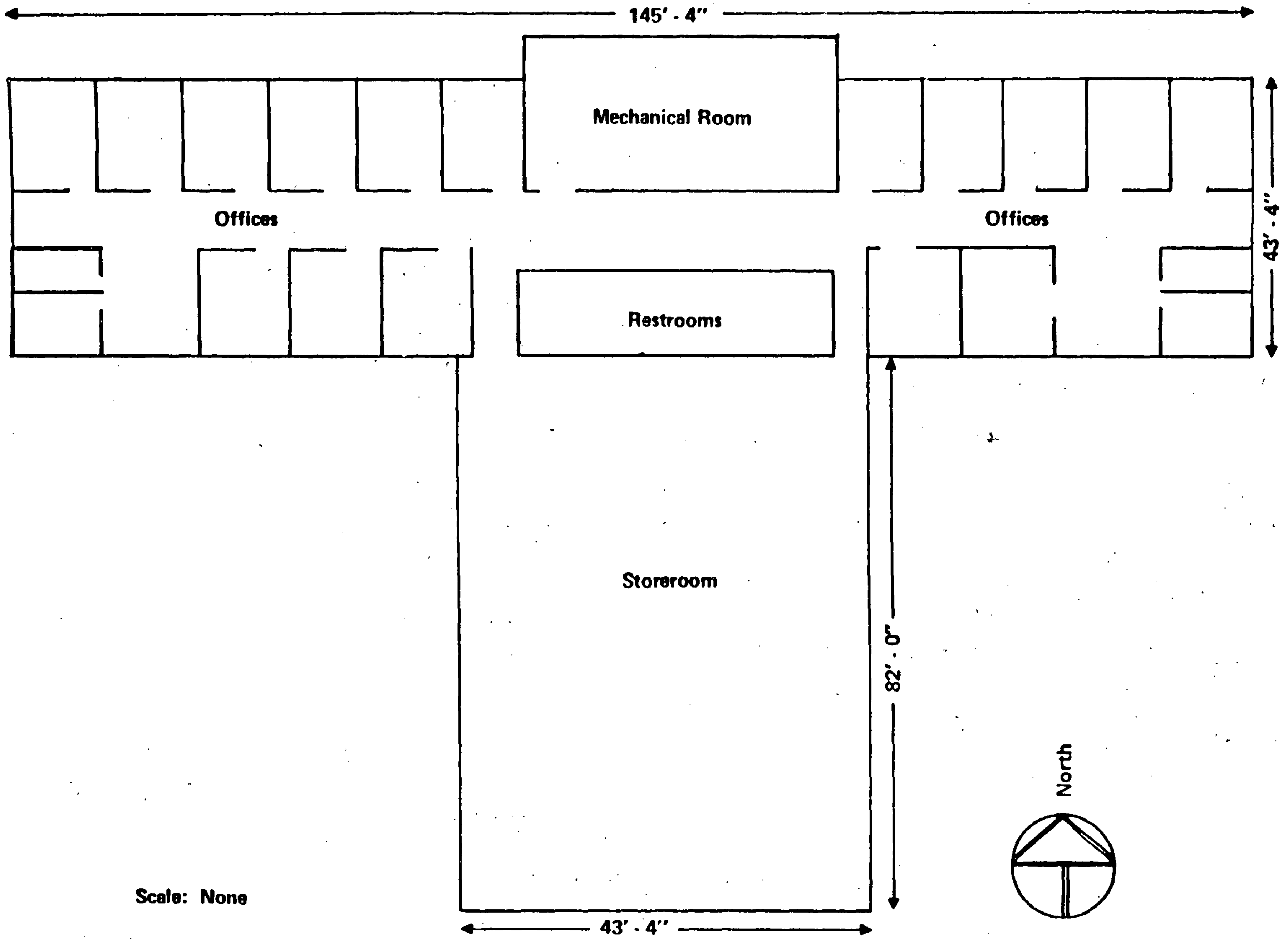
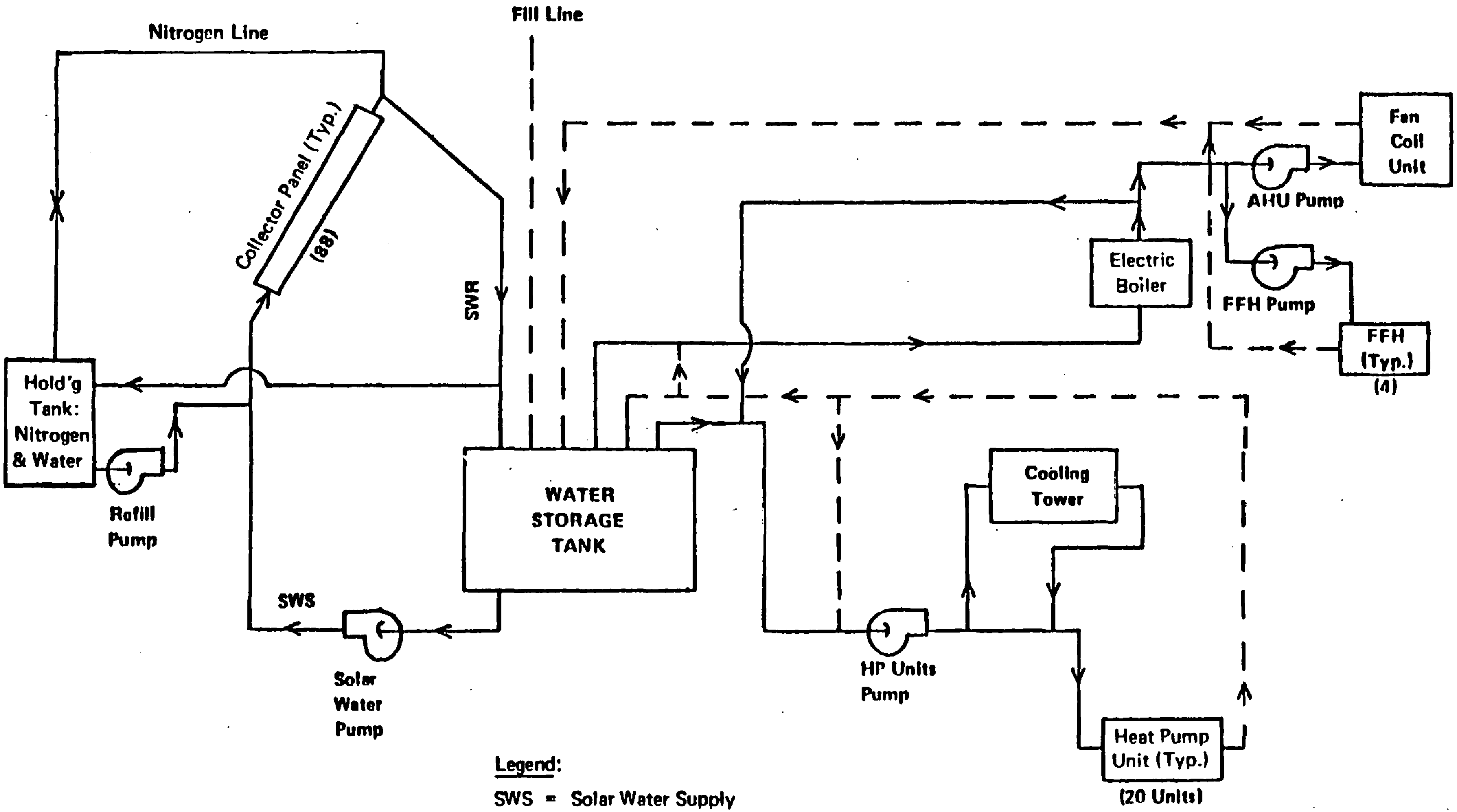


FIGURE (2)

FIGURE 3

SIMPLIFIED FLOW DIAGRAM



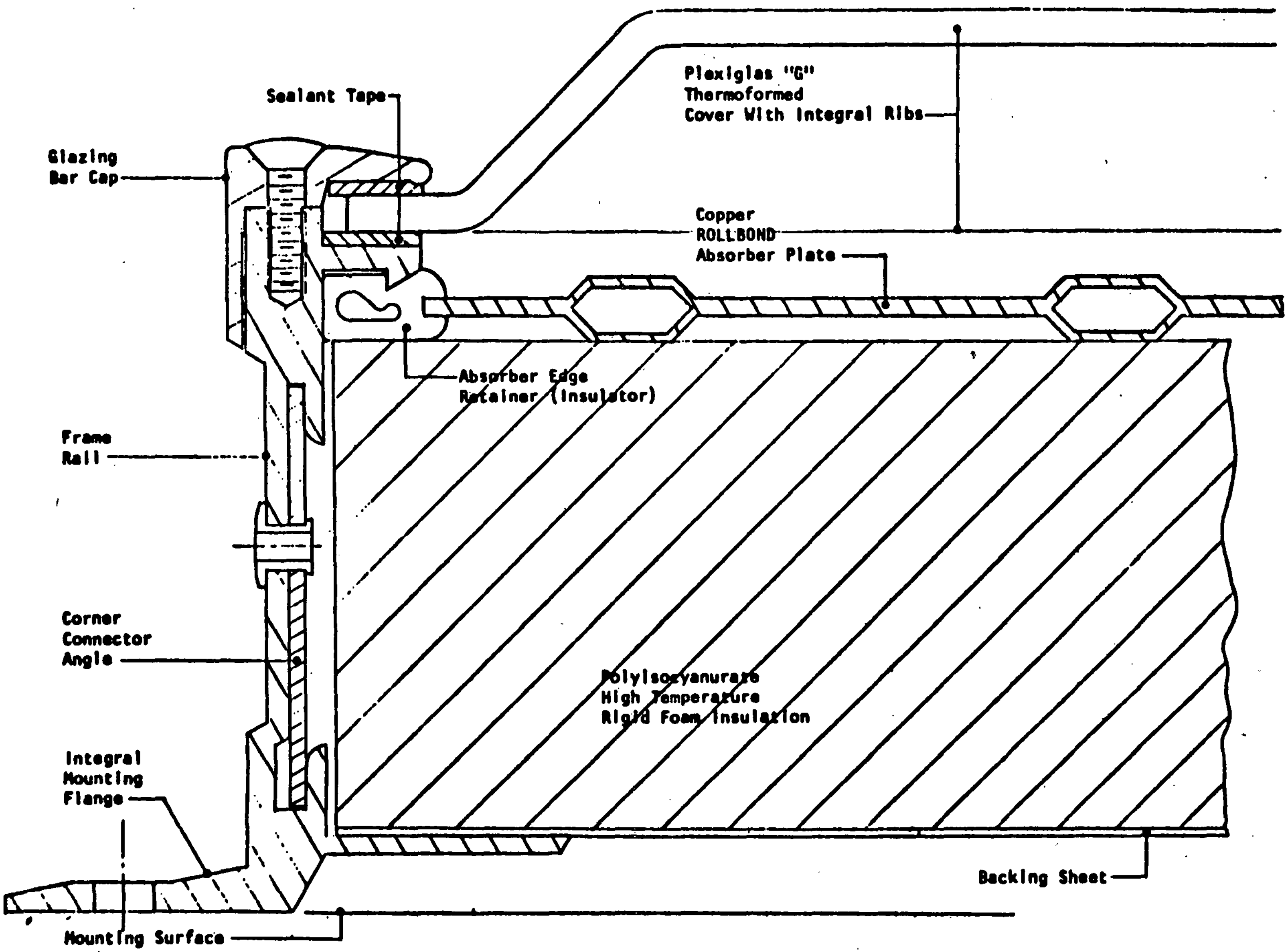
Legend:

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

FIGURE (3)

FIGURE 4

COLLECTOR CROSS SECTION

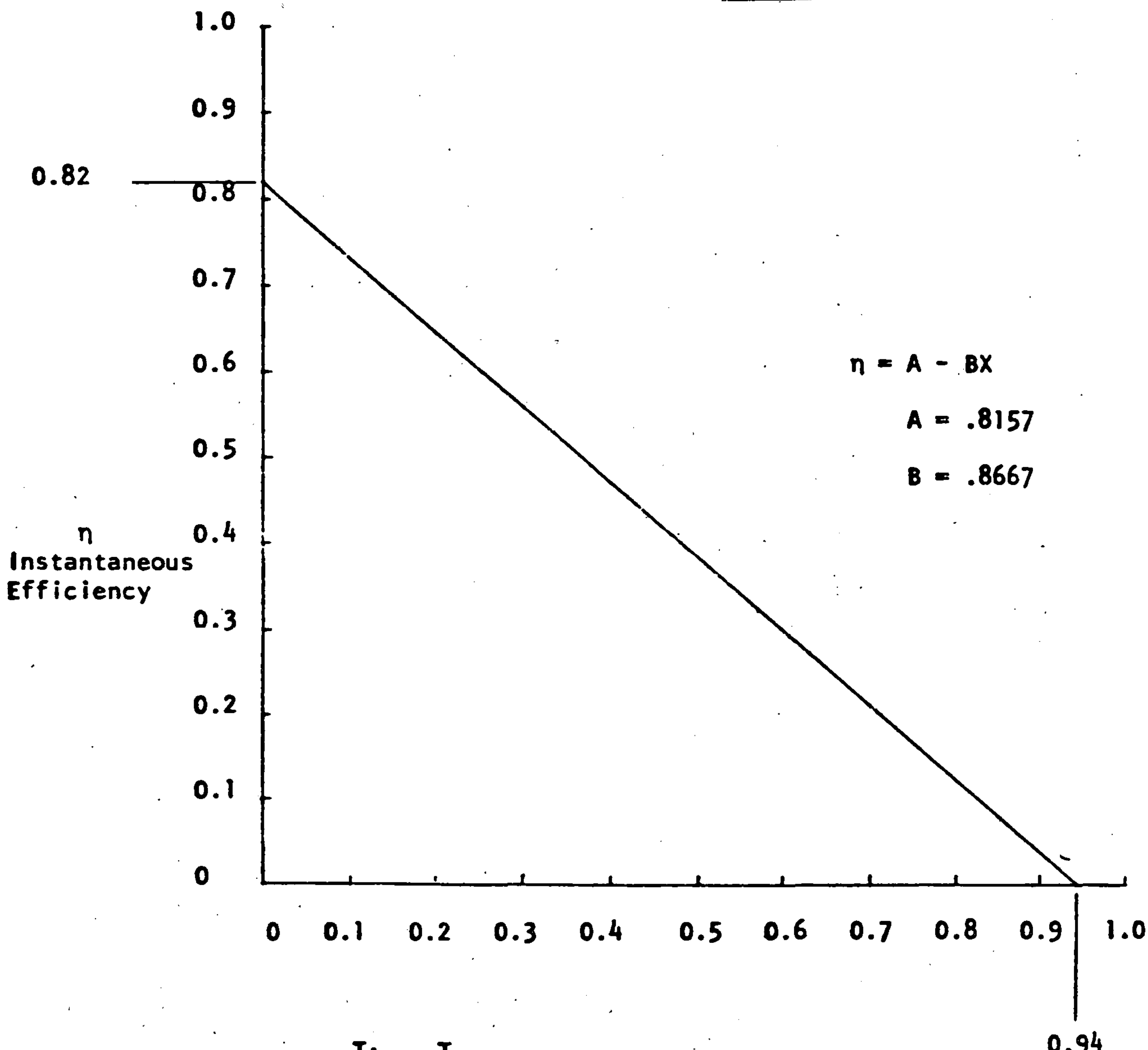


HELIOTHERM DC SOLAR COLLECTOR

FIGURE 4

FIGURE 5

COLLECTOR EFFICIENCY PLOT

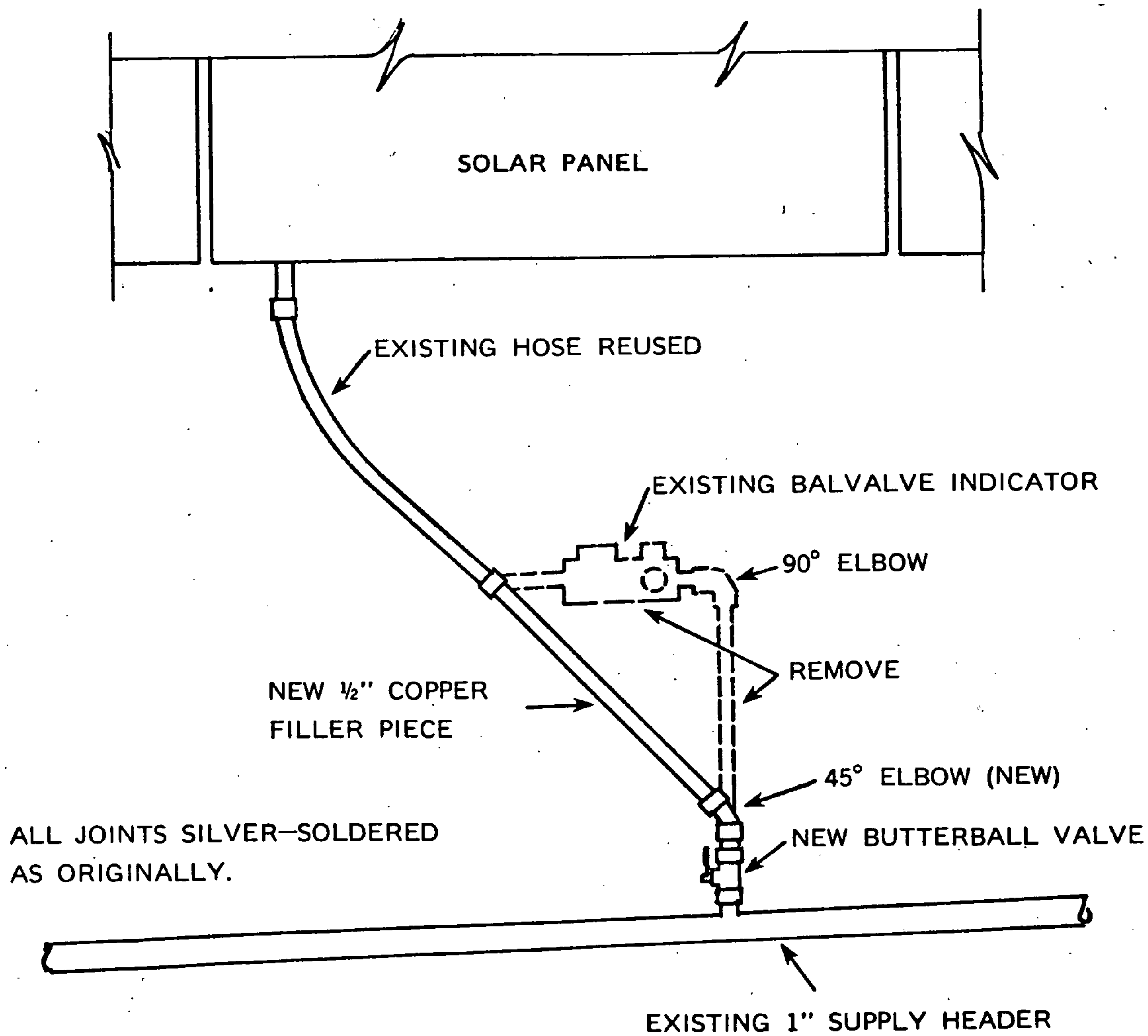


$$X = \{\frac{T_{in} + T_{out}}{2} - T_{amb}\} / Q_i$$

THERMAL PERFORMANCE TEST DATA
HELIOTHERM DC 24 SC SOLAR COLLECTOR

Test Performed by: Dr. David Jackson
Department of Mechanical Engineering
University of Connecticut
Storrs, Connecticut
September-October 1976

FIGURE 6
PLUMBING MODIFICATIONS



(TYPICAL FOR 88 PANELS)
NO SCALE

Table 1
PERFORMANCE MONITORING INSTRUMENTATION

(a) Temperature Measurements

No.	Designation	Name	Range (oF) Min.	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	F20U18	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

SOLAR PANEL DESCRIPTION

CONSTRUCTION & MATERIALS SUMMARY

ELEMENT	MATERIAL/SOURCE	FEATURES/COMMENTS
Cover	0.10 in. Plexiglas "G" Polymethylmethacrylate Rohm & Haas	Excellent UV and impact resistance; 20 year proven lifetime in Florida without transmission decrease. Maximum transmission ($\tau = 0.92$) rigid plastic collector cover available. Thermoformed covers provide light-weight, stiffness and improved high temperature performance. Impact resistance exceeds that of tempered glass. Widely used for skylights and general glazing in many commerical architectural applications.
Air Gap/Spacer	0.8 in./Silicone Rubber foam and Polysulfone rod	Thermally stable, low conductivity materials will not outgas at collector operating or no flow equilibrium temperatures.
Absorber Coating	Black Chrome electroplate over nickle Harshaw Chemical Company	Coating has proven stable optical/radiation characteristics, $\alpha \geq 0.95$ for excellent thermal efficiency at reasonable cost. $\epsilon \leq 0.10$
Absorber	0.04 in. ROLLBOND CDA 122 Copper OLIN Brass Co.	The highest efficiency flat plate absorber construction available. ROLLBOND is becoming an industry standard for quality, high performance collectors.
Insulation	2.0 in. Thermax TF600 Polyisocyanurate closed-cell foam, Aluminum foil-faced Celotex Corporation	Tested for two weeks as a lab oven door: with 350F on hotside, 70F on coldside, no warpage, deformation or degradation occured.
Frame	6063 T5/Aluminum Extrusion	Attractive lightweight framing of weather resistant aluminum alloy normally used for architectural applications. Readily paintable.
Perimeter Sealant	Architectural glazing tape; closed-cell foam, silicone inner, PVC outer, adhesive coated	UV resistant, used similarly for weather seals in commercial and industrial glazing.
Backing Sheet	0.025 in. Glass-reinforced Acrylic sheet.	Tough, weather-resistant, moisture and fungus-proof sheet protects back of insulation board against mechanical and environmental damage.

TABLE (3)

SYSTEM PERFORMANCE SUMMARY

	November 1978	December 1978	January 1979	February 1979	March 1979
Total Incident Solar Energy (Million Btu)	54.02	64.28	43.53	66.27	92.47
Operational Incident Solar Energy (Million Btu)	17.65	28.22	25.04	47.20	55.72
Collected Solar Energy (Million Btu)	8.93	13.03	11.66	21.53	21.90
Collection Efficiency (%)	16.5	20.3	26.8	32.5	23.7
Operational Collection Efficiency (%)	50.6	46.2	46.6	45.6	39.3
Energy Added to Storage (Million Btu)	0.43	0.39	-0.41	1.72	0.28
Auxiliary Thermal Energy (Million Btu)	21.11	28.10	29.57	27.15	5.32
System Operating Energy (Million Btu)	10.19	7.39	5.28	6.88	3.27
Solar Energy Used (Million Btu)	8.50	12.73	12.07	19.81	21.62
Space Heating Load (Million Btu)	39.80	48.22	46.92	53.84	30.21
Solar Fraction (%)	21.4	26.4	25.7	36.8	71.6
Collection Operational Energy (KWH)	62	89	82	133	167
Electrical Energy Savings (KWH)	113	938	1470	2898	2119
Average Ambient Temperature (°F)	52	43	38	31	51
Average Building Temperature (°F)	70	67	65	67	68

TABLE 4

SOLAR COLLECTION COMPARISON

	November	December	January	February	March
1. Clear Day Insolation Rate (BTU/ft^2)	1889	1768	1925	2189	2229
2. Long Term Sunshine (%)	53	49	45	56	57
3. Long Term Monthly Insolation (Million BTU)	63.43	56.72	56.71	72.49	83.18
4. Collected Solar Energy Prediction (Million BTU)	26.88	25.60	23.20	26.89	30.93
5. Prediction of Collection Efficiency (%)	42.4	45.1	40.9	37.1	37.2
6. 1978-79 Actual Insolation (Million BTU)	54.02	64.28	43.53	66.27	92.47
7. 1978-79 Collected Solar Energy (Million BTU)	8.93	13.03	11.66	21.53	21.90
8. Actual Collection Efficiency (%)	16.5	20.3	26.8	32.5	23.7

Notes:

Line 1: From ASHRAE 1978 "Applications Handbook", Table 3, page 58.6, for surface facing South tilted at 55° from horizontal.

Line 2: From ITT 1976 "Solar Heating Systems Design Manual", Table on page A-6, for Philadelphia.

Line 3: Computed = line 1 x line 3 x number of days x 2112 ft^2 collector area.

Line 4: From ITC "Preliminary Design Report", COO-2688-2, January 28, 1976.

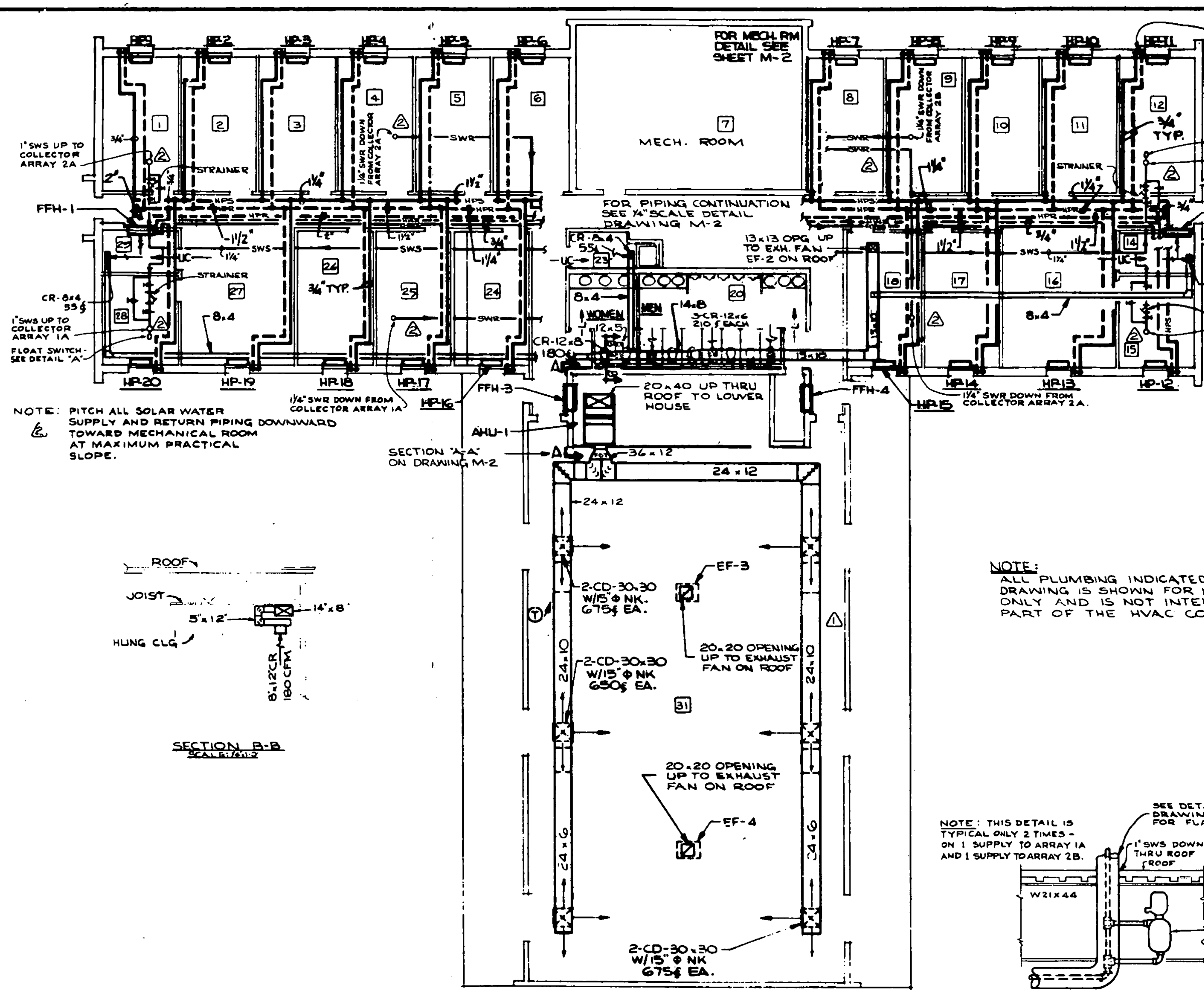
Line 5: Computed = (Line 4) / (Line 3) x 100

Lines 6 and 7: From IBM Monthly Performance Reports, References 10.4 through 10.8

Line 8: Computed = (Line 6) / (Line 7) x 100

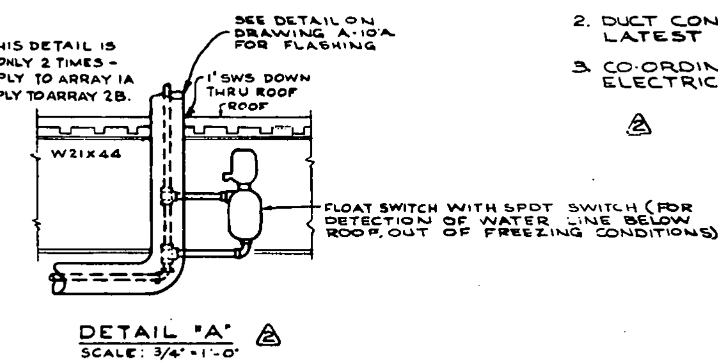
APPENDIX A

DESIGN DRAWINGS



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
CA.	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

REV.	DESCRIPTION	DATE
1	GENERAL REVISIONS AND REVISIONS TO BULLETINS 1 THRU 3	8-17-76
2	REVISED PER BULLETIN #6	11-12-76

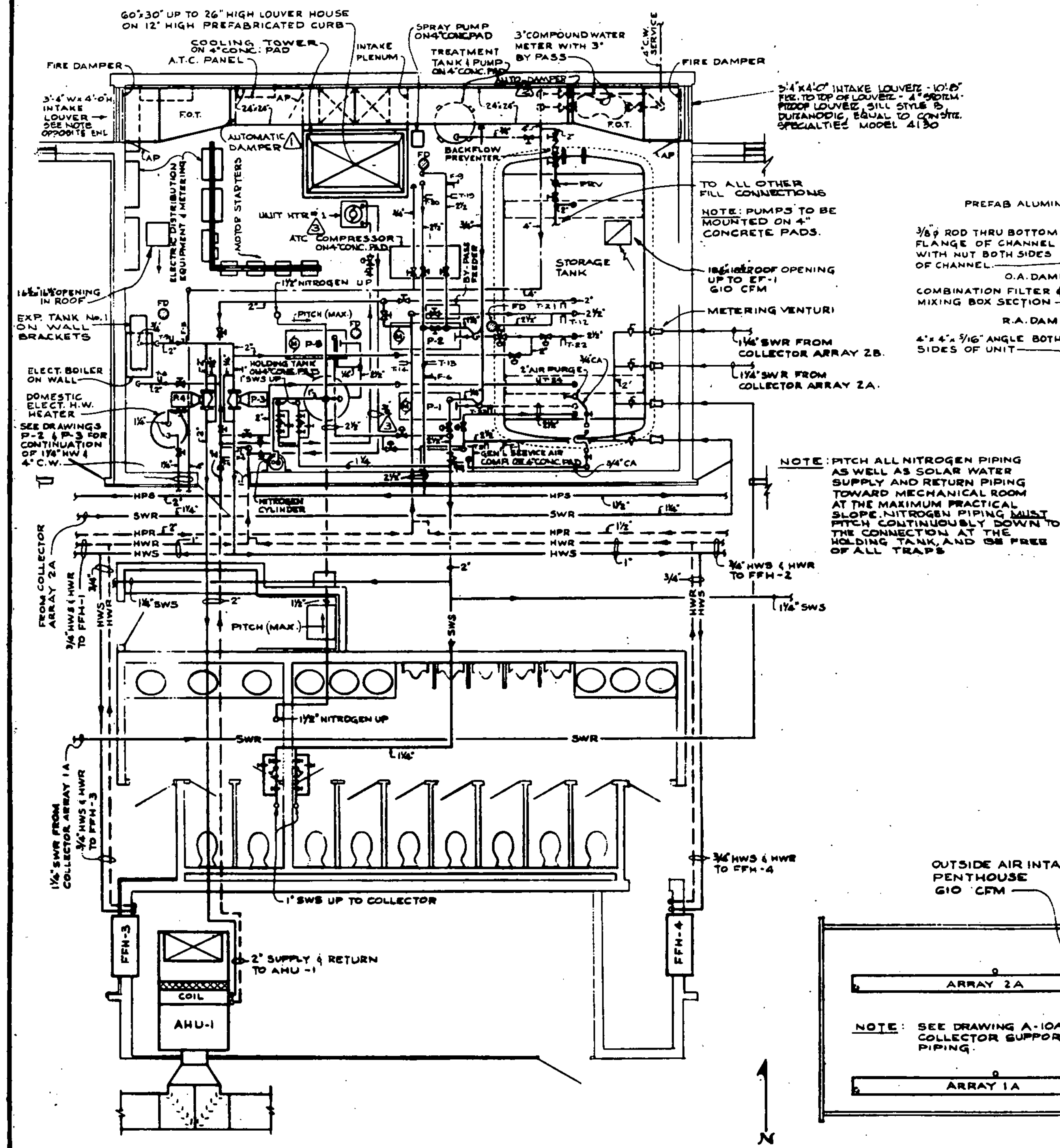
SHEET TITLE: MECHANICAL FLOOR PLAN & SYMBOL LIST

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

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

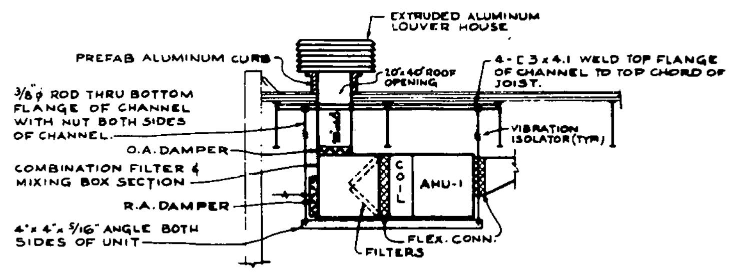
A SOLAR ENERGY PROJECT IN COOPERATION WITH THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

SHEET NO. M-1
JOB NO 00009-5



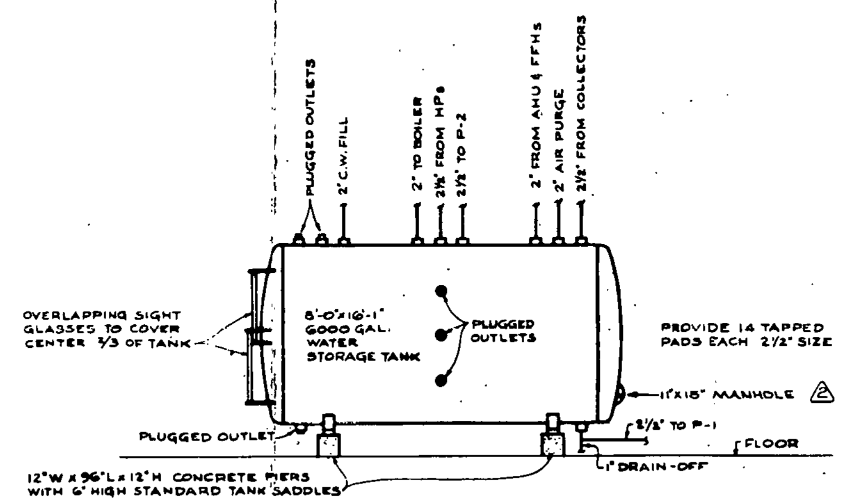
PART FLOOR PLAN 2

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



SECTION 'A'-'A'

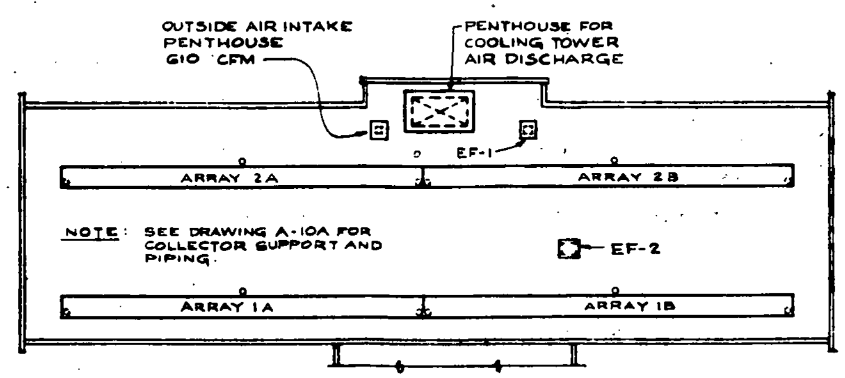
SCALE: 1/4"=1'-0"



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.



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	11-2-76
3	ADDED UNIT HEATER #1	1-31-77

SHEET TITLE: MECHANICAL ROOM PLAN AND SECTIONS

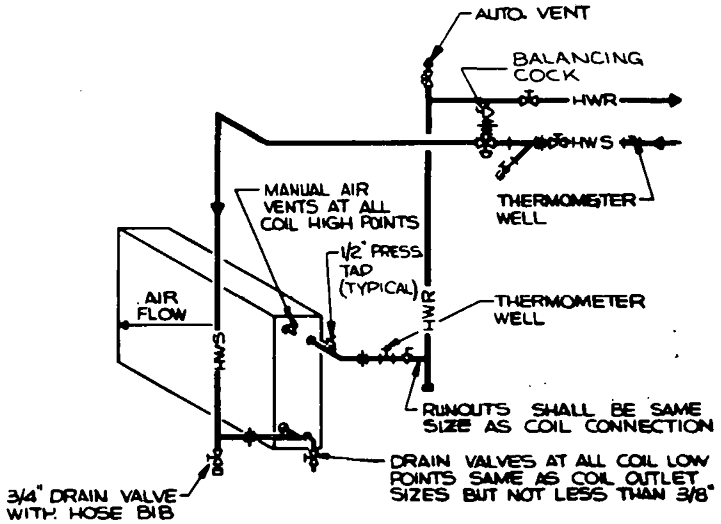
DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

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

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

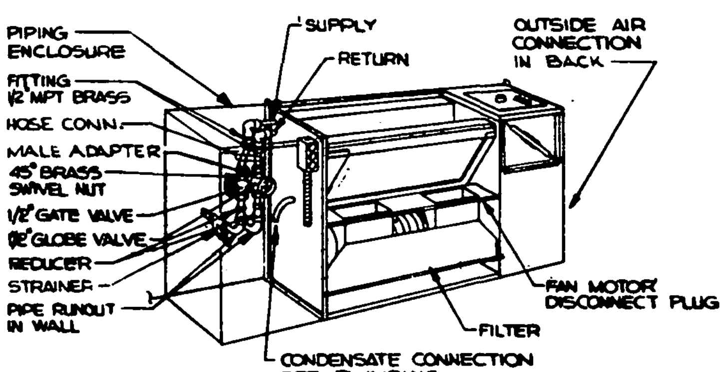
SHEET NO. M-2

JOB NO. 00009-5



HOT WATER HEATING COIL CONNECTIONS

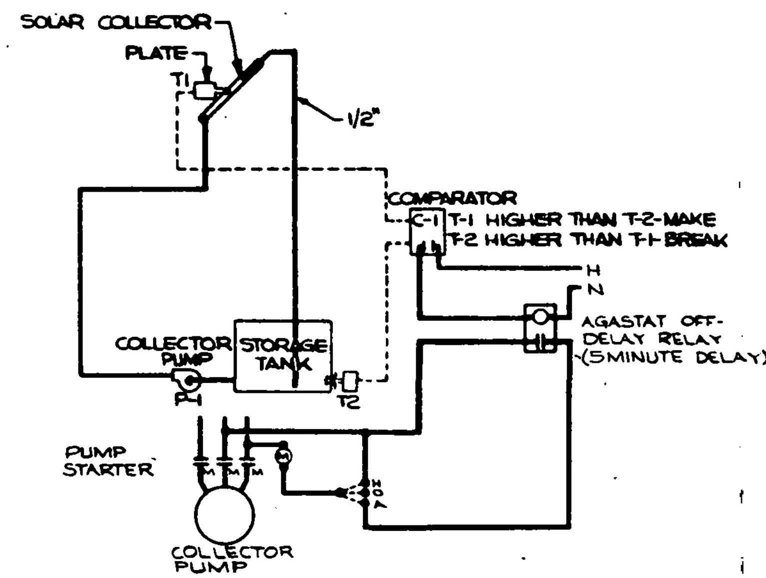
NO SCALE



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

HEAT PUMP DETAIL

NO SCALE



STORAGE TANK PUMP CONTROL DETAIL

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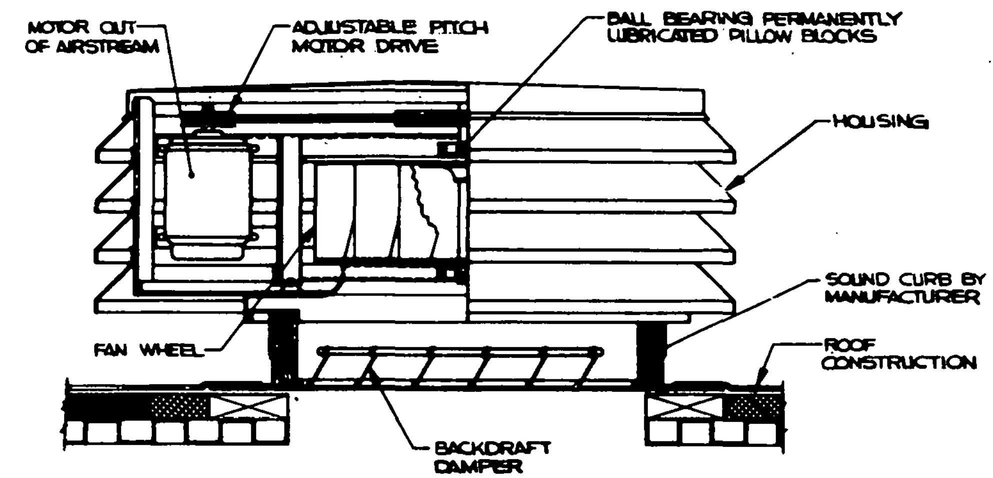
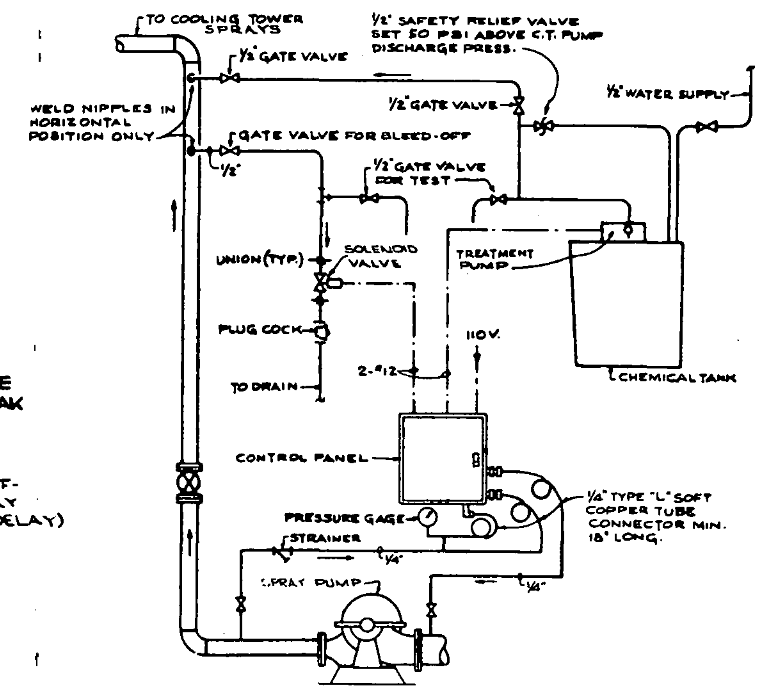


EXHAUST FAN DETAIL

INTAKE PENTHOUSE SIMILAR

NO SCALE



COOLING TOWER SPRAY CHEMICAL FEED SYSTEM WITH CONDUCTIVITY CONTROLLED BLEED-OFF

△2 NO SCALE

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

WALTER K. PLATT

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 SCHÈDULE

UNIT NO.	FAN DATA CFM	S.P.	MAX. O.V. FPM	BHP	MAX. FAN WHEELS	MOT. DATA MHP		HEATING COIL DATA AIR S.P.	EDB	LDB	WATER GPM	PD MAX	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	OUT-SIDE AIR C.F.M.	GPM	PD FT. H_2O	SUMMER OPERATION EWT °F	ENT. AIR TEMP DB	WB	TOTAL COOLING CAP. (BTUH)	COMP INPUT KW	FAN KW	HEAT OF REJECTION	LWT °F	WINTER OPERATION EWT °F	EAT °F	HEATING CAP (BTUH)	COMP INPUT (KW)	FAN INPUT (KW)	HEAT OF ABSOR. (BTUH)	LWT °F
HP-13,19	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
HP-1,11	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 ⚠2

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 Nº1 – 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 ¾ HP MOTOR, V-BELT DRIVE WITH BELT GUARD.

PUMP SCHEDULE ⚠2

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	—	½	
P-5	REFILL PUMP	48	50	1750	—	CENTRIFUGAL END SUCTION	—	2	

⚠5 UNIT HEATER Nº1 – 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

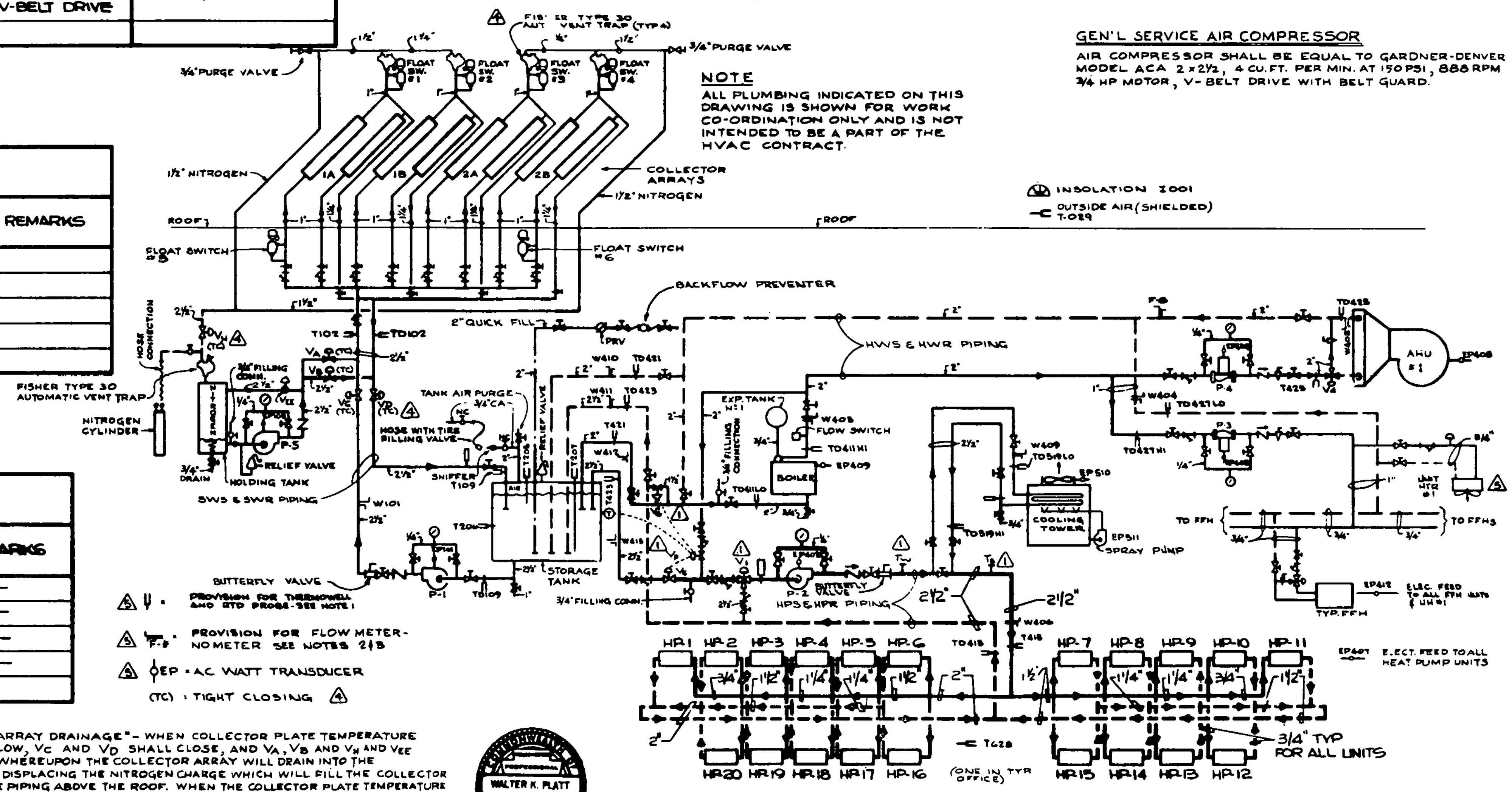
UNIT NO.	FAN DATA CFM NOMINAL	EXT. S.P.	RPM MAX.	AIR-ON HEATING COIL EDB	WATER GPM	P.D. FT.	EWT.	CAPACITY (BTU/HR.) APPROX.	MOTOR WATTS	REMARKS
FFH-1	200	—	1100	60°	1	0.24	110	6000	85	—
FFH-2	200	—	1100	60°	1	0.24	110	6000	85	—
FFH-3	200	—	1100	60°	1	0.24	110	6000.	85	—
FFH-4	200	—	1100	60°	1	0.24	110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

WALTER K. PLATT

⚠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 REVISION 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

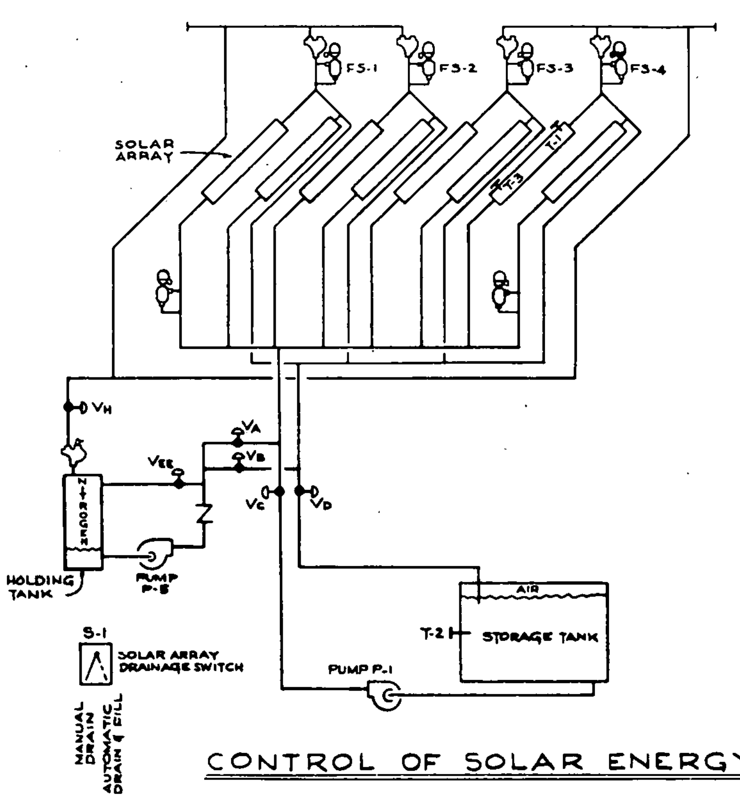
DATE: JUNE 21, 1976
SCALE: AS SHOWN
DRAWN BY

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"

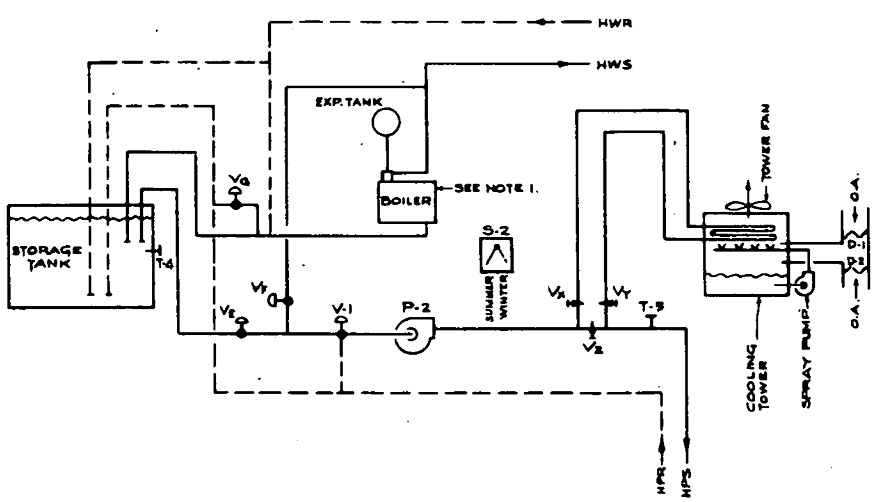
1. VALVES V_C AND V_D SHALL BE HELD CLOSED, VALVES V_A, V_B, V_{EE} AND V_H SHALL BE HELD OPEN.
2. PUMPS P-1 AND P-5 SHALL BE INOPERABLE.

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 70F 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).

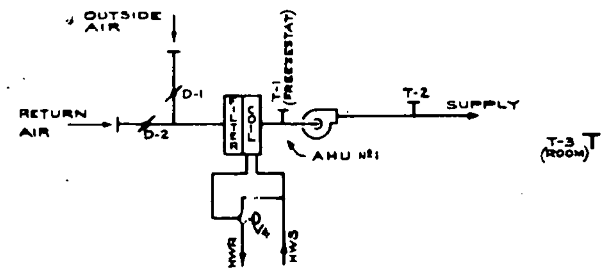
WITH S-2 INDEXED TO "WINTER"

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.

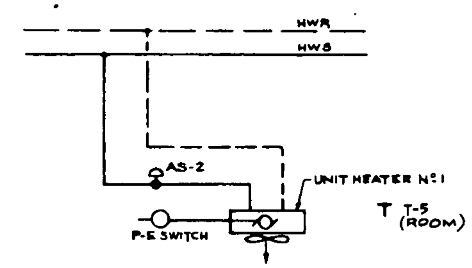
CONTROL OF HEAT PUMP LOOP SUPPLY AND RETURN



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.

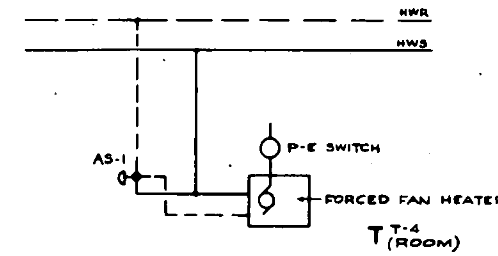
CONTROL OF AHU Nº1



YEAR-ROUND OPERATION

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

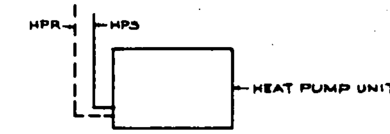
CONTROL OF UNIT HEATER Nº1



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

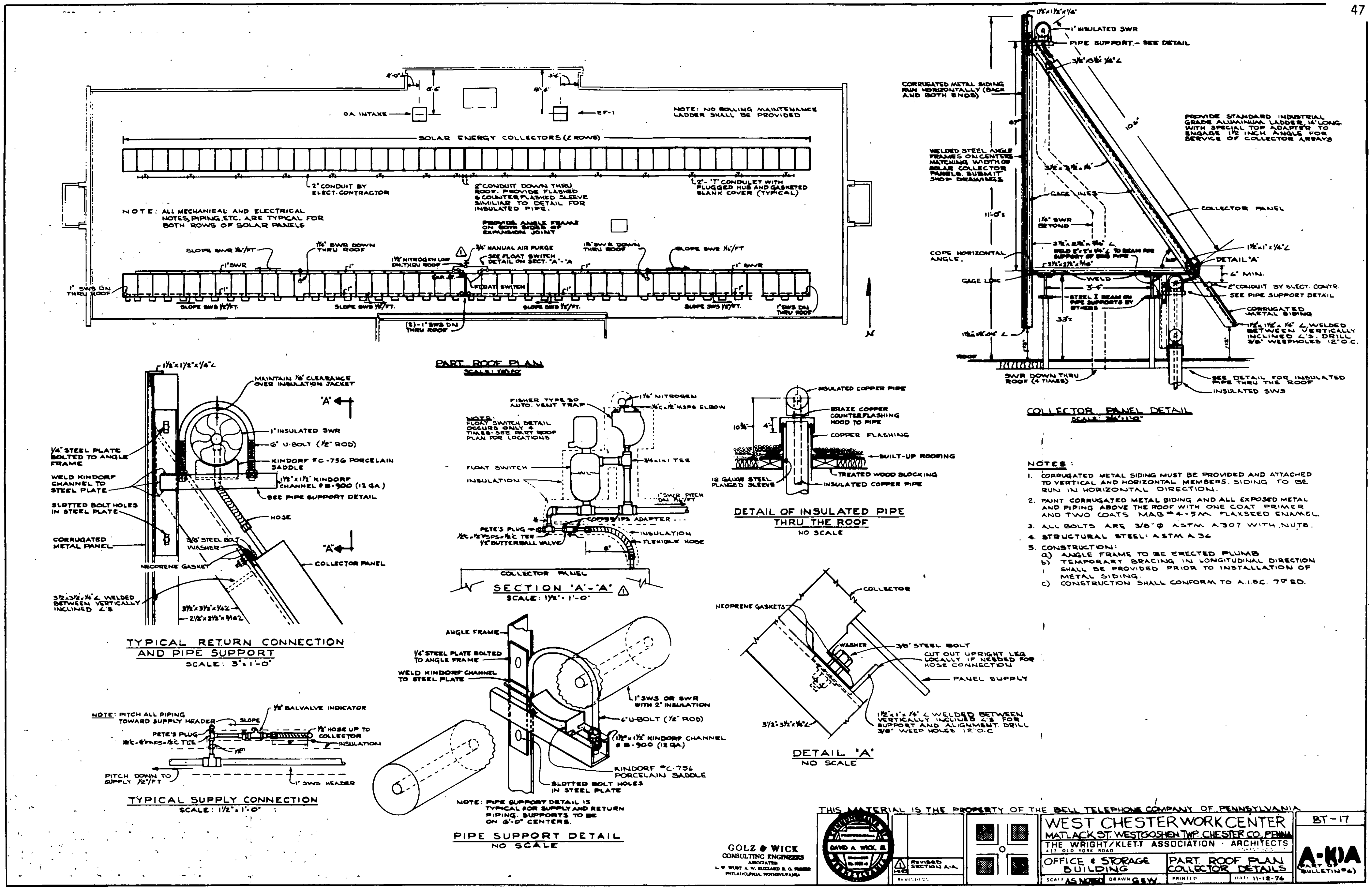
SHEET TITLE: TEMPERATURE CONTROL DIAGRAMS

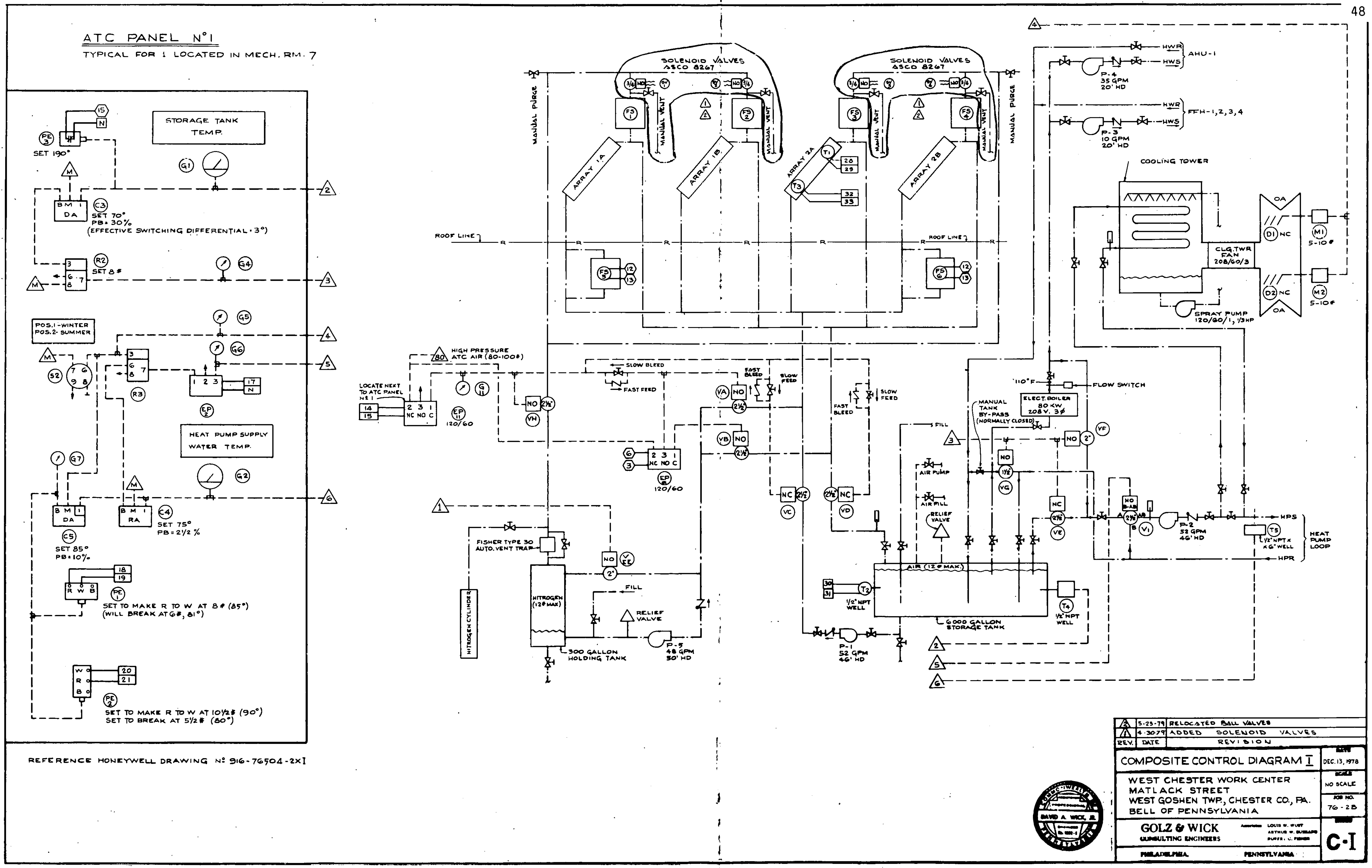
DATE: APRIL 28, 1977
SCALE: NONE
DRAWN BY: G & W

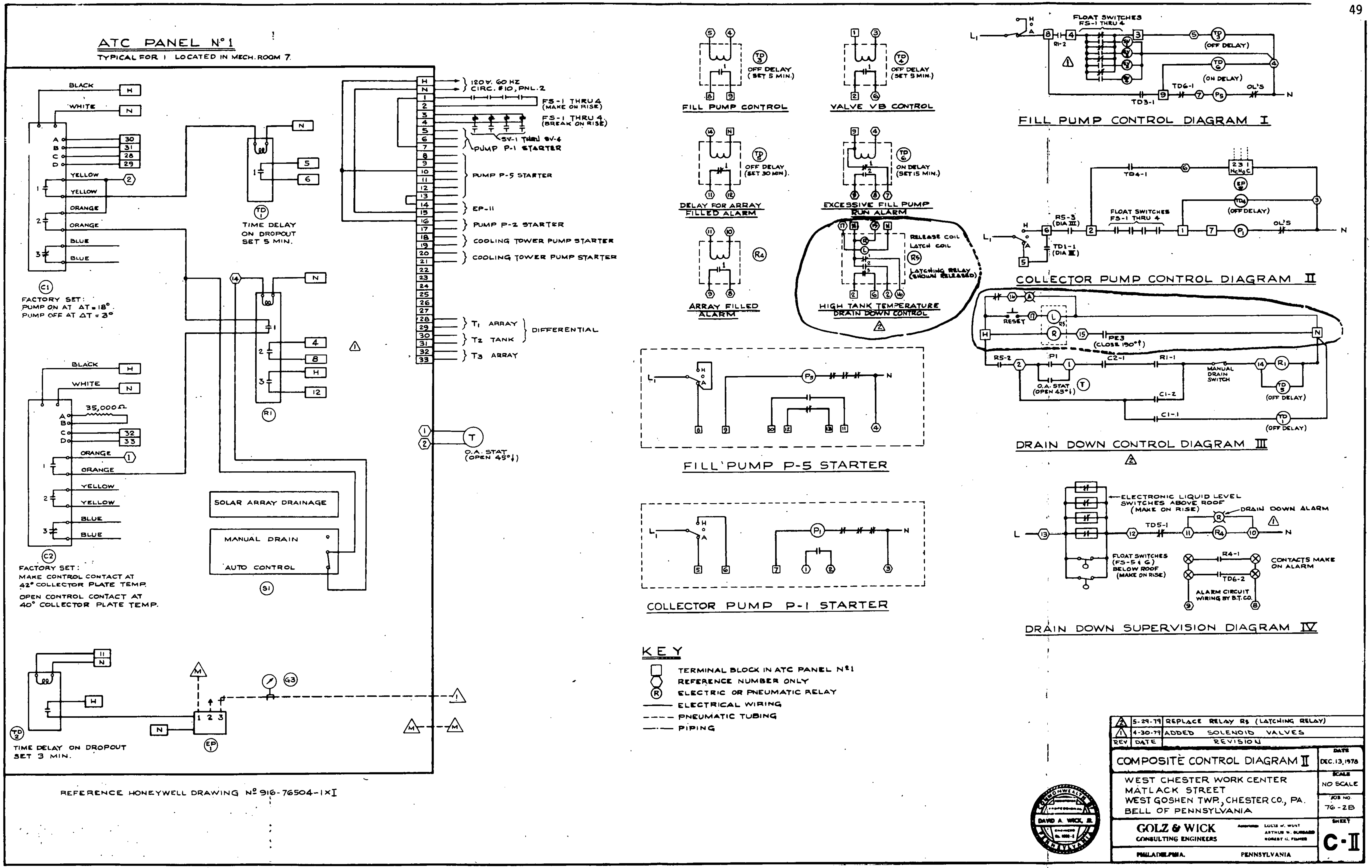
WEST CHESTER WORK CENTER
BELL OF PENNSYLVANIA
ONE PARKWAY
PHILADELPHIA, PENNSYLVANIA

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

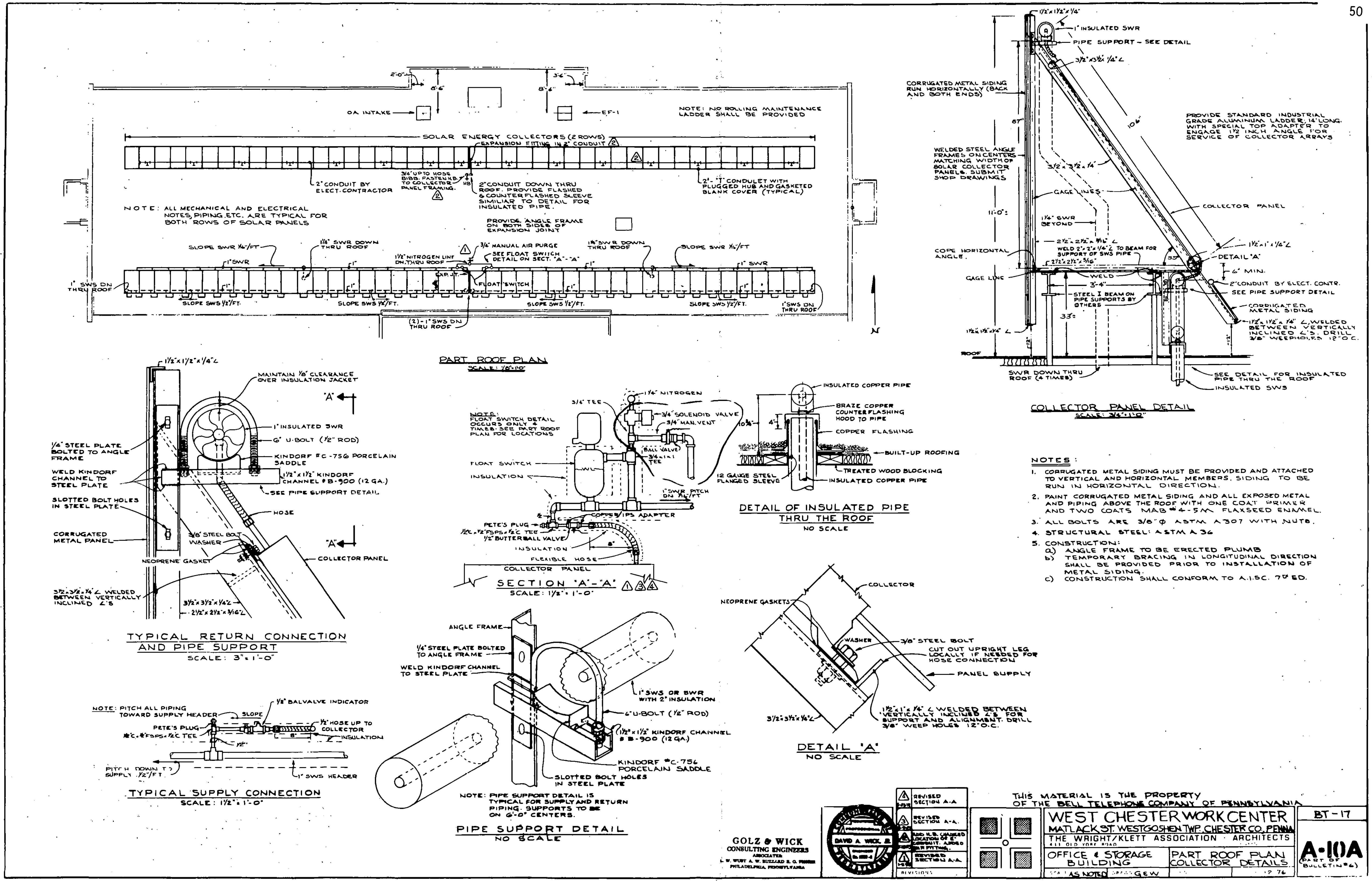
SHEET NO. M-5
JOB NO. 00009-5


NOTE: NO ROLLING MAINTENANCE LADDER SHALL BE PROVIDED
OA INTAKE
EF-1
SOLAR ENERGY COLLECTORS (2 ROWS)
2" CONDUIT BY ELECT. CONTRACTOR
2" CONDUIT DOWN THRU ROOF. PROVIDE FLASHED & COUNTERFLASHED SLEEVE SIMILIAR TO DETAIL FOR INSULATED PIPE.
2"- "T" CONDULET WITH PLUGGED HUB AND GASKETED BLANK COVER. (TYPICAL)
NOTE: ALL MECHANICAL AND ELECTRICAL NOTES, PIPING, ETC. ARE TYPICAL FOR BOTH ROWS OF SOLAR PANELS
PROVIDE ANGLE FRAME ON BOTH SIDES OF EXPANSION JOINT
3/4" MANUAL AIR PURGE
SEE FLOAT SWITCH DETAIL ON SECT. "A"-"A"
FLOAT SWITCH
1" SWS DN THRU ROOF
(2)-1" SWS DN THRU ROOF
PART ROOF PLAN
TYPICAL RETURN CONNECTION AND PIPE SUPPORT
SCALE: 3" = 1'-0"
MAINTAIN 1/8" CLEARANCE OVER INSULATION JACKET
1" INSULATED SWR
6" U-BOLT (1/2" ROD)
KINDORF FC-756 PORCELAIN SADDLE
1 1/2" x 1 1/2" KINDORF CHANNEL # B-900 (12 GA.)
SEE PIPE SUPPORT DETAIL
1/4" STEEL PLATE BOLTED TO ANGLE FRAME
WELD KINDORF CHANNEL TO STEEL PLATE
SLOTTED BOLT HOLES IN STEEL PLATE
CORRUGATED METAL PANEL
HOSE
3/8" STEEL BOLT WASHER
NEOPRENE GASKET
COLLECTOR PANEL
TYPICAL SUPPLY CONNECTION
SCALE: 1 1/2" = 1'-0"
NOTE: PITCH ALL PIPING TOWARD SUPPLY HEADER
PITCH DOWN TO SUPPLY 1/2"/FT
1" SWS HEADER
SECTION "A"-"A"
SCALE: 1 1/2" = 1'-0"
FISHER TYPE 30 AUTO. VENT TRAP
FLOAT SWITCH
INSULATION
PETE'S PLUG
1/2" BUTTERBALL VALVE
FLEXIBLE HOSE
COLLECTOR PANEL
PIPE SUPPORT DETAIL
NO SCALE
ANGLE FRAME
1/4" STEEL PLATE BOLTED TO ANGLE FRAME
WELD KINDORF CHANNEL TO STEEL PLATE
1" SWS OR SWR WITH 2" INSULATION
6" U-BOLT (1/2" ROD)
(1 1/2" x 1 1/2" KINDORF CHANNEL # B-900 (12 GA.)
KINDORF #C-756 PORCELAIN SADDLE
SLOTTED BOLT HOLES IN STEEL PLATE
NOTE: PIPE SUPPORT DETAIL IS TYPICAL FOR SUPPLY AND RETURN PIPING. SUPPORTS TO BE ON 6'-0" CENTERS.
DETAIL OF INSULATED PIPE THRU THE ROOF
NO SCALE
INSULATED COPPER PIPE
BRAZE COPPER COUNTERFLASHING HOOD TO PIPE
COPPER FLASHING
BUILT-UP ROOFING
TREATED WOOD BLOCKING
DETAIL "A"
NO SCALE
COLLECTOR
NEOPRENE GASKETS
3/8" STEEL BOLT
CUT OUT UPRIGHT LEG LOCALLY IF NEEDED FOR HOSE CONNECTION
PANEL SUPPLY
COLLECTOR PANEL DETAIL
1" INSULATED SWR
PIPE SUPPORT - SEE DETAIL
CORRUGATED METAL SIDING RUN HORIZONTALLY (BACK AND BOTH ENDS)
PROVIDE STANDARD INDUSTRIAL GRADE ALUMINUM LADDER 14' LONG WITH SPECIAL TOP ADAPTER TO ENGAGE 1 1/2 INCH ANGLE FOR SERVICE OF COLLECTOR ARRAYS
COLLECTOR PANEL
DETAIL "A"
COPE HORIZONTAL ANGLE.
WELD
SEE PIPE SUPPORT DETAIL
CORRUGATED METAL SIDING
SEE DETAIL FOR INSULATED PIPE THRU THE ROOF
INSULATED SWS
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.
THIS MATERIAL IS THE PROPERTY OF THE BELL TELEPHONE COMPANY OF PENNSYLVANIA
GOLZ & WICK CONSULTING ENGINEERS
WEST CHESTER WORK CENTER
MATLACK ST. WESTGOSHEN TWP. CHESTER CO. PENNA
THE WRIGHT/KLETT ASSOCIATION · ARCHITECTS
OFFICE & STORAGE BUILDING
PART ROOF PLAN COLLECTOR DETAILS
BT-17
A-10A
SCALE AS NOTED
DRAWN GEW
DATE 11-12-76


ATC PANEL N°1
TYPICAL FOR 1 LOCATED IN MECH. RM. 7
STORAGE TANK TEMP.
SET 190°
SET 70°
PB = 30%
(EFFECTIVE SWITCHING DIFFERENTIAL = 3°)
SET 8#
POS. 1 - WINTER
POS. 2 - SUMMER
HEAT PUMP SUPPLY WATER TEMP.
SET 75°
PB = 2 1/2 %
SET 85°
PB = 10%
SET TO MAKE R TO W AT 8# (85°)
(WILL BREAK AT 6#, 81°)
SET TO MAKE R TO W AT 10 1/2 # (90°)
SET TO BREAK AT 5 1/2 # (80°)
REFERENCE HONEYWELL DRAWING N° 916-76504-2X1
SOLENOID VALVES ASCO 8267
MANUAL PURGE
MANUAL VENT
ARRAY 1A
ARRAY 1B
ARRAY 2A
ARRAY 2B
ROOF LINE
HIGH PRESSURE ATC AIR (80-100#)
LOCATE NEXT TO ATC PANEL N°1
120/60
SLOW BLEED
FAST FEED
FAST BLEED
SLOW FEED
FISHER TYPE 30 AUTO. VENT TRAP
NITROGEN CYLINDER
NITROGEN (12# MAX)
300 GALLON HOLDING TANK
FILL
RELIEF VALVE
P-5 48 GPM 30' HD
P-1 52 GPM 46' HD
AIR PUMP
AIR FILL
AIR (12# MAX)
1/2" NPT WELL
6000 GALLON STORAGE TANK
MANUAL TANK BY-PASS (NORMALLY CLOSED)
ELECT. BOILER 80 KW 208 V. 3Ø
110° F
FLOW SWITCH
HWR
HWS
AHU-1
P-4 35 GPM 20' HD
FFH-1,2,3,4
P-3 10 GPM 20' HD
COOLING TOWER
OA
CLG. TWR FAN 208/60/3
5-10#
SPRAY PUMP 120/60/1, 1/3 HP
P-2 52 GPM 46' HD
HPS
HPR
HEAT PUMP LOOP
1/2" NPT x 6" WELL
5-25-79 RELOCATED BALL VALVES
4-30-79 ADDED SOLENOID VALVES
REV. DATE REVISION
COMPOSITE CONTROL DIAGRAM I
DEC. 13, 1978
NO SCALE
76-2B
WEST CHESTER WORK CENTER
MATLACK STREET
WEST GOSHEN TWP., CHESTER CO., PA.
BELL OF PENNSYLVANIA
GOLZ & WICK
CONSULTING ENGINEERS
PHILADELPHIA PENNSYLVANIA
C-1



ATC PANEL N°1
TYPICAL FOR 1 LOCATED IN MECH. ROOM 7
120V. 60 HZ CIRC. #10, PNL. 2
FS-1 THRU 4 (MAKE ON RISE)
FS-1 THRU 4 (BREAK ON RISE)
SV-1 THRU SV-4
PUMP P-1 STARTER
PUMP P-5 STARTER
EP-11
PUMP P-2 STARTER
COOLING TOWER PUMP STARTER
COOLING TOWER PUMP STARTER
T1 ARRAY
T2 TANK
T3 ARRAY
DIFFERENTIAL
TIME DELAY ON DROPOUT SET 5 MIN.
FACTORY SET: PUMP ON AT ΔT = 18° PUMP OFF AT ΔT = 3°
FACTORY SET: MAKE CONTROL CONTACT AT 42° COLLECTOR PLATE TEMP. OPEN CONTROL CONTACT AT 40° COLLECTOR PLATE TEMP.
O.A. STAT (OPEN 45°↓)
SOLAR ARRAY DRAINAGE
MANUAL DRAIN
AUTO CONTROL
TIME DELAY ON DROPOUT SET 3 MIN.
REFERENCE HONEYWELL DRAWING Nº 916-76504-1XI
FILL PUMP CONTROL
VALVE VB CONTROL
DELAY FOR ARRAY FILLED ALARM
EXCESSIVE FILL PUMP RUN ALARM
ARRAY FILLED ALARM
HIGH TANK TEMPERATURE DRAIN DOWN CONTROL
RELEASE COIL
LATCH COIL
LATCHING RELAY (SHOWN RELEASED)
FILL PUMP P-5 STARTER
COLLECTOR PUMP P-1 STARTER
FILL PUMP CONTROL DIAGRAM I
FLOAT SWITCHES FS-1 THRU 4
COLLECTOR PUMP CONTROL DIAGRAM II
DRAIN DOWN CONTROL DIAGRAM III
MANUAL DRAIN SWITCH
DRAIN DOWN SUPERVISION DIAGRAM IV
ELECTRONIC LIQUID LEVEL SWITCHES ABOVE ROOF (MAKE ON RISE)
DRAIN DOWN ALARM
FLOAT SWITCHES (FS-5 & 6) BELOW ROOF (MAKE ON RISE)
CONTACTS MAKE ON ALARM
ALARM CIRCUIT WIRING BY B.T.CO.
KEY
TERMINAL BLOCK IN ATC PANEL Nº1
REFERENCE NUMBER ONLY
ELECTRIC OR PNEUMATIC RELAY
ELECTRICAL WIRING
PNEUMATIC TUBING
PIPING
2 5-29-79 REPLACE RELAY R5 (LATCHING RELAY)
1 4-30-79 ADDED SOLENOID VALVES
REV DATE REVISION
COMPOSITE CONTROL DIAGRAM II
DATE DEC. 13, 1978
SCALE NO SCALE
JOB NO 76-2B
SHEET C-II
WEST CHESTER WORK CENTER
MATLACK STREET
WEST GOSHEN TWP., CHESTER CO., PA.
BELL OF PENNSYLVANIA
GOLZ & WICK CONSULTING ENGINEERS
PHILADELPHIA PENNSYLVANIA



OA INTAKE
EF-1
NOTE: NO ROLLING MAINTENANCE LADDER SHALL BE PROVIDED
SOLAR ENERGY COLLECTORS (2 ROWS)
EXPANSION FITTING IN 2" CONDUIT
2" CONDUIT BY ELECT. CONTRACTOR
3/4" UP TO HOSE BIBB. FASTEN HB TO COLLECTOR PANEL FRAMING.
2" CONDUIT DOWN THRU ROOF. PROVIDE FLASHED & COUNTERFLASHED SLEEVE SIMILIAR TO DETAIL FOR INSULATED PIPE.
2" - "T" CONDULET WITH PLUGGED HUB AND GASKETED BLANK COVER (TYPICAL)
NOTE: ALL MECHANICAL AND ELECTRICAL NOTES, PIPING, ETC. ARE TYPICAL FOR BOTH ROWS OF SOLAR PANELS
PROVIDE ANGLE FRAME ON BOTH SIDES OF EXPANSION JOINT
SLOPE SWR 1/16"/FT
1 1/4" SWR DOWN THRU ROOF
1/2" NITROGEN LINE DN. THRU ROOF
3/4" MANUAL AIR PURGE
SEE FLOAT SWITCH DETAIL ON SECT. "A"-"A"
1 1/4" SWR DOWN THRU ROOF
1" SWS DN THRU ROOF
FLOAT SWITCH
SLOPE SWS 1/2"/FT.
(2)-1" SWS DN THRU ROOF
PART ROOF PLAN
SCALE: 1/8"=1'-0"
TYPICAL RETURN CONNECTION AND PIPE SUPPORT
SCALE: 3"=1'-0"
MAINTAIN 1/8" CLEARANCE OVER INSULATION JACKET
1" INSULATED SWR
6" U-BOLT (1/2" ROD)
KINDORF #C-756 PORCELAIN SADDLE
1 1/2" x 1 1/2" KINDORF CHANNEL # B-900 (12 GA.)
SEE PIPE SUPPORT DETAIL
1/4" STEEL PLATE BOLTED TO ANGLE FRAME
WELD KINDORF CHANNEL TO STEEL PLATE
SLOTTED BOLT HOLES IN STEEL PLATE
CORRUGATED METAL PANEL
3/8" STEEL BOLT WASHER
NEOPRENE GASKET
COLLECTOR PANEL
HOSE
TYPICAL SUPPLY CONNECTION
SCALE: 1 1/2"=1'-0"
NOTE: PITCH ALL PIPING TOWARD SUPPLY HEADER
1/2" BALVALVE INDICATOR
1/2" HOSE UP TO COLLECTOR
PETE'S PLUG
1" SWS HEADER
SECTION "A"-"A"
SCALE: 1 1/2"=1'-0"
NOTE: FLOAT SWITCH DETAIL OCCURS ONLY 4 TIMES. SEE PART ROOF PLAN FOR LOCATIONS
1 1/4" NITROGEN
3/4" TEE
3/4" SOLENOID VALVE
3/4" MAN. VENT
BALL VALVE
FLOAT SWITCH
INSULATION
1" SWR PITCH DN 1/16"/FT
COPPER/IPS ADAPTER
1/2" BUTTERBALL VALVE
FLEXIBLE HOSE
COLLECTOR PANEL
PIPE SUPPORT DETAIL
NO SCALE
ANGLE FRAME
1/4" STEEL PLATE BOLTED TO ANGLE FRAME
WELD KINDORF CHANNEL TO STEEL PLATE
1" SWS OR SWR WITH 2" INSULATION
6" U-BOLT (1/2" ROD)
1 1/2" x 1 1/2" KINDORF CHANNEL # B-900 (12 GA.)
KINDORF #C-756 PORCELAIN SADDLE
SLOTTED BOLT HOLES IN STEEL PLATE
NOTE: PIPE SUPPORT DETAIL IS TYPICAL FOR SUPPLY AND RETURN PIPING. SUPPORTS TO BE ON 6'-0" CENTERS.
DETAIL OF INSULATED PIPE THRU THE ROOF
NO SCALE
INSULATED COPPER PIPE
BRAZE COPPER COUNTERFLASHING HOOD TO PIPE
COPPER FLASHING
BUILT-UP ROOFING
TREATED WOOD BLOCKING
12 GAUGE STEEL FLANGED SLEEVE
INSULATED COPPER PIPE
DETAIL "A"
NO SCALE
COLLECTOR
NEOPRENE GASKETS
3/8" STEEL BOLT
WASHER
CUT OUT UPRIGHT LEG LOCALLY IF NEEDED FOR HOSE CONNECTION
PANEL SUPPLY
1 1/2" x 1" x 1/4" ∠ WELDED BETWEEN VERTICALLY INCLINED ∠'S FOR SUPPORT AND ALIGNMENT. DRILL 3/8" WEEP HOLES 12" O.C.
COLLECTOR PANEL DETAIL
SCALE: 3/4"=1'-0"
1" INSULATED SWR
PIPE SUPPORT - SEE DETAIL
CORRUGATED METAL SIDING RUN HORIZONTALLY (BACK AND BOTH ENDS)
PROVIDE STANDARD INDUSTRIAL GRADE ALUMINUM LADDER, 14' LONG, WITH SPECIAL TOP ADAPTER TO ENGAGE 1 1/2 INCH ANGLE FOR SERVICE OF COLLECTOR ARRAYS
WELDED STEEL ANGLE FRAMES ON CENTERS MATCHING WIDTH OF SOLAR COLLECTOR PANELS. SUBMIT SHOP DRAWINGS
GAGE LINES
COLLECTOR PANEL
1 1/4" SWR BEYOND
WELD 2"x2"x1/4" ∠ TO BEAM FOR SUPPORT OF SWS PIPE
COPE HORIZONTAL ANGLE
DETAIL "A"
6" MIN.
2" CONDUIT BY ELECT. CONTR.
SEE PIPE SUPPORT DETAIL
STEEL I BEAM ON PIPE SUPPORTS BY OTHERS
CORRUGATED METAL SIDING
1 1/2" x 1 1/2" x 1/4" ∠ WELDED BETWEEN VERTICALLY INCLINED ∠'S. DRILL 3/8" WEEPHOLES 12" O.C.
SWR DOWN THRU ROOF (4 TIMES)
SEE DETAIL FOR INSULATED PIPE THRU THE ROOF
INSULATED SWS
ROOF
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 A 36
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.
GOLZ & WICK
CONSULTING ENGINEERS
PHILADELPHIA, PENNSYLVANIA
REVISED SECTION A-A
REVISED SECTION A-A
REVISED SECTION A-A
REVISIONS
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THE WRIGHT/KLETT ASSOCIATION · ARCHITECTS
OFFICE & STORAGE BUILDING
PART ROOF PLAN COLLECTOR DETAILS
AS NOTED
GEW
BT-17
A-10A
(PART OF BULLETIN #6)

APPENDIX B

FINALIZED SOLAR COLLECTION CONTROLS

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DESCRIPTION OF CONTROLS

FOR

SOLAR ENERGY COLLECTION SYSTEM

BELL OF PENNSYLVANIA, WEST CHESTER WORK CENTER

FILLING

1. BEFORE ATTEMPTING TO ADD WATER TO THE SYSTEM FOR ANY PURPOSE, INDEX THE SOLAR ARRAY SWITCH S-1 TO "MANUAL DRAIN". THIS WILL OPEN VALVES V_A. V_B, V_H, V_{EE} AND THE SOLENOID VALVES AT THE TOPS OF THE ARRAYS, SIMULTANEOUSLY CLOSING VALVES V_C AND V_D. WATER MAY NOW BE ADDED THROUGH THE SEPARATE FILL CONNECTIONS FOR THE HOLDING AND STORAGE TANKS AND AIR AND NITROGEN PRESSURES CAN BE ADJUSTED. WITH WATER LEVELS UP TO THE MARKS ON THE TANKS, WITH THE ARRAY DRY BUT WITH ALL PARTS OF THE HEAT PUMP LOOP FILLED, AND ALL AUXILIARY HEATING LINES FILLED, AIR PRESSURE IN THE STORAGE TANK SHOULD BE APPROXIMATELY 14 PSI AND NITROGEN PRESSURE IN THE HOLDING TANK SHOULD BE APPROXIMATELY 4 PSI.WHEN TANKS ARE FILLED AND PRESSURES ARE CORRECT SWITCH S-1 SHOULD BE INDEXED TO "AUTOMATIC" WHICH WILL PROVIDE THE NORMAL SEQUENCE OF OPERATION DESCRIBED LATER HEREIN.

AUTOMATIC DRAIN-DOWN CONTROLS

1. THERE ARE SEVERAL CONTROLS BUILT INTO THE SYSTEM WHICH WILL AUTOMATICALLY CAUSE THE ROOF ARRAY TO DRAIN INTO THE HOLDING TANK, AS FOLLOWS:

   A) THERMOSTAT T-4 IN THE STORAGE TANK, ASSOCIATED WITH PE-3, WILL RELEASE RELAY R-5 WHEN THE TANK TEMPERATURE RISES TO 190F. THE RELEASE OF RELAY R-5 (A LATCHING-TYPE RELAY) WILL OPEN CONTACT R5-2 WHICH DE-ENERGIZES RELAY R-1 CAUSING DRAIN-DOWN. SIMULTANEOUSLY, CONTACT R5-1 WILL CLOSE, LIGHTING AN ANNUNCIATOR. R-5 WILL REMAIN RELEASED UNTIL MANUALLY LATCHED BY PUSHING THE RESET BUTTON. THIS IS TO PREVENT AUTOMATIC REFILLING OF THE ARRAY WHEN THE STORAGE TANK IS UP TO TEMPERATURE AND THUS AVOID THE STEAMING WHICH RESULTS FROM HOT WATER BEING INJECTED INTO HOT ARRAY PANELS. OPERATING PERSONNEL ARE TO BE INSTRUCTED NOT TO PUSH THE RESET BUTTON UNTIL STORAGE TANK TEMPERATURE HAS DROPPED TO APPROXIMATELY 170F AND THE COLLECTION PLATE TEMPERATURE IS BELOW 220F.

B) CONTROLLER C-2, CONTACT C2-1, WILL DE-ENERGIZE RELAY R-1 AND CAUSE DRAIN-DOWN WHEN THE COLLECTOR PLATE TEMPERATURE DROPS TO 40F.

C) CONTROLLER C-1, CONTACT C1-2, WILL DE-ENERGIZE RELAY R-1 AND CAUSE DRAIN-DOWN WHEN THE FOLLOWING TWO CONDITIONS OCCUR SIMULTANEOUSLY:

(1) THERE IS AN INSUFFICIENT DIFFERENTIAL IN TEMPERATURE BETWEEN THE ARRAY AND THE STORAGE TANK (PUMP P-1 WILL NOT BE OPERATING).

(2) THE OUTSIDE TEMPERATURE IS BELOW 45F.

2. THE DRAIN-DOWN STATUS IS SUPERVISED BY FOUR ELECTRONIC LIQUID LEVEL SWITCHES ABOVE THE ROOF AND TWO FLOAT SWITCHES BELOW THE ROOF WIRED THRU THE CONTACT OF TIME DELAY RELAY TD5 TO ENERGIZE RELAY R4. THE OPERATION IS SUCH THAT AN ALARM IS INITIATED IF DRAIN-DOWN IS NOT ACCOMPLISHED WITHIN THE TIME PERIOD ESTABLISHED BY RELAY TD5. THIS ALARM IS SENT AUTOMATICALLY TO A REMOTE OFFICE.

3. ADDITIONALLY, THE ARRAY WILL BE DRAINED WHENEVER THE MANUAL/AUTOMATIC DRAIN SWITCH IS INDEXED TO "MANUAL DRAIN".

NORMAL SEQUENCE OF OPERATION

1. ASSUMING THE ARRAY TO BE DRAINED AND SOLAR ENERGY BEING NOW AVAILABLE, WHEN THE SOLAR COLLECTOR PLATE TEMPERATURE (SENSED BY SENSOR T-1) RISES ABOVE THE STORAGE TANK WATER TEMPERATURE (SENSED BY SENSOR T-2) BY A DIFFERENTIAL GREATER THAN THAT SET ON CONTROLLER C-1, CONTROLLER C-1 OPERATES TO ENERGIZE RELAY R-1 WHICH OPERATES RELAYS TD-3 AND TD-6 AND STARTS REFILL PUMP P-5. AN AUXILIARY NORMALLY OPEN CONTACT ON THE STARTER FOR P-5 OPERATES TO ENERGIZE RELAY EP-1 WHICH IN TURN CLOSES VALVE V_{EE} ROUTING THE DISCHARGE OF PUMP P-5 TO THE SOLAR ARRAYS. AT THIS POINT THE ARRAYS ARE BEING FILLED THROUGH BOTH THEIR TOP AND BOTTOM CONNECTIONS. THIS CONTINUES UNTIL FLOAT SWITCHES FS1 THROUGH FS4 ALL TRIP, INDICATING FULL PANELS. BECAUSE IT HAS BEEN FOUND THAT THIS FIRST INDICATION OF COMPLETELY FILLED ARRAYS IS SOMETIMES ERRONEOUS, THE NORMALLY OPEN AND NORMALLY CLOSED CONTACTS OF THE FLOAT SWITCHES ARE USED TO CONTROL THE SOLENOID VALVES AND RELAY TD-3 TO MAINTAIN THE FILL PUMP P-5 IN OPERATION, WITH VALVE V_B NOW CLOSED, FOR AN ADDITIONAL SET PERIOD OF TIME. DURING THIS EXTRA PERIOD OF OPERATION OF PUMP P-5, DURING WHICH ALL FILLING ACTION OF THE PUMP IS DIRECTED ONLY TO THE BOTTOM CONNECTIONS OF THE ARRAYS, THE NITROGEN

REMAINING IN THE ARRAYS IS FORCED TO THE TOP AND OUT THROUGH THE SOLENOID VALVES TO THE HOLDING TANK. THE FLOAT SWITCH CONTACTS ARE WIRED TO CLOSE THE SOLENOID VALVES AS SOON AS WATER RISES TO THE FLOAT SWITCHES. THIS EXTRA PERIOD OF FILLING LASTS APPROXIMATELY FIVE MINUTES. DURING THIS PERIOD, EXCEPT FOR MOMENTARY BREAKS AS NITROGEN ESCAPES PAST THE FLOAT SWITCHES AND SOLENOID VALVES, COLLECTOR PUMP P-1 IS OPERATING AGAINST CLOSED VALVE V_C. WHEN RELAY TD-3 TIMES OUT, ENDING THE EXTRA PERIOD OF ARRAY FILLING BY PUMP P-5, PUMP P-5 WILL STOP AND RELAY TD-6 WILL BE DE-ENERGIZED. A NORMALLY CLOSED CONTACT ON THE STARTER OF PUMP P-5 WILL OPERATE TO ENERGIZE THREE-WAY SOLENOID EP11 WHICH IN TURN WILL OPERATE TO CLOSE VALVES V_A, V_B AND V_H, AND OPEN VALVES V_C AND V_D THUS PERMITTING COLLECTION OF SOLAR ENERGY. IN THE EVENT THAT THE SYSTEM HAD NOT COMPLETELY FILLED BEFORE RELAY TD6 HAD TIMED OUT, PUMP P-5 WOULD AUTOMATICALLY BE STOPPED AND A CONTACT WOULD MAKE TO SEND AN ALARM TO A REMOTE OFFICE.

2. TIME DELAY RELAY TD2 OPERATES TO HOLD VALVE V_{EE} CLOSED TO PREVENT BACK DRAIN INTO THE HOLDING TANK WHILE VALVES V_A AND V_B ARE CLOSING. WHEN TD2 TIMES OUT EP1 IS DE-ENERGIZED AND V_{EE} OPENS.

3. THE CONTACTS OF FLOAT SWITCHES FS-1 THROUGH FS-4 THAT CLOSE ON WATER RISE ARE SERIES CONNECTED AND PERMIT OPERATION OF COLLECTION PUMP P-1 WHEN THE ARRAY IS FILLED.

4. WHEN THE T-1 TO T-2 DIFFERENTIAL FALLS BELOW THE "PUMP OFF" SETTING ON CONTROLLER C-1, C-1 OPERATES TO STOP PUMP P-1.

GOLZ, WICK & FISHER

JUNE 11, 1979

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