SYSTEM MANUAL FOR THE UNIVERSITY OF PENNSYLVANIA
RETROFITTED SOLAR HEATED PHILADELPHIA ROW HOME
(SolaRow)

TOPICAL REPORT

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PHILADELPHIA ROW HOME"

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ABSTRACT

The University of Pennsylvania SolarRow house, an urban row home retrofitted for comfort and domestic hot water heating, was extensively instrumented for performance monitoring and acquisition of weather and solar radiation data. This report describes the heating and instrumentation systems, provides the details for instrumentation, piping and valve identification, and specifies the operation and maintenance of the heating and data acquisition systems.

The report includes: 1) system flow diagrams, 2) valve and cable identification tables, 3) wiring diagrams, and 4) start-up, normal operation, shut-down, maintenance and trouble-shooting procedures. It thus provides the necessary technical information to permit system operation and monitoring, overall system performance analysis and optimization, and acquisition of climatological data.

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1. INTRODUCTION

A row home in Philadelphia, at 3920 Spruce Street and adjacent to the University of Pennsylvania campus, was retrofitted to provide solar comfort and domestic hot water heating. This three story structure has about 4,000 ft² of floor area, including the basement. The design and construction of the solar system was based on the concept of minimal changes to the existing structure and utilization of the original heating systems as the back-up. The calculated building design heat load, including domestic hot water, is 70,000 BTU/hr. The solar system was designed to provide approximately 77 (10⁶) BTUs annually. This amounts to approximately 50% of the projected yearly requirement. A detailed description of the SolarRow house construction modifications and solar energy systems is contained in [1] and [2].

In order to monitor and optimize system performance, the design and construction of the instrumentation and data acquisition system (DAS) were implemented as described in [3] and [4]. System and component performance evaluation criteria as defined by the National Bureau of Standards [5] and as developed by the Principal Investigator, were utilized in designing the instrumentation system.

The overall objective of this report is to provide:

- 1) Identification and installation hook-up description of all instrumentation, valves and control systems to optimize check-out, trouble-shooting and system modifications,
- 2) Operating procedures for the heating and data acquisition systems and
- 3) Maintenance instructions for the above.

In general, solar heating systems are reasonably simple and easy to operate. The great detail provided in this report was required due to the experimental and research nature of this project, thus increasing the reliability of the operation and of the data, and is not otherwise needed for commercial solar installations of this type.

2. THE HEATING SYSTEMS

2.1 Description of Heating Systems

The solar heating system was designed to provide both the comfort heating and domestic hot water heating for the house. For these applications, the conventional heating systems were retained for back-up. The existing systems are an oil-fired furnace with an associated forced air system for comfort heating and a gas-fired water heater for domestic hot water heating. An overall system diagram is shown in Fig. 2-1.

2.1.1 Comfort Heating System

The comfort heating system consists of three loops. They are the solar energy collection loop, the building heat demand loop and the warm air loop. A diagram of these systems is shown in Fig. 2-2.

A fourth loop, the thermal storage system, is also present for filling the storage tanks, maintaining a minimum level in the tanks and for tank draining. A gage glass located between storage tanks #1 and #2 indicates the water level in the tanks. A diagram of this system is shown in Fig. 2-3. A photograph showing the three storage tanks (prior to insulation) and associated piping is shown in Fig. 2-4.

2.1.1.1 Solar Energy Collection Loop

The solar energy collection loop pump circulates water from the storage tanks through the solar collectors, where the water is heated, and back to the tanks, where the hot water is stored. Five rows of collectors are positioned at an angle of 55° to the horizontal and face, just as the house, 10° west of south. For a photograph showing an overall view of the collectors, see Fig. 2-5. Each of the first four collector rows in the direction of flow consist of seven solar panels connected in parallel. These collector panels were manufactured by the International Environment Corporation and utilize roll bonded copper absorbers. The overall size of each solar panel module is 102" (2.59m) high by 23" (0.58m) wide with a collector area of 13.9 ft^2 (1.29 m^2), (95" x 21"). The fifth (last) collector row consists of five solar panels connected in parallel. These collector panels were manufactured by the Pittsburgh Plate Glass Company and utilize copper tubes thermally bonded to the copper absorber plate. The overall solar panel module size is 76" (1.93m) high by 34" (0.914m) wide with a collector area of 17.1 ft^2 (1.59 m^2), (75" x 33"). These two types of collectors were selected for comparison purposes. All the collectors utilize double-glazed tempered glass with copper flat-black absorbers. They provide a total net collection area of 475 ft^2 (44.13 m^2).

The three thermal storage tanks have a combined capacity of 1080 gallons of water. These steel tanks, three feet (0.914m) in diameter and seven feet (2.133m) high, have an internal baked-on 4-6 mil (0.10-0.15mm) thick phenolic coating (Heresite P-403, Heresite and Chemical Company, Manitowoc, WI 54220) for corrosion protection. Externally, the tanks are insulated with six inches (0.152m) of fiberglass. Details of the storage tank connections and dimensions are shown in Fig. 2-6.

Flow through the system is provided by a close-coupled centrifugal pump as shown in Fig. 2-2. The pump is rated 20 gpm at a total net head of 110 feet. Performance curves are shown in Fig. 2-7 from [6] page 4. The Goulds model 3642 pump is fitted with bronze plugs and impeller. For this specific application, the pump provides flow at 7-10 gpm and is driven at 3500 rpm by a 2 hp Marathon Electric Company motor. Additional pump and motor data is provided in the Maintenance Section 5.2 of this report.

In order to minimize noise and vibration, the pump was mounted on rubber-in-shear vibration isolators. In addition, the pump is isolated from the piping by use of one foot lengths of flexible reinforced rubber hose (1-1/2" nominal size, 150 psig working pressure) at both the suction and discharge sides.

2.1.1.2 Building Heat Demand Loop

Controlled by the room thermostat, the building heat demand pump circulates the hot water from the storage tanks through the water-to-air heat exchanger, which is located at the inlet to the combustion chamber of the existing furnace, and back to the storage tanks. A rated flow of 10 gpm at a total net head of 16 feet is provided by an in-line centrifugal bronze booster pump, Bell and Gossett Type B1PR. Performance data is shown in Fig. 2-8 from [7] page 4. For this application, the pump supplies a flow rate of 8 gpm through the system and is driven at 1750 rpm by a directly-coupled 1/6 h.p. Bell & Gossett motor. Additional pump and motor data is provided in the Maintenance Section 5.2 of this report.

The water to air heat exchanger utilizes two hot water coils, Aerofin Corporation, type CH as shown in Fig. 2-9 and 2-10. Each coil consists of two rows with a face area of 3.34 ft² (0.31m²). Each of the two coils has 12 tube face widths and 2.5 ft (0.762m) nominal tube lengths of 5/8" O.D. copper tubing with copper helical fins.

When the temperature of the water in storage is adequate, the solar energy input alone provides the house interior space temperature. If the desired house temperature drops further to a predetermined value, the furnace turns on automatically. In this case, the demand heat system acts as a preheater. Further decrease in storage temperature will cause the demand heat loop to shut down. Details of the specific temperatures and system operation are provided in the Control Systems Section (No. 2.3.3) of this report.

A new Honeywell Protectorelay, RA117A, was installed in the oil fired furnace in October 1977, to replace an older device which failed. This one-piece, stack-mounted control cycles the burner on demand of the thermostat and shuts down the burner on loss of flame or system malfunction. See the Control Systems Section 2.3.3 of this report for details. The system was further upgraded with the installation of a new oil burner (Model E, Wayne Home Equipment Co.) in January of 1978, after the old one broke down.

2.1.1.3 Warm Air Loop

The forced warm air loop supplies air to be heated in the water-to-air heat exchanger and the furnace combustion chamber as required. The heated air is then conveyed throughout the house by means of an uninsulated duct system.

The blower fan provides the air circulation throughout the house and is located at the inlet to the water-to-air heat exchanger. This radial blade fan is powered through a pulley system by a 1/2 hp, 1725 rpm Leland Motor. Originally a three inch (7.62cm) diameter pulley was mounted to the motor shaft and was connected by a V-belt to the 14 inch (35.6cm) diameter pulley on the air blower shaft. This combination provided an air flow rate of 1350 cfm. In order to overcome the additional pressure drop resulting from the addition of the new hot water-to-air heat exchanger, the rotational speed of the air blower was increased to yield an air flow rate of 1700 cfm.

This was accomplished by increasing the motor shaft pulley diameter to 3-3/4 inches (9.53cm). This pulley is an integral part of the new three position pulley system (3, 3-3/4 and 4-1/2 inch diameter pulleys) mounted to the motor shaft. A photograph of the drive system is shown in Fig. 2-10.

2.1.1.4 Thermal Storage Loop

The thermal storage system loop functions to fill and maintain the water level in the storage tanks and permit system drainage. The storage tanks and associated systems, solar energy collection loop and heat demand loop, are filled and the level in the storage tanks is maintained by means of the automatic make-up feed valve, V-219, McDonnell No. 25A, McDonnell & Miller, Inc. See Figs. 2-3 and 2-4. This valve is actuated by the water level in the storage tanks, which is also indicated by the gage glass level indicator, L200. If the water level decreases below the desired set point, then the make-up feed valve opens and provides cold water from the city water supply to the Solar Domestic Hot Water Heating System, SDHWS. This water enters via the solar collection loop pump suction line between storage tanks number 2 and 3 which connects near the bottom of each storage tank. When the level of the storage tanks reaches the required value, then V-219 automatically shuts the supply off.

Drainage of the storage tanks and associated systems is accomplished by closing the supply line valve (V-311) to V-219 and opening the drain valves at the bottom of each tank, V-221, V-222 and V-223. The water is drained to the building's main waste pipe (located in the corner opposite the DHWH) through a check valve, V-224. This valve protects from inadvertent back fill from the waste pipe (See Fig. 2-3).

2.1.2 Solar Domestic Hot Water Heating System

The solar domestic hot water heating system (SDHWS) heats the water from the city supply by passage through heat exchangers immersed in the hot water in storage tanks number 2 and 3. These water immersion type heat exchangers were designed and built at the University and are connected in parallel. Each storage tank unit has two concentric spiral 1/2" soft copper tube coils with an overall length of 256 feet (78.0m), 128 feet (39.0m) per coil. The coils were wound around brass rods at outer diameters of 10-1/2 and 14 inches. A photograph of the unit is shown in Fig. 2-11. Each coil provides a heat exchange area of 21 ft² (1.95m²) and is connected for parallel flow with a heat exchange area of 42 ft² (3.90m²) per unit per storage tank. Hence the total heat exchange area for the SDHWS is 84 ft² (7.80m²).

From these heat exchangers, the flow combines and goes to the gas-fired hot water heater. Downstream of this heater the hot water goes through a tempering valve (V-309) which mixes cold water with the hot water if the hot water temperature exceeds a specified level. This valve provides a safety precaution against excessively hot water reaching the user. A system diagram is shown in Fig. 2-3.

City water pressure of typically about 50 psig provides flow through the system to the various outlets throughout the house. The domestic hot water heater (DHWH) is used in this application as a back-up which heats the water if the solar preheat is inadequate. The heater is a conventional gas-fired unit. Water temperature is automatically maintained by the heater's thermostat as described in Section 2.3.4.

The 75 gallon capacity hot water heater, Bradford-White Corporation, Model 75S5LN, is rated at 75,000 BTU/hr input with a recovery time for 100°F temperature rise of 63 minutes, and a peak load rating of 138.0 cfh of natural gas, as specified in [8].

2.2 System Diagrams & Valve Lists

An overall system diagram showing the solar collector loop, heat demand loop, warm air loop, and control system is shown in Fig. 2-1. Detailed system diagrams including all valves and flow meters with respective numbers are shown in Figs. 2-2 and 2-3. Fig. 2-3 also includes the storage tank system.

Complete valve lists for each system are contained in Tables 2-1 through 2-4. In general isolation cocks are installed at the inlet to all pressure gages, however, they are not numbered. Also the Thermoflo Balancer flow meters have a built-in butterfly valve which is not numbered.

The actual insulation materials over piping lines in the basement are painted for ease of identification. The systems are color-coded as follows:

Solar Collector Loop Piping

Green from storage tanks to outside riser to collectors

Yellow from collector return line to storage tanks

Demand Loop Piping

Red from storage tanks to heat exchanger in furnace housing

Pink return from heat exchanger to storage tanks

SDHWS Piping

Blue from cold water supply to heat exchangers and to DHWH

Orange from heat exchangers and DHWH to the supply main

2.3 Control Systems

2.3.1 General Description

The comfort heating system control wiring diagram (as shown in [2] Fig. 7) is included in this report as Fig. 2-12. Operation of the solar collection loop is controlled by a differential temperature controller with frost override. Air temperature within the house is controlled by a two-stage thermostat (located on the second floor) interfacing with a thermal storage tank aquastat and a conventional back-up oil burner controller.

The water level in the storage tanks is automatically maintained by the make-up feed controller, valve V-219.

The solar domestic hot water heating system is controlled by the auxiliary hot water heater's existing thermostat. A tempering valve downstream of the heater also serves to limit the maximal temperature of the hot water supply.

A detailed list of controllers along with the applicable sensors is provided in Table 2-5.

An overall photograph of the control panel located in the basement is shown in Fig. 2-13. This panel contains various controllers and power supplies. Adjacent to this panel is the junction box servicing the basement instruments, and the aquastat controller.

2.3.2 Solar Collection System

Operation of the solar collection system is controlled by the Fix-flo Controller, C-1, with frost override [9] (Differential Temperature Controller) located on the control panel in the basement. This controller functions by the interaction of both differential and absolute temperature sensing inputs provided. The controller operates the collector loop pump and associated solenoid valves as shown on the control schematic diagram Fig. 2-14 and Fig. 2-12. The general sensor locations are also shown in Fig. 2-1.

The temperature difference is measured between the absorber surface of the hottest collector (any collector in the last row) and the temperature of the water near the bottom of the storage tanks. Specifically, the absorber sensor was installed from the back of collector 5-4, 1 foot (0.305m) from the collector top near the collector centerline. When this temperature difference, ΔT_{C-S} , is equal to or greater than the set turn-on differential, the controller starts the collector loop circulation pump. There is a time delay set at 3 seconds (but which can be varied to 60 seconds) before starting this pump to allow the opening of solenoid valves S2 (V-142) and S3 (V-104). These valves are kept closed when the pump is not operating and when the system has not been drained. Solenoid valves S1-A, -B, -C, -D, (V-146 through V-149) energize (close) when pump starts. There are no on or off time delays associated with the S1 valves.

When ΔT_{C-S} is less than the turn-off differential setting, then the controller stops the pump; opens S1 and after a time delay energizes (closes) valves S2 & S3. This time delay is used to eliminate any water hammer effects that would occur if the valves were closed against the pump. The drain-down solenoids S1-A, -B, -C, & -D are opened when the pump is shut down to allow drainage if S2 and S3 are opened for freeze protection.

Freeze protection is provided to the controller by two sensors. One measures the temperature of the coldest collector absorber, which is located at the occasionally shaded bottom of the second row of collectors, specifically 8 inches (20.3cm) from the bottom of collector 2-6 at the back side. The other measures the ambient air near the collector centerline 1 inch (2.54cm) away from the back of collector 2-6, 4 inches (10.16cm) from the collector bottom and 2 feet (0.61m) above the roof. These sensors were installed in accordance with the manufacturer's recommendations [10]. If either of these sensors measure a temperature equal to or below 38°F while the collector loop pump is not operating, then the frost control opens S2 and S3 and drains the system into the storage tanks. On the other hand, if the collector loop pump is operating (ΔT_{C-S} is above the controller turn-off setting) then an override to the frost signal is provided by the controller and the frost control does not activate the solenoid valves. This is an important feature of the controller.

A summary of the control logic for the controller and applicable temperature difference settings are shown in Table 2-6.

As a custom-feature, a 12 position switch unit is attached to the controller C-1 to allow variations of the collector loop pump turn-on temperature differentials, while maintaining the 3°F turn-off differential. A list of these variations is shown in Table 2-7. This feature was installed to determine the overall effect of operating at various turn-on temperature differentials during the optimization experiments (Section 4.1.5.2).

located adjacent to the controller C-1, Figure 2-12, is a manual bypass switch which is provided to operate the S1 solenoid valves. In the "Off" position the solenoid valves S1-A, -B, -C, and -D are de-energized and the valves open. Seeking the path of lowest pressure drop the flow is thereby routed from the first row collector outlet manifold back to the storage tanks bypassing the remaining collector rows. This allows operation of the first collector row only, in periods of reduced load. In addition each solenoid valve can be manually operated, de-energized, so that the system flow can be routed through the desired number of collector rows, 1 through 4. For example, de-energizing S1-C will provide flow through three rows of collectors.

System air control is maintained by two mechanical, float type automatic air vents, which are located at the highest point in the upper header for each collector row. One is a conventional hydronic air vent (Model 703, Amtrol, Inc.), V-155 through V-159, which has an air venting capacity of 0.28 scfm at 12 psi pressure difference. This capacity is sufficient to vent the air released from the water during circulation. The other is a combination air vent and vacuum breaker (Model VB8-76-BR-T-PP-B 3/4" Special, The Johnson Corp.), V-150 through V-159, which has a larger air venting capacity of 10 to 20 scfm for 1 to 5 psi pressure difference. This unit is a combination air vent and vacuum breaker, which is installed to allow rapid air venting during system filling operations, and adequate air admission to insure rapid drain-down for freeze protection (but it doesn't allow venting of air during normal operation).

Another air vent is an integral part of the air purger valve, V-139, upstream of the system flow meter, W100. This vent (Model 703, Amtrol, Inc.) is installed to eliminate the potential adverse effect of air on the accuracy of the flow meter readings.

2.3.3 Space Heating System

The space heating system is comprised of the demand system loop, the warm air loop, and the back-up conventional furnace. The air temperature within the house is controlled by the two-stage room thermostat Controller C-2 (Barber-Colman, TC-154) mounted on the wall of the second floor hallway immediately outside the Data Acquisition System (DAS) room. The wiring diagram for the thermostat with connections to the furnace is shown in Fig. 2-15.

The wiring goes to the DAS Room and then is routed outside, as shown in Fig. 2-16, and down to the basement. The detailed interconnection hook-up between the demand pump, power supply, aquastat and 24 volt bypass is shown in Fig. 2-17.

The TC-154 commercial room thermostat is used for the sequenced switching of the demand pump, furnace, and associated air blower. Two bimetal control elements operate snap-acting switches. A single setting adjustment dial simultaneously adjusts the control points of both bimetal elements. Then the calibrating screw on the left hand element is used to set the differential between stages. A thermometer with a 50-90°F range is located above the dial setting area in the cover. The individual switch differential is 1 to 2°F, while the differential between stages is adjustable from 2-10°F, [11].

For our two-stage heating application, the thermostat was calibrated in accordance with the general instructions, Section B of [12]. Refer to this section for the complete procedure, as shown in Fig. 2-18 [12] Fig. 7. The adjustment dial was set at room temperature and the dial calibration screw was adjusted so that the blade just makes contact to the left side and then to the right side for the furnace. Then the adjustment dial was set 5°F lower to set the differential between stages. The between-stage differential calibration screw was adjusted so that the blade just makes contact to the left side and then to the right side for the demand pump.

Upon decreasing house air temperature, the demand pump will be activated first, supplying solar heat to the house. If the temperature continues to drop below the 5°F differential setting, then the furnace is also activated. Both units will cycle as necessary between $\pm 1^\circ\text{F}$ of their respective settings. Upon increasing temperature, the furnace deactivates at 1°F above the setting and continued increasing temperature to 1°F above the demand pump temperature setting deactivates this pump.

Operation of the demand pump is also controlled by the Honeywell Aquastat Model L 4008 B, [3]. This aquastat Controller C-3 is hooked-up in series with the thermostat as shown in Fig. 2-17. The control circuit is completed on temperature rise of the storage tank water to 80°F. When the temperature drops below the 80°F setting, the aquastat opens the control circuit thereby deactivating the demand pump. This prevents the circulation of stored water which is too cold for heating purposes.

A manual bypass switch 5 (Fig. 2-13) is provided in the 24V circuit to allow operation of the demand pump independent of the thermostat and aquastat controls. Using this bypass immediately starts up the demand pump and the furnace's air blower.

Operation of the warm air system is tied-in directly with operation of the demand pump and furnace (Refer to Fig. 2-12). The air blower is automatically activated along with the demand pump. There is no time delay encountered with this combination. If the demand pump is not operating and the furnace is activated, then the air blower will start-up after a few minutes time delay which is controlled by the furnace low temperature cut-out switch. This switch closes when the furnace temperature exceeds the minimal temperature setting. Shut-down of the demand pump, when the furnace is not operating, simultaneously deactivates the air blower. If the furnace is operating and the demand pump is deactivated, then the air blower continues to run. Also upon shut-down of the furnace, the air blower will continue to run until the furnace drops to the low temperature cut-out switch setting.

The overall control logic for the comfort heating system is shown in Table 2-8.

In order to distribute the air flow as required throughout the house, dampers are positioned in the warm air system ducts. The locations and relative settings of the dampers are shown in Fig. 2-19.

The back-up conventional oil fired furnace is controlled by a Honeywell, Protectorelay [14] oil burner control RA117A (C-4) as shown in Fig. 2-12, [12], Fig. 7. This one piece, stack-mounted oil burner primary control cycles the burner on demand of the thermostat and shuts down the burner on loss of flame, or system malfunction, or ignition failure. The control box layout and oil burner circuit diagram are shown in Fig. 2-20.

In conjunction with the operation of the solar collection loop and the heat demand loop, the storage tank system maintains the water level in the storage tanks. As necessary, the make-up feed water valve, Controller C-5, automatically adds water to the system from the city water supply line. This make-up water feeder, McDonnell & Miller No. 25A [15], is a float operated valve which is positioned relative to the desired level in the tanks. This position was based-on maintaining a maximum level in the storage tanks, while allowing sufficient capacity for system drain-down. The original system design took into account the volume of water needed to be drained, approximately 160 gallons, among the 3 storage tanks. This amounts to a height of 13" from the tank top through which the centerline of the float is positioned. Details of the level control valve are shown in Fig. 2-21 taken from [15].

2.3.4 Solar Domestic Hot Water Heating System (SDHWHS)

The city supply water is heated via a water-to-water heat exchanger by the water in the thermal storage tanks. There is no control in this segment of the system. The water from the SDHWHS is supplied directly to the domestic hot water heater as shown in the system diagram, Fig. 2-3.

In this conventional gas-fired hot water heater, the desired water temperature is set on the thermostat dial (range of 50 - 160°F) and controlled automatically. This thermostat and dial are part of the Unitrol R110 RT-P series (Robertshaw Controls Company) Controller C-6 as shown in Fig. 2-1. Also, the existing controller contains an automatic gas shut-off system which is actuated by high water temperatures (>180°F) for extra safety. Details for this controller are contained in [16].

For this application as a precaution against scalding, a Watts tempering valve Model No. 70A (Controller C-7) is located downstream of the DHWH. If the water temperature exceeds the set temperature (of say 140°F), then this valve allows cold city supply water to mix with the hot water as necessary. The tempering valve can be set to control in the range of 120-160°F, [17].

3. THE PERFORMANCE MONITORING SYSTEM

3.1 General Description

The performance monitoring system was designed to allow the measurement and recording of system operating parameters as well as weather data for overall performance evaluations. Key elements inherent in obtaining accurate performance results were the design and selection of the instrumentation, the use of appropriate instrument installation techniques, the choice of pertinent sensor signal conditioning methods, implementation of calibration facilities, and the selection of an effective and economical method for data acquisition. For a detailed description of these elements, refer to [3] and [4].

3.2 Instrumentation Identification

The rationale for choosing the instrumentation and DAS for this SolarHouse is explained in [4]. All the various instruments are listed in the Instrumentation Table 3-1, under the applicable systems in the order as follows: Climatological, Collector, Thermal Storage, Domestic Hot Water System and Space Heating Systems. This list was updated from the list provided in [3]. DAS Channel numbers were added as well as specific serial numbers for sensors. Table No. 3-1 also contains all the local indicating pressure, flow and temperature gauges, which are not monitored by the DAS.

At present, a total of 63 channels of data are monitored by the DAS and recorded on magnetic tape and printed on paper. A list of these instruments in channel number order is shown in Table No. 3-2. This list is provided for cross-referencing as well as other hook-up details.

Another list of the DAS instrumentation is grouped according to the type of measurement (all pressure gauges, RTD's, etc. together) and shown in Table No. 3-3. This table also defines the cable hook-up connection locations in the junction boxes (basement and roof, Figs. 3-1 and 3-2 respectively), cable bundle number and individual wire color identification. Photographs of the basement and roof junction boxes are shown in Figs. 3-3 and 3-4, respectively. Details of the type of cables which were utilized for instrumentation wiring hook-ups are provided in Table No. 3-4.

3.3 Instrumentation Wiring Diagrams

Detailed wiring diagrams are provided for all DAS instrumentation channels, in channel number order, in Appendix B of this report. Location of specific instrumentation details are readily available after noting the DAS channel number from Tables 3-1, 3-2 or 3-3.

3.4 Code Numbering System

The code numbering system used for the instrumentation and valves on this project was adopted from [5]. This was done in order to standardize the identification of sensors according to type and system function for the National Solar Heating and Cooling Demonstration Program. The code consists of a four or five character name consisting of one or two letters designating sensor type or measured/calculated quantity and a three digit number identifying the subsystem or data group. A listing of the code as defined in [5] is provided in Table 3-5. Although all the items defined are not utilized for our project, they are included to provide the complete list.

3.5 The Data Acquisition System

An 80 channel Esterline-Angus Data Acquisition System Model PD-2064 was selected as discussed in [4] to monitor the detailed performance of the SolarHouse. This model is a key-programmable DAS which is controlled by a microprocessor. For a detailed description of the unit see [18]. The functional elements of the system, as shown in [18], Fig. 1-1, is included in this report as Fig. 3-5.

The system includes the options as follows:

- *programmable zero offset range
- *digital averaging
- *dual rate output option 253
- *dual rate channel group scan
- *24 channels of dual set-point Hi-Lo Alarms
- *dual common alarm relays
- *program bank including 3 additional files, and
- *memory save

In addition, the system was interfaced to output simultaneously to a magnetic tape recorder and to a wide-carriage printer.

A photograph of the DAS console showing the individual component locations and the continuous reading instrumentation is shown in Fig. 3-6. The applicable instrumentation definitions, and interfacing hook-up details to the DAS are provided in Section 3.2 of this report. The 63 data inputs to the DAS as well as one zero voltage reference channel are provided in channel number order in Table 3-2. This list also defines the DAS connector pin locations inside the console. A diagram of these connections is shown in Fig. 3-7.

A line diagram of the wiring from the terminal strip connections located in the DAS console to the junction boxes in the basement and roof is provided in Fig. 3-8.

3.5.0 Pulse Accumulator and RTD Wiring

The details for the pulse accumulator hook-ups are shown in Fig. 3-9.

During normal operation, the pulse outputs from the tempering water supply flow meter (DAS 62) and the gas flow to the DHWH (DAS 63) are input to these pulse accumulators continuously as shown on Fig. 3-9. At the time when these channels are scanned by the DAS, the analog DC signal proportioned to the accumulated number of pulses is read by the DAS, and the pulse accumulators are reset to zero at the end of each scan.

The current supply for each RTD current loop is located in the DAS console. A hook-up sequence for the RTDs in each current supply loop is shown in Table 3-6. The two programmable constant current sources are Callex Mfg. Co. Model 7203, a low thermal drift version of Model 930, [19] with an output current versus temperature coefficient of $\pm 0.002\%$ FS/ $^{\circ}\text{C}$.

3.5.1 Tape Recorder System

The recording system is a Kennedy Model 9832 Dual Buffered Digital 9 track magnetic tape recorder. The unit can accept data asynchronously at data rates up to 250,000 characters per second. The standard tape speed is 25 inches per second and the density is 800 BPI. To verify proper data recording on tape, a read-after-write check is executed automatically by the recorder. Using 1/2" wide 1200 foot long standard magnetic tape and scanning at five minute intervals, one reel lasts approximately two weeks. The tape recorder is used to store the data. After completing a tape, the data is transferred to one of the University's large computers where it is reduced and plotted.

The recording system interfaces directly with the DAS. Additional tape recorder information is contained in [20].

3.5.2 Printer System

The printer used is a Digital Equipment Company Model LA36 DECwriter II with the LAXX-KG EIA interface. This interface was used for adaption to the DAS by Esterline Angus. The unit is set-up to print 6 channels of data across the width of the carriage on regular computer paper at a maximal rate of 30 characters per second. A sample channel print-out, annotated with instrumentation number and description is shown in Table 3-7.

Basically the unit is used as a printer terminal, but it can also transmit data at a rate of 10, 15 or 30 characters per second by selecting the appropriate BAUD Rate switch. The line length is 132 characters maximum. The horizontal spacing is 10 characters per inch and the vertical spacing is 6 lines per inch. For detailed information, refer to [21].

3.5.3 DAS Console Direct Reading Instrumentation

Mounted in the DAS console are various direct reading instruments as listed in Table 3-2. They provide real time readings for over-viewing the heating system's operation and the climatological station.

In addition, the elapsed time meters, as discussed in Section 3.6 of this report, are located adjacent to the DAS Console, Fig. 2-15. These meters provide a back-up for checking system operation and overall performance evaluations, both when the DAS system operates and when it happens to malfunction.

3.6 Elapsed Time Meters

The elapsed time meters measure the cumulative operating time of various units as a redundancy check to improve the data acquisition reliability. Monitored are the cumulative operating times of the demand loop and solar collector loop pumps, the solenoid valves used for freeze protection, the warm air fan, and the auxiliary energy flows of gas to the DHWH and oil to the furnace. The seven meters are panel mounted and located in the DAS room as shown in Fig. 2-15. Details of the wiring hook-up in the DAS room are shown in Fig. 3-10. The cables are routed to the basement and are connected at the Control Panel as shown in Fig. 3-11.

The A.C. Hour meters are manufactured by Engler Instrument Co., [22]. These meters register up to 999.99 HRS and have a side mounted reset button. Different models were chosen based on the applicable input voltage from the units. A list of the models is provided in Table 3-8.

3.7 Gas Flame Detector (DHWH) & Relative Humidity Fan Alarm Monitor Box

The monitor box for the domestic hot water heater (DHWH) gas flame detector and the relative humidity fan alarm is located in the DAS room adjacent to the elapsed time meter panel as shown in Fig. 2-16.

The gas flame detector utilizes a photo-voltaic cell, Centronic OSD5-5PV, to provide an output signal with a relatively very short On & Off time response (milliseconds). This detector is aimed at the gas flame at the bottom of the hot water heater. A sleeve and lens are attached to the photo-voltaic cell to avoid undesired radiation from reaching the 5mm² sensing element. The output from the photo-voltaic cell is connected to the monitor box as shown in Figs. 3-12 and 3-13. The signal is converted by a volt-sensor Callex Model 415-215, to drive the on-off relay contacts which operate the DHW gas supply elapsed time meter (Fig. 3-10) and the red and green indicator lamps, "Fire On" and "Fire Off", respectively.

In order to attain accurate relative humidity readings, a constant air flow is required across the sensor, which is housed in the radiation shield on the roof. A normally-open contact closes with air flow (green lamp on). This relay signal is routed through terminal strip positions H15 and 16 in the roof junction box, Fig. 3-2, to the monitor box as shown in Figs. 3-12 and 3-13. Normally, the fan operates continuously. If the air flow stops, the fan alarm will be initiated as indicated by the red lamp-on at the monitor box.

The detailed wiring schematic for the monitor box and associated sensors is shown in Fig. 3-14. A test switch on the monitor box may be operated manually to check the operation of the red and green indicator lamps for both applications.

3.8 Overall System Display Box

The Overall System Display Box is located in the DAS room as shown in Fig. 2-16. This display box contains an enlarged copy; approximately 30" x 30", of the Overall System Flow Diagram as shown in Fig. 3-1. The systems are color coded as defined in Section 2.2 of this report. Eleven neon indicator lights are mounted on the face of the flow diagram corresponding to the specific items being monitored on the elapsed time meters. By observing the lamps, the operational status of the system is determined as defined by the lamp-on representation shown on Table 3-8.

The plexiglass covered display box is accessible from the rear to the lamp terminal strip connections. The display box wiring is essentially connected in parallel with the elapsed time meters, as shown in Fig. 3-10. Two multi-conductor cables are hooked-up from the 4" x 4" junction boxes to the display box.

4. OPERATING PROCEDURES

4.1 Heating System

4.1.1 Outline of Heating System Operations

Normal overall system operation is automatic. The various control systems, as defined in Section 2.3 of this report, operate the pumps and the air blower, actuate the solenoid valves, cycle the furnace and the domestic hot water heater and maintain safe system operation.

An overview of the various system and equipment operations in the basement area is attained by recording the applicable information as identified on Data Sheet (D.S.) No. 1, located in Appendix A of this report. In general, data is recorded during system operation when performing normal check-out in the basement area. Similarly during normal system check-out in the DAS room, the readings of the elapsed time meters are recorded on D.S. No. 2 (Appendix A).

4.1.1.1 Solar Collector Loop (Figure 2-2)

The normal solar collector loop flow rate is 7 to 10 gpm, with a pump discharge pressure of 40-45 psig and a pressure of 1-5 psig at the last collector row outlet header. System operation is controlled by the differential temperature controller as explained in Section 2.3.2 of this report. For this controller, the power light is always on. The "pump on" or "frost on" lights are activated when these subsystems are operating.

Under normal pump operating conditions, the solenoid valves S2 (V142) and S3 (V104) are in the open position and the S1 valves (V146-149) are in the closed position. This allows flow throughout the system, without bypassing any solar collectors. When the solar collector pump is not running, solenoid valves S1-A to -D are open and solenoid valves S2 and S3 are in the closed position. S2 and S3 are kept closed to avoid unnecessarily frequent drain downs and subsequent fillings which have a number of negative results: frequent admission of air into the system as well as higher pump-motor loads and poorer collector efficiency during these transients. Also S1 valves are open to allow the drain lines to empty into the storage tanks if the frost control is activated. Note: The original S1 valve in the line is no longer hooked-up. Therefore it is always open.

During normal operation the S1 valves bypass switch #4 on the control board in the basement is in the "On" position. Placing the switch in the "Off" position opens the power circuit, keeping the valves open. In order for solenoid valves S1, S2 and S3 to fail safe, power to them closes the valves and loss of power opens the valves. Therefore, on loss of electric power, the system will automatically drain and provide frost protection.

4.1.1.2 Heat Demand and Warm Air Loops (Figure 2-2)

The normal flow rate in the heat demand loop is 8 gpm with a pump discharge pressure of 8-10 psig. Performance data for the Bell & Gossett Series PR Pump is shown in Fig. 2-8. The blower fan which conveys warm air throughout the house operates in conjunction with the demand pump. This fan provides 1700 cfm through the warm air loop, and starts-up simultaneously with the demand pump.

The space heating system is controlled by the two-stage thermostat as defined in the control section of this report, 2.3.3. The demand pump is set to start and maintain a temperature of say 75°F, as set on the thermostat, providing the temperature within the storage tanks is at or above 80°F. Otherwise, the aquastat will deactivate the pump. For an inter-stage differential of 50°F, if the temperature within the house drops in this case to 70°F, then the back-up furnace is activated by the thermostat. When operating with the furnace, but without the demand pump, there is a time delay between furnace start-up and fan start-up of approximately 3 minutes. This is to prevent cold air from circulating through the house, since it takes a few minutes for the furnace combustion chamber to arrive at the desired temperature.

4.1.1.3 Solar Domestic Hot Water Heating System (Fig. 2-3)

The normal flow rate in the system varies as a function of the hot water demand throughout the house. As hot water is used, water flows from the city water supply through the SDHW and then the DHWH. The DHWH thermostat (on the gas-fired heater) is typically set at approximately 130°F by a dial setting at the mid-zone notch [6] and automatically controlled at this temperature. The gas flow to the heater is initiated as required to maintain this desired temperature.

As a safeguard against excessive temperature at the outlet from the DHWH, the water flows through a tempering valve. This thermostat controlled valve automatically mixes cold water with the hot water supply as the set temperature of 140°F is reached.

4.1.1.4 Storage Tank System (Fig. 2-3)

Normal operation of the solar collection loop, heat demand loop and SDHW loop utilizes the water contained in the storage tanks. The water level is automatically maintained by the make-up feed valve V-219. RTD's are installed in storage tanks numbers 1 and 2 to determine the vertical temperature distribution. Isolation valves are provided for each RTD. They are normally open but can be closed to isolate the device for repair or replacement.

The sequence of isolation is first to withdraw the RTD till its end clears the valve (but not beyond the compression fitting's seal), since the RTD extends through the valve into the tank, and then to close the valve.

The normal operating water level in the storage tanks is 15 (+1) inches as shown on the gage glass, which correlates with a level of 71 (+1) inches in the tanks. Zero inches on the gage glass correlates with a level of 56 inches in the tanks. The overall tank height is 84 inches. When draining the solar collection loop for freeze protection, the level rises to 21(+1) inches as shown on the gage glass.

During system draindown and filling, air entry or exit respectively is accomplished through an opening in the manifold line at the top of tank number 2. A pressure relief

valve is also contained in this line, if for some reason the pressure should build up. A pressure gauge installed at the same location reads atmospheric pressure during normal operation. See Fig. 2-4.

4.1.2 Filling of Systems

Prior to system fill verify completion of scheduled overall system maintenance and repairs. Also check that all associated systems are ready to be placed on-line.

4.1.2.1 Valve Line-Up

Storage Tank System

- a) Close drain valves at bottom of storage tanks, V-221, -222 and -223.
- b) Verify open normally open valves associated with the storage tank gage glass tank level indicator, V-214 through V-218. Close valve slightly and then open full (counterclockwise).
- c) Verify closed drain valve V-220.

Solar Collection Loop

- d) Verify open solar collector pump suction valves V-101, -102 and -103 and the butterfly valves integral with the thermoflo balancer flow meters W-101, -102 and -103.

Demand Heat Loop

- e) Verify open demand heat pump suction valves V-401, -402, and -403 and the butterfly valves integral with the thermoflo balancer flow meters W-401, -402, -403.
- f) Verify open demand heat pump globe valves V-407, -408 and -409 in the return line to storage tanks and the butterfly valves integral with the thermoflo balancer flow meters W-404, -405 and -406.

Solar Domestic Hot Water Heating System (SDHWHS)

- g) Verify closed city water supply line V-311 to make-up feed valve V-219. This valve should be closed in conjunction with system draindown operations.

- h) Verify open inlet city supply valve V-300 and valve V-310.

4.1.2.2 Filling Operations

Storage Tanks and Associated Piping

- a) Open SDHWS water supply line valve V-311 to make-up feed valve V-219 and fill the system. Check the system level as shown on gage glass L-200 for stabilization.

Solar Collection Loop

- b) Line-up the solar collection loop as shown in Fig. 2-2. (Verify that all valves are open unless designated NC, normally closed, on the diagram).
- c) Place power on the solar collection loop pump by closing circuit breaker Switch 8 at the basement control board (Fig. 2-13). Start the pump by pressing and holding in the test button or by normal controller operation.
- d) Run the pump until all air is vented and the system is full. The make-up feed valve will continue to fill as necessary. Observe the movement of the water level in the gage glass L-200. Make sure it does not over or under-fill the system.

Demand Heat Loop

- e) Line up the Demand Heat Loop as shown in Fig. 2-2.
- f) Place circuit breaker Switch 10 in the Up ("On") position for the demand heat loop pump, P2, at the basement control board (Fig. 2-13). Start the pump by turning on the 24 volt bypass Switch 5.
- g) Run the pump until all air is vented and the system is full. The make-up feed valve will continue to fill as necessary. Observe the movement of the water level in the gage glass L-200.
- h) The overall system is now ready for normal operation.

4.1.3 System Start-Up and Operation-Verification

In setting-up for normal system operation, all manually operated valves are positioned in the normally open or closed position as applicable and as shown in Figs. 2-2 and 2-3. All valves are open unless designated NC (Normally Closed). Verify that the control systems are on-line with switches and dials in the normal operating position as indicated in Table 4-1 and shown in Fig. 2-13.

Solar Collection Loop

4.1.3.1 System Start-Up

As necessary perform or verify the following steps (Also refer to Table 4-1):

- a) Line-up the solar collection loop as shown in Fig. 2-2.
- b) Place circuit breaker Switch 8 in the Up ("On") position for solar collector pump, P1, at the basement control board, Fig. 2-13.
- c) Apply power to Differential Temperature Controller, C1, at the basement control board. Place Switch 1 on C1 to "Operate", and turn 12 position Switch 2 to position 12.
- d) Place Switch 4 "On" for Solenoid Valves S1-A, -B, -C and -D.
- e) Place Switch 6 to position 2.2 for Solenoid Valves S2 and S3.
- f) Operation of the system functions on automatic control. See section 2.3.2 for details on controller operations.

4.1.3.2 Setting System Flow Rate and Storage Tank Flow Balance

Record test results on Data Sheet #3, Appendix A.

- a) Throttle down on the inlet globe valves V-143, -144 and -145 to the storage tanks and set the flow rate in the range of 7-10 gpm as read by the "Ramapo" flow meter (W100) on DAS channel # 25. This mV reading divided by the 10 mV input voltage excitation yields the mV/V excitation value required for reading the flow rate as shown on the calibration curve in Fig. 4-1.

- b) Determine the amount of opening for the three inlet globe valves, V-143, -144 and -145, to the storage tanks to meet the nominal 7-10 gpm system flow rate and to balance the flow to the storage tanks. Based on the total system flow rate determined in step a), check the flow on the thermoflo balancer flow meters, W-104, -105 and -106 (located at the inlet to the storage tanks) for balance - approximately equal flow to each tank. Adjust the applicable inlet globe valves to balance the flow within the 7-10 gpm total flow range, and record the amount of opening.

Note 1: With the inlet globe valves closed, a reference line was drawn vertically on the valve handle and adjacent valve bonnet position. Thus the movement of the valve handle relative to the stationary marking on the bonnet determines the amount of valve opening (the valves are less than one turn open).

Note 2: Flow rate changes also may be made by adjusting the thermoflo balancer built-in butterfly valve. Future testing will establish the preferred method.

4.1.3.3 Setting Collector Row Balanced Flow Distribution (This can be done only after the pertinent temperature measuring instrument is completed.)

Record test data on Data Sheet No. 4, Appendix A.

- a) Set-up temperature sensing devices to determine the outlet temperature from each collector in a specific row.
- b) With the system operating in the normal mode, record the outlet temperature from each collector. After evaluation of the temperature data, adjust as necessary the applicable globe valve(s) at the collector outlet: higher temperatures in a line indicate lower flow rates. After system flow stabilization, observe the outlet temperatures for uniformity.
- c) Repeat step b) until the outlet temperatures are within 1°F. Record final valve positions.

Note: With the valves closed a reference line was drawn vertically on the valve handle and on the valve bonnet in-line position. Thus the movement of the valve handle marking relative to the stationary marking on the bonnet determines the amount of valve opening.

- d) Repeat steps a) - c) for each of the other four rows.

Heat Demand and Warm Air Loops

4.1.3.4 System Start-Up

As necessary perform or verify the following steps.
As a further guide refer to Table 4-1.

- a) Adjust Switch 3 for the Aquastat Controller, C3, to the 80°F position.
- b) Place Switch 5 in the "Off" position, demand pump 24V bypass.
- c) Adjust Switch 7, delay circuit for demand pump to 0.6 position.
- d) Place circuit breaker Switches 9 and 10 to the Up, ("On") position, respectively for air fan and demand pump power.
- e) Set thermostat 2-stage controller, C2, to the desired 1st stage temperature. This controller and associated circuitry automatically controls the system operation. See Section 2.3.3 for details on controller operations.

4.1.3.5 Setting System Flow Rate & Storage Tank Flow Balance

Record results on Data Sheet No. 5, Appendix A.

- a) Determine the total flow rate in the system as read by the Invalco flow meter (W-400) on DAS channel #6. The flow reading is provided in gpm at the DAS console, or by utilizing the mV conversion curve as shown in Fig. 4-2.
- b) Check the amount of opening for the three inlet globe valves, V-407, -408 and -409, to the storage tanks as noted on the data sheet. Also check the flow as read on the thermoflo-balancer flow meters, W-404, -405 and -406, located at the inlet to the storage tanks. Based on the flow rate determined in step a) and the flow meter readings, adjust the applicable globe valves to attain the required flow and balance.
- c) Balance the flow from the three storage tanks by observing the flow as indicated on the thermoflo-balancer flow meters W-401, -402 and -403, located in the suction line to the pump, and adjusting the applicable thermoflo-balancer built-in butterfly valve as necessary.

4.1.3.6 Warm Air Loop Flow and System Checkout

Record on Data Sheet No. 6, Appendix A.

- a) Determine the total flow rate in the system as read by the Air Monitor flow meter on DAS #34. Also check the pressure difference between the fan inlet and discharge as read on Magnehelic gage in basement, typically 0.4 to 0.5 inches of water.
- b) Check ducting for leaks.
- c) Check that all heat registers (in each room throughout the house) are open and not blocked-off.
- d) Verify that the dampers are in the positions as shown on the warm air system diagram Fig. 2-18.
- e) In conjunction with steps c) and d), check the velocity of air flow from each register throughout the house and adjust the dampers as necessary to balance the overall system. Record the final position of all dampers.

4.1.3.7 Checking Aquastat Controller Temperature Setting

Record results on Data Sheet No. 1, Appendix A.

- a) In conjunction with operation of the solar collection loop, observe the increase in storage tank temperature relative to sensing element location and correlate with the actual setting of the Aquastat Controller (C-3). The demand pump is activated upon increase of temperature to $80(+2)^{\circ}\text{F}$ and deactivated at $80(-2)^{\circ}\text{F}$.
- b) As necessary adjust the Aquastat set screw to activate the pump as specified above. Mark the final position on the temperature dial.

Note: If necessary, adjust the temperature setting (higher) on the thermostat controller (C-2) in order to provide a signal so that the demand pump will start as a function of storage tank temperature.

Solar Domestic Hot Water Heating System

4.1.3.8 System Start-Up

As necessary, perform or verify the following steps.

- a) Line-up the SDHWHS as shown in Fig. 2-3.
- b) Set the hot water heater controller, C6, slightly lower than the 140°F midpoint position.

- c) City water supply line automatically provides flow for the various functions as required.

4.1.3.9 Checking Flow Rate and Balance Between Heat Exchangers

Record test results on Data Sheet No. 7, Appendix A.

- a) Open hot water outlet taps in the house as necessary to provide a high flow rate for the system.
- b) Determine the total flow rate in the system as read by "Flow Technology" flow meter (W-300) on DAS channel #58. The flow reading is provided in gpm at the DAS console, or by utilizing the mV conversion curve as shown in Fig. 4-3.
- c) Check the amount of opening for the two outlet globe valves, V-304 and V-305, from storage tanks #2 and #3, respectively. Also check the flow as read on the thermoflow-balancers W-302 and W-303 located at the inlet to the heat exchanger in the storage tanks and the pressure gage reading P302(L), and P303(L), respectively.
- d) Check the outlet temperature from each heat exchanger outlet, as read on T301 and T302, DAS channel #55 and #56 respectively.
- d) Adjust the outlet globe valve V-304 and V-305 as necessary to balance the flow or outlet temperature or pressure.

4.1.3.10 Setting Tempering Valve Temperature

Record on Data Sheet No. 8, Appendix A.

- a) Check test results for tempering valve operation or adjust DHWH controller to increase temperature. Determine temperature at which valve was actuated as read on the RTD at the outlet from the DHWH, T-304 (DAS channel #59). Also check flow meter, W-301, actuation.
- b) Adjust tempering valve setting as necessary to attain the required 140°F actuation.

Note: Water @ 140°F causes a third degree burn in 5 seconds (Burn Foundation of Greater Delaware Valley).

4.1.3.11 Gas Flame Detector Check-out

- a) During operation with the gas on to the DHWH as noted on DAS channel 63, check that the red "Fire On" lamp is on. The green lamp is on when there is no gas flow, "Fire Off."
- b) Another method utilizes the test switch located at the monitor box in the DAS room, Figs. 2-16, 3-13, and 3-14. By turning the test switch to position 1, when the gas flow is off, the green lamp goes off and the red lamp ("Fire On") goes on. When the gas flow is on, turning the switch to position 2 causes the red lamp to go off and the green lamp ("Fire Off") to go on. Using this test switch verifies the circuitry for the red and green lamp operation, excluding the flame detector. In addition, this check effects the elapsed time meter readings. Consequently, this method is performed as quickly as possible and then the switch is re-positioned to operation. This will result in a minimal error in the elapsed time meter readings.

Storage Tank System

4.1.3.12 System Start-Up

As necessary perform or verify the following steps:

- a) Line-up the Storage Tank System as shown in Fig. 2-3.
- b) The water level in the storage tanks is automatically maintained by the make-up feed valve as supplied from the SDHWS.

4.1.3.13 Make-Up Feed Valve Operation Verification

Record on Data Sheet No. 8, Appendix A.

Note: Throughout the overall systems fill (Section 4.2) performance, the operational check of this valve was checked. Therefore, this section may be performed only if deemed necessary.

- a) Reduce the level of water in the storage tanks by opening the desired drain valve(s), V-221 -222 and -223 (located at the bottom of the storage tanks). The tank level for normal operation is 15 ($\pm$ 1) inches.
- b) Observe the levels at which the make-up feed valve (V-219) initiates and stops. The valve is specified to close at

1/2 inch above the float section centerline as shown in Fig. 2-21 from [15]. This centerline corresponds to the normal tank level as read on the gage glass, L-200, of 15 (+1) inches which also corresponds to the overall water level in the tank of 71 inches. Also refer to storage tank dimensions as shown in Fig. 2-6.

4.1.4 Normal System Operation

In the course of normal automatic operation, the systems are on-line as detailed in Section 4.3. In order to maintain and verify normal system operation, proceed as follows:

- a) Check each system for normal operation by recording the parameters as defined on the respective data sheet. Perform on a weekly basis or as operational conditions warrant. See data sheets in Appendix A.
- b) Record the elapsed time meters (located in the DAS room) on Data Sheet No. 2, Appendix A. Perform as convenient on a daily basis.
- c) Verify those items set in start-up as necessary (at least annually).
- d) Observe the overall system display box in the DAS room to check the lamp on representative for the specific solenoid valves, pumps, DHW gas flow, oil burner motor and furnace blower as specified in Table 3-8. Double check results occasionally by observing applicable channel values as shown on the Decwriter printout.
- e) Observe the gas flame detector "Fire On" and "Fire Off" indicator lamps, red and green respectively and the relative humidity fan alarm, Fan off (red) and Fan on (green) on the monitor box in the DAS room.

4.1.5 Special Operating Conditions

Solar Collection Loop

4.1.5.1 Operation with First Collector Row Only

During the summer months it may be desirable to operate in this mode to protect against excessive temperatures.

- a) Set the S-1A through S-1D bypass switch 4 on the control board in the basement to "Off", Fig. 2-13.
- b) Operate the system as usual. The flow will pass through the first collector row and then out the drain line through check valve V-146 and back to the storage tanks.
- c) Each S1 valve can be operated manually to allow 2, 3 or 4 collector rows to be on-line.

4.1.5.2. System Optimization as a Function of Differential Temperature Controller Set-Point

- a) Set the dial on the 12 position switch 2 to the desired turn-on differential temperature position as shown in Table 2-7. This switching device is located adjacent to the controller on the basement control board, Fig. 2-13.
- b) Operate the system in the normal mode (Switch 4, S1 "On", Section 4.1.3.1) and evaluate the test results.
- c) Repeat steps a) and b) as necessary to determine the optimum setting for overall system operation.

4.1.5.3 Operation with One or Two Storage Tanks On-Line

- a) Isolate the storage tank(s) not on-line. Close its inlet and outlet valves.
- b) Close thermoflo-balancer built-in butterfly valve associated with each valve closed in a) to provide double valve closure.
- c) If storage tanks #2 or #3 are isolated, close outlet valve from SDHWH system, V-304 or V-305, respectively.
- d) Operate system as in normal operation.

4.1.5.4 Isolation of a Solar Collector

In order to isolate an individual solar collector for repairs or as necessary proceed as follows:

- a) Shut down the solar collection loop.
- b) Close the outlet globe valve at the top of the collector.
- c) Disconnect the inlet line to the collector and insert a plug in the outlet line from the header.
- d) Place the solar collection loop back on-line.

The solar collector system can be operated in this mode with the flow being distributed to the other collectors in the row.

- e) Shut down the collector loop and reverse functions in steps b), c) and d) to place collector back on-line as necessary.

Heat Demand and Warm Air Loops

4.1.5.5 Thermostat Environment Optimization

During normal operation, care need be exercised to subject the thermostat to average second floor conditions.

- a) Open and keep open the doors to the room on the Delancy Street side. This will allow the heat from the register in this room to be directed to the thermostat.
- b) Close and keep closed the door off the second floor hall leading to the first floor side entrance. This will minimize the cold drafts on entering or leaving through this side entrance.

Note: Repositioning of the thermostat will be evaluated. (Perhaps to the second floor room on the Delancy Street side or the installation of an exhaust fan from this room to the hallway.)

- c) During the heating season record on a daily basis on Data Sheet No. 9 the thermostat setting, temperature reading, date and time. Correlate this data with the demand pump, furnace and room air temperature DAS data, Data Sheet No. 10, Appendix A.

4.1.5.6 Operation with One or Two Storage Tanks On-Line

Operate system with applicable storage tanks isolated as defined in Section 4.1.5.3.

SDHWHS

4.1.5.7 Operating Heat Exchangers in Series

At present the heat exchangers are hooked-up for parallel operation only. Evaluation of the test results will determine the desirability of operating in series. This could be accomplished by slight modifications to the piping system.

4.1.5.8 Operating with One Heat Exchanger On-Line

Isolate the storage tank off line by closing the outlet globe valve V-304 or V-305 as required. System flow will flow through the one applicable tank.

Storage Tank System

4.1.5.9 Drain-Down During Overall System Operation

- a) Isolate storage tank(s) for drain down: Close inlet and outlet valves from associated solar collection and heat demand loops.

Note: If storage tank #2 or #3 is drained close applicable SDHWHS outlet globe valve V-304 or V-305. If both are drained, leave both open.

- b) Close gage glass isolation valve(s) as applicable (V-214, -215, -216, water lines from storage tanks).
- c) Open drain valve(s) at bottom of applicable tank(s) and completely drain the tank.
- d) Perform desired repair or maintenance as required.

4.1.5.10 Fill During Overall System Operation

- a) Close drain valve(s) at bottom of applicable tank.
- b) Open applicable solar collection loop suction line valve(s) V-101, -102 and -103 and thermoflo balancer butterfly valve(s) W-101, -102, and -103. The tank will fill from the on-line tank(s). Make-up feed valve will automatically add water to maintain overall level in tanks.

- c) After tank(s) fill up open gage glass cut out valve(s) as applicable.
- d) Place tank(s) back on-line by opening inlet valve from solar collection loop and inlet and outlet valves from demand heat loop. Also open outlet valve from heat exchanger V-304 or V-305, if applicable. The system is now set-up for normal three tank operation.

4.1.6 Trouble-Shooting

In general, perform trouble-shooting as required to determine system or component anomalies. When bypass valves are provided, they allow servicing of the flow meters while automatic system operation continues. In this situation the bypass valve is opened and the isolation valves upstream and downstream of the flow meter are closed. Thus the flow meter is isolated.

4.1.6.1 Solar Collector Leak Check-Out

- a) With the solar collection loop on-line, inspect the inlet and outlet connections for leaks.
- b) If a leak is observed, identify the specific leak point or general area if possible. Then fix as necessary if the leak area is accessible.
- c) If the leak is not accessible (internal to the collector container), isolate the solar collector as defined in Section 4.1.5.4.
- d) Remove the solar collector from the support structure and disassemble as follows:
 - 1) Remove the side, top and bottom mounting bolts and pieces anchoring the collector to the support structure.
 - 2) Push the collector assembly from the rear so that both the bottom and top end connections clear through the support structure. Lift and move the collector assembly to the clear area in front of the collector row. Position the unit with the glass side down. CAUTION: Exercise care in lifting and removing the collector assembly (three people should be used to perform this function).

- 3) Remove the aluminum side pieces from all four sides. Pry loose the ends with a screw driver and then pull the sides off (for PPG collectors).
- 4) Lift off the back container and insulation.
- e) Pressure test the collector and identify the leak area.
- f) Fix the leak area as required.
- g) Repeat the pressure test to assure that the leak has stopped.
- h) Reassemble the solar collector.
- i) Reinstall the unit in the support structure, reversing the procedure in step 2) on the preceding page.
- j) Hook-up the piping to the solar collector removing the plug at the inlet header.
- k) Place the solar collection loop back on-line and verify the elimination of the leak.

4.1.6.2 Furnace Check-Out

Operation of the oil-fired back-up furnace is automatic as activated by the thermostat controller, C-2. If the system is not activated thereby, perform the following steps as necessary:

- a) Remove the thermostat cover and check if contacts are positioned at left side detent magnets (completing circuit and calling for operation, Fig. 2-18). The right hand bimetal element is for the demand pump and the left hand bimetal element is for the furnace.
- b) Verify that the emergency switch 11 is in the up position for power "On". This switch while in the up position is normally covered with masking tape to minimize inadvertent shut-down. The switch is located at the top of stairs (1st floor) on left side when going down (opposite the light switch). In an emergency, such as a fire in the basement, close this switch (down position) to shut power to the furnace.
- c) Check fuel oil level in tank (front room Spruce Street side).

- d) Press reset button at back of furnace, and if all above does not help:
- e) Call furnace service oil company.

4.1.6.3 Thermoflo Balancer Flow Meter Glass Cleaning or Replacement

- a) Isolate the unit(s) to be worked on. This will necessitate shut down of the applicable system (solar collection or demand, Section 4.1.7.1 or 4.1.7.2). Ideally this would be performed during System Drain-Down.
- b) Dismantle the unit by removing the four cap screws from the end flanges and follow the other steps as shown in [23].
- c) Clean or replace applicable elements and reinstall in system. Care must be exercised to alternately tighten each side gradually.
- d) Place the unit and system back on-line.

4.1.7 System Shut-Down

In general, an individual loop may be shut down for repairs while the remaining systems are operating. For example, the solar collection loop may be secured, while the demand loop and SDHWS loop are operating.

4.1.7.1 Solar Collection Loop

- a) Disconnect differential temperature controller, C1, power supply at the basement control board.
- b) As a double check, position the solar collector loop pump circuit breaker switch 8 down, "off", at the basement control board area.
- c) As necessary isolate from the storage tank system.

4.1.7.2 Heat Demand and Warm Air Loops

- a) Secure power to the air fan and demand pump by positioning circuit breaker switches 9 and 10 down, "Off" at the basement control board area. Note: Either one may be closed separately as required.
- b) As necessary isolate from the storage tank system.

4.1.7.3 SDHMS

As necessary isolate the system as follows:

- a) Close V-301, inlet valve upstream of flow meter W-300 and open normally closed inlet valve to DHWH, V-307, to allow flow to heater while bypassing the storage tanks.
- b) Close inlet valve from city water supply V-300. This shuts off the total water supply to house.

4.1.7.4 Storage Tank System

Shut down this system in conjunction with drain-down operations as detailed in Section 4.1.8.

4.1.8 System Drain-Down

4.1.8.1 Storage Tanks

Annually during the summer maintenance shut-down, drain-down the storage tanks, inspect for corrosion and perform applicable maintenance.

- a) Secure power to the solar collector loop pump and the heat demand pump by opening circuit breaker switches 8 and 10 at the Basement Control Board Area (Fig. 2-13).
- b) Close cold water supply valve V-311 to the make-up feed valve V-219.
- c) Verify open normally open valves V-214 through V-218 to assure gage glass drain-down.
- d) Break the union connection in the drain line adjacent check valve V-224 and hook-up funnel to allow inspection of the water drained.
- e) Open widely the drain valve at the bottom of each storage tank V-221, -222 and -223, respectively for tank numbers 1, 2 and 3. The tanks may be drained individually in order to check the outlet flow for debris. In this case open individual drain valve and inspect the outlet flow as described in d). Collect any debris and when the flow is clear, close the drain valve, reattach the drain line from d) and allow the tank to drain. Repeat the procedure for each tank.

- f) The tank will not completely drain, since there is a static head in the drain line. Thus the bottom of the tank needs to be pumped out with an auxiliary pump after removing the main pump suction line flange connection.
- g) Clean-out bottom of storage tanks. Remove the large flange connections at the side of the tanks and check the inside tank coating for peeling. Use a hose to apply water under pressure to the tank sides and generally clean-off as necessary. (The hose may be hooked-up to the flow meter calibration valve V-315 and the city water supply used.) Contact tank coating vendor as necessary.
- h) Perform storage tank repairs or maintenance checks as necessary.
- i) Using the hose as set-up in step g) flush out the remaining sections of the storage system (the gage glass and connections from the storage tanks) as necessary. Disconnect and clean gage glass as necessary.
- j) In conjunction with the storage tank drain-down and flush, as necessary perform associated drain-down and flush of the solar collection loop (Section 4.1.8.2) heat demand loop (Section 4.1.8.3) and solar domestic hot water system (Section 4.1.8.4). Also perform repair and maintenance of these systems as required.

4.1.8.2 Solar Collection Loop

As necessary drain the applicable piping sections.

- a) Secure the system in accordance with Section 4.1.7.1.
- b) Drain the pump suction lines by opening valve V-100 at the outlet from the strainer.
- c) Drain the return line to the storage tanks by opening valve V-161 at the outlet from the strainer.
- d) Drain the pump outlet piping by disconnecting the pressure gage or other suitable fitting.
- e) Flush as necessary in connection with the storage tank filling by running the pump and draining through strainer valve V-161, or by using the city water supply from hose connection at valve V-315 to applicable piping sections.

4.1.8.3 Heat Demand Loop

As necessary drain the applicable piping sections:

- a) Secure the system in accordance with Section 4.1.7.2.
- b) Drain the pump suction piping by opening valve V-400 at the outlet from the strainer.
- c) Drain the pump discharge piping by opening valve V-412, hose connection for flow meter calibration.
- d) Flush as necessary in conjunction with the storage tank filling by running the pump or by using the city water supply from the hose connection at valve V-315 to the applicable piping sections.

4.1.8.4 Solar Domestic Hot Water Heating System

As necessary drain the applicable piping sections.

- a) Isolate the system in accordance with Section 4.1.7.3.
- b) Drain-down the system by opening V-315, hose connection for flow meter calibration testing.
- c) Flush the system using the city water and flow through V-315. Then close this valve and break a convenient connection near the inlet to the DHWH. Flush the system through this connection.

4.2 Climatological Station

All weather measurements are recorded automatically on the DAS. They include the outside air temperature, barometric pressure, relative humidity, wind velocity (3 orthogonal directions), and total and diffuse insolation. In addition, panel meters on the DAS console provide a continuous display of these weather measurements, except for the diffuse insolation reading.

4.2.1 Diffuse Insolation Radiometer: Shadowband Positioning

Diffuse insolation readings are obtained from the pyranometer by casting a shadow centered on the unit's sensing element (1 cm² receiver as shown on Data Sheet No. 11, Appendix A, and in Fig. 4-4). Thus, the direct radiation is eliminated, and the pyranometer reads only the diffuse sky radiation from the clouds.

Keeping the shadow centered on the receiver requires adjustment of the shadowband to suit the changing position of the sun relative to the plane of the earth's equator, sun declination angle, as provided in Table 13.2 from [24]. The data from this table was extrapolated to obtain daily values as shown in Table 4-2. When daily changes in declination angle of less than 0.2 degrees are prescribed, the frequency of adjustment may be lengthened accordingly. For any one day, the declination angle is assumed constant.

In order to account for the fraction of the radiation screened by the shadowband, a correction is applied by the computer in the data reduction program. The diffuse data is multiplied by the factors as tabulated in Table 4-3 from [25] for the 40°N latitude position. This yields an accuracy of ± 2 percent. For additional radiation meter details, see [26].

The diffuse insolation radiometer, shadowband and support structure are shown in Fig. 4-4. The radiometer is located approximately 15 inches (0.38 meters) above the top of collector 1-1, first collector row - first collector from the west.

4.2.1.1 Shadowband Adjustment Procedure

Generally, check the shadow cast on the radiometer on a daily basis, when the sun is unobscured by clouds. Record the applicable data on Data Sheet No. 11 (D.S. 11, Appendix A). An overall view of the radiometer shadowband assembly and support structure is provided in Fig. 4-5. Access to the shadowband assembly is attained by stepping atop the chimney adjacent the end of collector row number 1.

- a) Determine the declination angle for the specific date from Table 4-2.
- b) Record the actual shadow position "a" above and "b" below the radiometer as defined on D.S. 11, Appendix A.

- c) Loosen left side wing bolt (Item 10) which clamps the side bar (Item 3A supporting the shadowband) to the latitude angle plate. Refer to Figs. 4-6 and 4-4 for identification of Item numbers. Move the side bar so that the applicable angle (as marked on top of the side bars) is opposite the index mark engraved on the plate with the latitude scale. Use the monthly scale card which provides 0.5° markings to allow accurate readings between the 5° marks engraved on the side bars. See Fig. 4-7. Then tighten the wing bolt (10) fixing the side bar position. Repeat this step for the right side declination angle setting.

NOTE: Since reading the right side scale is not accessible, the setting is accomplished by transferring the dimension from left side scale relative to the leading edge of the latitude plate Item 5A (see Figs. 4-6 and 4-4).

- d) Record the shadow position "a" and "b" on D.S.11, Appendix A.
e) As necessary, adjust the shadowband right and left bar supports.

NOTE: This adjustment and the baseplate spacer alignment (Fig. 4-4) compensate for the orientation of the collectors which face 10° west of south.

4.2.1.2 Example for Setting Shadowband for September 12th

Photograph taken on this date shown in Fig. 4-4.

- a) The declination angle from Table 4-2 is 4.45° degrees.
b) Initial measurements are noted say $7/16"$ and $5/16"$, respectively for "a" and "b" with the declination angle at 4.83° as set the previous day. This is to verify that the radiometer is in fact not receiving direct radiation.
c) The side bars are moved so that the 4.45° value is opposite the index mark.
d) Measurements are taken for "new" shadow position, "a" and "b", say $6/16"$ and $6/16"$.
e) In this case, no adjustment of the left and right bar supports would be necessary. (These supports were set at $3-3/4$ and 8, respectively for left and right.)

NOTE: For days around the summer and winter solstice (December 22 and June 22, respectively), the daily declination angle changes are of the magnitude of 0.03° degrees.

The accuracy involved in making these small daily changes obviates the necessity of doing so. When the angle change reaches approximately 0.2 degrees, then the change should be made.

4.2.2 Relative Humidity Indicator

For normal operation, the power switch is in the ON position and the indicator light will be on accordingly at the DAS console, Fig. 3-6. The three-position switch "Operate/0%/100%" is placed on "operate", and a direct readout is provided at the instrument and at DAS No. 17. The other two positions are used to calibrate the indicator scaling electronics. Occasionally check the scale by switching to the 0% and 100% positions. In these positions, a simulated signal is input to check the accuracy of scale settings. Additional details are provided in the Instruction Manual, [27].

The detailed calibration procedures utilizing the Weather Measure Corporation HMK-11 Humidity Calibrator S/N 13585 are provided in [28].

The relative humidity sensing element is housed in a probe which is mounted in the aerated radiation shield on the roof. Also located in this assembly is the outside air temperature sensing device, DAS No. 10.

Air is circulated through the assembly by means of a fan. For normal operation the fan is on as noted by the green indicator lamp on the monitor box in the DAS room. When the fan stops the green indicator lamp turns off and the red indicator lamp turns on. A test switch is provided on the monitor box to check-out the fan lamp indicator circuitry, Figs. 3-13 and 3-14. Placing the switch to the fan position, while the fan is operating, switches the green lamp off and the red lamp on. The switch is then returned to the Operation position. Another check is performed by turning the fuse off. After about 10 seconds, the green lamp turns off and the red lamp turns on. Install the fuse and verify that the lamps reverse. Fan operation can also be observed by the general fan noise level in the vicinity of the radiation shield on the roof.

4.2.3 Wind Anemometer

The wind anemometer is mounted atop a 10 foot high rigid pole, located adjacent to the roof junction box. Its elevation along the pole is adjustable. This instrument measures the three U, V and W components, orthogonal vectors, of the wind. For normal operation, the power switch is in up-position of the Indicator-Translator unit mounted in the DAS console, providing power to the blower (indicated by pilot light above switch) and receptacle in the unit base. A general assembly drawing of the indicator unit is shown in Fig. 4-8 from [28]. Toggle switches as noted on Fig. 4-8, allow the selection of either the high (up) or low (down) range for each of the three dual range meters on the control panel. The low and high ranges are scaled 6-0-6 m/s and 30-0-30 m/s, respectively. A cable and wiring diagram is shown in Fig. 4-9 from [28].

IMPORTANT: Leave range switches in "high" position for 30-0-30 m/s range, to avoid over-driving the meters on windy days.

The unit is a Gill UVW Anemometer Model 27004 with indicator translator Model 27503 R, [29]. The unit is wired to provide a positive signal for U and V component wind flows from the propeller's front (causing counterclockwise propeller rotation). Opposite windflow direction causes clockwise propeller rotation and the signal polarity reverses. The W or vertical wind component is wired to provide a negative output for wind flow from top to bottom, downdraft, which causes counterclockwise propeller rotation.

The propellers, 19 cm dia. x 30 cm pitch, used for this application are extremely lightweight, molded polystyrene. They are rated at 0.2-0.3 m/s threshold and a maximum speed of 40 m/s (axial flow), 30 m/s (all angle flow).

4.2.4 Total Insolation Radiometer, Barometer and Outside Ambient Air Resistance Temperature Detector (RTD)

Outputs from the total insolation radiometer DAS No. 13, barometer DAS No. 18 and outside air RTD DAS No. 10 are continuously displayed on the DAS console, Fig. 3-6, and recorded on the DAS at the required time intervals. There are no specific operating procedures for these instruments.

4.3 The Data Acquisition System (DAS)

Once programmed and placed on-line with associated equipment, the DAS automatically scans, records and prints-out all 63 channels of data. The detailed operating procedures for the various components are contained in the following sections.

4.3.1 Programming the PD-2064 DAS

The overall DAS programming procedure method is contained in the Operating Procedure Section of [18] which includes the PD-2064 Operational Flow Diagram and Keyboard Programming Chart. In addition, a simplified Programming Flow Chart from [18] is shown in Fig. 4-10.

A summary of Program Bank Files is listed in Section 4.3.1.6.

4.3.1.1 Normal System Operation

During normal operation, the indicator lights are on for the following functions: "Write Status", "Write Enable", "On Line" and "Load", see Fig. 4-11. At the programmed NEXT SCAN time, the microprocessor display goes blank and 4-5 sec. later, the Decwriter starts to print-out the data. (Note that running the special "Dig Av with Continuous Scan" program of 4.3.1.7 will cause the display to be blank all the time, because the DAS is constantly "busy" scanning). At the conclusion of the print-out the "Data in Memory" indicator light goes on for an instant and then the magnetic tape moves. See Fig. 4-11, Tape Recorder Controls and Indicators, for a layout diagram and explanation.

Specifically for present normal system operation, the programming steps are provided in this section. Initially, the range code of 2 corresponding to 0-400MV range was input for all channels, Section a) Step 14, since this was the most frequent range required. Then in Section c) Step 5 the range code values of 1 or 3 were input for the applicable channel pairs. A print-out of these range constants as well as the other channel constants and system constants are shown in Table 4-4 for operating with both the tape recorder and printer on-line (I-0,3). This program was stored in File 0 (Zero) of the Program Bank as specified in Section 4.3.1.4.

a) Apply Power and Set Initial Load Point As Necessary

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	Red Switch	Blank	If system is off, push power on. Power Switch lights up.
2		LLLLLLLL	Initial load point.

b) Block Programming to set Channel Constants

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1		00000003	Read Channel 3 in random memory.
2		00000000	Select beginning channel 0.
3		00021713	Enter channel 0 and read data for channel 0 in memory from last scan.

4.3.1.1b) (Cont'd)

I-O CHANNEL CONSTANT

STEP	PRESS	READ IN DISPLAY	
4	I-0	2	Read I-0 code 2 in memory for channel 0.
5	MINUS	0-----	Press MINUS special function key seven times. (Preparation for next step which will advance minus to position one in register, the most significant digit position).
6	3	-----3	3 specifies code for both printer and tape: see Table below
7	ENTER	21213	Enter I-0 code for channel 0 and all follow-on channels. Read data for channel 0 in memory from last scan. I-0 code 1 now applies to all system channels 0-248.

FD-3064
SYSTEM CONFIGURATION

Power 120v 60hz
 Analog Channels 64
 Digital Channels _____
 Output 1 DECWRITER
 Output 2 MAG TAPE9832
 Serial No. 990470A

T34A54

I-O TABLE

Code	Input	Output
0	Analog	SKIP
1	Analog	Device 1
2	Analog	Device 2
3	Analog	Devices 1 & 2
4	Digital	SKIP
5	Digital	Device 1
6	Digital	Device 2
7	Digital	Devices 1 & 2
8		STOP SCAN
9		STOP OUTPUT

CORRECTION FUNCTION, **CORR FUNCT**, CHANNEL CONSTANT

STEP	PRESS	READ IN DISPLAY	
8	CORR FUNCT	X	Read "CORR FUNCT" code in memory for channel 0.
9	MINUS	X-----	Press MINUS seven times.
10	0	-----0	0 specifies none, See Table on next sheet.
11	ENTER	XXXXX	Enter code for channel 0 and all follow-on channels. Read data stored in memory for channel 000.

4.3.1.1b) (Cont'd)

RANGE CHANNEL CONSTANT

STEP	PRESS	READ IN DISPLAY	
12	<div>RANGE</div>	XXXX	Read Range Code in memory for channel 0.
13	<div>MINUS</div>	X-----	Press Minus seven times.
14	<div>2</div>	-----2	2 specifies 400 MV range. See Table below.
15	<div>ENTER</div>	XXXX	Enter code for channel 0 and all follow-on channels. Read data stored in memory for channel 000.

UNITS CHANNEL CONSTANT

16	<div>UNITS</div>	X	Read Units Code in memory for channel 0.
17	<div>MINUS</div>	X-----	Press Minus seven times.
18	<div>0</div>	-----0	0 specifies MV units. See Table below.
19	<div>ENTER</div>	XXXX	Enter code for channel 0 and all follow-on channels. Read data stored in memory for channel 000.

PD-2004 SYSTEM CONFIGURATION

Power 120V 60Hz
Analog Channels 64
Digital Channels _____
Output 1 DECWRITER
Output 2 MAG TAPE 9832
Serial No. 990470A

734A54

CORRECTION FUNCTION TABLE Code CF

0	None
1	_____
2	_____
3	DIGITAL AVE
4	DUSCAN
5	_____
6	_____
7	_____
8	N/A
9	N/A

RANGE TABLE Code Range

0	_____
1	4000 MV
2	400 MV
3	40 MV
4	_____
5	_____
6	_____
7	_____
8	N/A
9	N/A

UNITS TABLE Code Units

0	MV
1	V
2	DF
3	DC
4	PSI
5	P/M
6	R/M
7	P/S
8	HZ
9	HR

4.3.1.1b) (Cont'd)

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
20	CHAN SELCT	000	Read channel 0 number
21	6	00000006	
22	4	00000064	
23	ENTER	XXXXX	Enter channel 64 and read data in memory.
24	I-0	X	Read I-0 code in memory for channel 64.
25	9	00000009	Press 9, See I-0 Table. This stops the output after channel pair 62/63. Thus the channel scan is from 0-63.
26	ENTER	XXXXX	Enter code for channel 64. Read data stored in memory for channel 64.

4.3.1.1

c) Program to Set System Constants

STEP	PRESS	READ IN DISPLAY	
1	REF CHAN	XX	Read Reference Channel
2	0	X0	-
3	ENTER	LLLLLLLL	Enter Reference Channel. Read load point.
4	CHAN INTVL	XX	Read Channel Interval.
5	0	X0	
6	ENTER	LLLLLLLL	Enter Channel Interval. Read load point.
7	SCAN INTVL	XXXXXXXX	Read Scan Interval between data scans in days, hours, minutes and seconds.
8	5	XXXXXXXX5	
	0	XXXXXXXX50	
	0	XXXXX500	
9	ENTER	LLLLLLLL	Enter Scan Interval, 5 minutes and 0 seconds. Read load point.
10	MINUS	0000000-	
	MAN REC		Initiates output of stored operating program so that keyboard entries may be viewed and verified. See Table 4-4 for System Constant and Channel Constant values.

4.3.1.1

d) Program to Set Range Channel Constants for Individual Channel Pairs

STEP	PRESS	READ IN DISPLAY	
1	CHAN SELECT	XXX	Read channel in random memory.
2	6	XX6	
3	ENTER	XXXXX	Read data for channel 6 in memory from last scan.
4	RANGE	2	Read Range Code in memory for channels 6 and 7 as programmed in Section 4.3.1.1 b) 14.
5	1	1	1 specifies 4000 MV range
6	ENTER	XXXXX	Read data stored in memory for channel 6.
7			Repeat steps 1-6 above for channels 14, 16, 18, 20, 58 and 62. All these channel pairs are set for the 4000 MV range.
8			Repeat steps 1-6 above for channels 12, 24 and 32, except Enter a Range Value of 3, which specifies the 40 MV range.
9	UNITS, UNITS, MINUS MAN REC	0000000-	Initiates output of stored operating program so that range constants input may be verified. See Table 4-4 for system constants.*
10	MAN REC	00000000	Manually starts an immediate scan of 1 data frame-output of data for applicable channels. Display blanks out during scan. At completion of scan zeroes appear. This verifies required overall output.

* Note: Do not initiate MINUS MAN REC sequence after time function, since this will output data scan.

4.3.1.1 d) (Cont'd)

STEP

- 11 Store the program in the Program Bank File 0 as defined in Section 4.3.1.4
- 12 Recall the program from the Program Bank File 0 as defined in Section 4.3.1.5

4.3.1.2 Operation with Magnetic Tape Recorder Only

As desired for recording data on the magnetic tape recorder only, the basic program for Normal System Operation was modified in the following way. Only the I-O channel constant was block programmed in accordance with Section 4.3.1.b) Steps 1-7 and 20-26. The applicable I-O value of 2 was entered for this condition.

A print-out of the channel and system constants for this condition is shown in Table 4-4. This program was stored in File 1 of the Program Bank as defined in Section 4.3.1.4. Then the program from File 0 of the Program Bank was recalled as specified in Section 4.3.1.5.

4.3.1.3 Flow Meter Calibration

In conjunction with the flow meter calibration testing as described in Section 4.3.5.1 of this report, the PD-2064 unit was programmed to scan only the flow meter channels (and complementary channels pairs). A sample data scan and the system and channel constants for this application are shown in Table 4-5. This program is currently stored in Memory File No. 2.

Channels 0-60 were programmed for the same channel and system constants as the basic program stored in Memory File No. 0, except the I-O code of zero was entered. Then the code of 1 was entered (for the decwriter output only) for the flow meter channels 6, 24 and 58. The detailed programming procedure starts with the basic program from Memory File 0 on-line and proceeds as follows:

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	<div style="border: 1px solid black; padding: 2px; display: inline-block;">INPUT</div>	LLLLLLLL	As necessary press input to engage initial load point.
I-O CHANNEL CONSTANT			
2	<div style="border: 1px solid black; padding: 2px; display: inline-block;">CHAN SELECT</div>	XXX	Read channel in random memory.
3	<div style="border: 1px solid black; padding: 2px; display: inline-block;">0</div>	00000000	Selects beginning channel 0.
4	<div style="border: 1px solid black; padding: 2px; display: inline-block;">ENTER</div>	XXXXX	Read data for channel 0.

4.3.1.3 (cont'd)

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
5	I-0	X	Read I-0 code in memory for channel 0.
6	MINUS	0-----	Press minus special function key 7 times.
7	0	-----0	0 specifies skip.
8	ENTER	XXXXX	Read data for channel 0 in memory from last scan.
9	CHAN SELCT	000	Read channel 0 number.
10	6	00000006	
	0	00000060	
11	ENTER	XXXXX	Enter channel 60 and read data in memory.
12	I-0	0	Read I-0 code in memory for channel 60.
13	9	9	This stops the output after channel pair 58/59. Thus the channel scan is from 0-59 and skips all following channels.
14	ENTER	XXXXX	Read data stored in memory for channel 60.
15	CHAN SELCT	060	Read channel in random memory.
16	6	00000006	
17	ENTER	XXXXX	Read data for channel 6 in memory from last scan.
18	I-0	0	Read I-0 in memory for channel 6 as programmed in step 7.

4.3.1.3 (cont'd)

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
19	<div>1</div>	1	Specifies analog device 1 which is Decwriter.
20	<div>ENTER</div>	XXXXX	Read data stored in memory for channel 6.
21-26			Repeat steps 15-20, respectively for channel pair 24/25.
27-32			Repeat steps 15-20, respectively for channel pair 58/59.
33	<div>MINUS</div> <div>MAN REC</div>	0000000-	Initiates output of stored operating program so that channel and system constants may be verified. See Figure 4-5 for print-out.
34	<div>MAN REC</div>		Manually starts an immediate scan of 1 data frame-output of data for applicable channels. This verifies required overall output. See typical print-out as shown in Table 4-5.
35	Store program in Program Bank File No. 2 in accordance with Section 4.3.1.4.		

4.3.1.4 Loading an Operating Program into a Program Bank File

After setting-up the desired program parameters, proceed as follows:

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	<input type="button" value="INPUT"/>	LLLLLLLL	As necessary from AUTO, engages initial load point.
2	<input type="button" value="UNITS"/>	LLLLLLLL	Press UNITS or any other channel constant key (I-O, CORR FUNCT, RANGE) twice to engage initial load point.
3	<input type="button" value="ENTER"/>		Either ENTER or CLEAR ENTRY key may be pressed to address the memory bank routine.
4	<input type="button" value="MINUS"/>	0000000-	Press Twice for "unconditional write" function.
	<input type="button" value="MINUS"/>	000000--	
5	<input type="button" value="0-9"/>	00000--0	With numeric keys, 0 to 9 address file location number into which operating memory is to be written. (Example: file location 0)*
6	<input type="button" value="ENTER"/>	LLLLLLLL	Copy of operating program is now stored in Program Bank.

*See list of existing Program Bank files in Section 4.3.1.6. The Solarow PD-2064 has sufficient RAM devices to store eight different files in the Program Bank: File 0 to File 7.

4.3.1.5 Loading a Program Bank File into current Operating Memory

Note: If power is already on start with Step 3

STEP	PRESS	READ IN DISPLAY	
1			Power Key Light (red) and Power fail LED lights go on.
2		LLLLLLLL	Engages initial load point. Power fail LED goes off.
3		1LLLLLLL	Press UNITS or any other channel constant key (1-0, CORR FUNCT, RANGE) twice to engage initial load point.
4			Either ENTER or CLEAR ENTRY key may be pressed to address the memory bank routine.
5		0000000A High Alarm 0000000A Low Alarm	Either HIGH ALARM or LOW ALARM Key may be pressed to read program from memory bank into the current operating memory.
6		000000A1 High Alarm 000000A1 Low Alarm	With numeric keys, address the file location number from which stored program is to be read into the operating memory. (Example: File location 1)
7		LLLLLLLL	The program from the addressed file location is now loaded into the operating memory.

4.3.1.6 Listing of Program Bank Files:

File 0: "Standard" program; Channel 00-63; both Decwriter & tape.
(Sec. 4.3.1.1)

File 1: "Standard" program; Channel 00-63; tape only.
(Sec. 4.3.1.2)

File 2: Flowmeter calibration; Channel 6-7, 24-25, 58-59; Decwr. only.
(Sec. 4.3.1.3)

File 3: Digital Avg. Program; Channel 00-63; both Decwriter & tape.
(Sec. 4.3.1.7, Addenda section)

4.3.1.7 New Digital Averaging Program - (See Addenda Section)

4.3.2 Placing the DAS On-Line

Completion of this section, places the system on automatic operation.

4.3.2.1 Apply Power & Set Initial Load Point As Necessary

Perform as defined in Section 4.3.1.1 a).

4.3.2.2 Placing The Magnetic Tape Recorder & Decwriter On-Line

Perform as specified in Sections 4.3.6.1 and 4.3.7.1, respectively.

4.3.2.3 Recalling Applicable Program from Program Bank

Perform as specified in Section 4.3.1.5.

4.3.2.4 Setting "ID", "TIME" & "NEXT SCAN" Functions

a) Programming to Set "ID", Frame Identification.

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	ID	XXXX	Displays previously set frame identification, 4 digits.
2	0	XXX0	0 } Used for special functions
	1	XX01	
	1	X011	1 } These 2 digits define month: 11, Nov.
	1	0111	
3	ENTER	LLLLLLLL	Enter ID. Read load point.

b) Programming to Set System Current "TIME" Function

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	TIME	00000006	Read time (seconds) since power-on.
2	7	00000007	This begins process of entering 7 day, 10 hr., 30 min., and 10 sec.

4.3.2.4 b) (cont'd)

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
2(cont'd)	<input type="text" value="1"/>	00000071	
	<input type="text" value="0"/>	00000710	
	<input type="text" value="3"/>	00007103	
	<input type="text" value="0"/>	00071030	
	<input type="text" value="1"/>	00710301	
	<input type="text" value="0"/>	07103010	Read 7th day, 10th hour, 30th minute and 10th second.
3	<input type="text" value="ENTER"/>	LLLLLLLL	ENTER time. Read load point.
4	<input type="text" value="TIME"/>	07103017	This confirms day, hour, minute and second settings and to observe time advancing.

c) Programming to Set "NEXT SCAN" System Constant

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	<input type="text" value="NEXT SCAN"/>	XXXXXXXX	Read time set for next scan.
2	<input type="text" value="0"/>	XXXXXXXX0	
	<input type="text" value="7"/>	XXXXXX07	
	<input type="text" value="1"/>	XXXXX071	
	<input type="text" value="1"/>	XXXX0711	
	<input type="text" value="4"/>	XXX07114	
	<input type="text" value="5"/>	XX071145	
	<input type="text" value="0"/>	X0711450	

4.3.2.4 c) (cont'd)

STEP	PRESS	READ IN DISPLAY	
2(cont'd)	0	07114500	Read 7th day, 11th Hour, 45th minute, 0 seconds.
3	ENTER	LLLLLLLL	Enter Next Scan. Read load point.

4.3.3 Normal Operation

Once the system is on-line, the data monitoring and recording functions are automatic.

4.3.3.1 General Monitoring of Channel Data, Placing System on "AUTO" and Taking a Manual Scan Readout

Perform as Required

a) General Monitoring of Channel Data

STEP	PRESS	READ IN DISPLAY	
1	INPUT	LLLLLLLL	If system is on Auto, press input to engage initial load point.
2	CHAN SELCT	XXX	Read random channel in memory.
3	2	00000002	
	5	00000025	
4	ENTER	XXXXX	Read data from last scan.
5	CHAN READ	XXXXX	Read real time data at one second intervals.
	ENTER	LLLLLLLL	Return to load point before selecting another function.
6	NEXT CHAN	XXXXX	In order to short cut programming this key reads next channel (without selecting & entering) data from last scan.

In conjunction with Step 5, adjust solar collection system flow rate as necessary, 7 to 10 gpm, by checking DAS No. 25.

- b) Placing the System on "AUTO" Mode of Operation: PRESS AUTO

In general after completing programming and whenever the system is operated automatically without inputs, the system is placed in "AUTO". This powers-down operating mode, while allowing the automatic scanning and recording to be performed as specified. The display blanks-out in this mode.

- c) Taking A Manual Scan Readout: PRESS MAN
REC

Pressing the "MAN REC", manual record, button starts an immediate scan of 1 data frame-output of data for channels 0-63. The display blanks out during scan. At completion of scan zeroes appear. In general, this button is not pressed with the system on-line, but rather when checking out system programming.

- d) Taking a Readout of Channel Constants: PRESS MINUS MAN
REC

4.3.3.2 Regular Month and Day Change (ID, TIME & NEXT SCAN)

At the end of each month the day continues to index and the month as input in the ID remains the same. Therefore every month, the ID, TIME and NEXT SCAN are updated as follows:

- a) Set the applicable ID as shown in Section 4.3.2.4 a).
- b) Program the current time to reflect the applicable date of new month as shown in Section 4.3.2.4 b).
- c) Program the "NEXT SCAN" to reflect the applicable date of new month as shown in Section 4.3.2.4 c).

4.3.3.3 Servicing the Magnetic Tape Recorder and Decwriter

- a) Every 2 weeks (approximately) change the magnetic tape as specified in Section 4.3.6.2 of this report.
- b) Change the Decwriter ribbon and paper supply as specified in Section 4.3.7.2 of this report.
- c) Clean the tape head and roller guides with iso-propyl alcohol using a cotton swab. Access to the tape head is attained by lifting the cover. NOTE: Do not apply excess alcohol to the tape head area.

4.3.3.4 General System Adjustments

In general, check the Decwriter on-line print-out values to verify system performance. Whenever a value is out of line, make applicable changes and monitor the channel as specified in Section 4.3.3.1. Some specific parameters which are checked are as follows:

- a) DAS No. 25, Solar Collection Loop Flow rate
Adjust inlet globe valves to the storage tanks as necessary to attain the 7 to 10 gpm flow rate while reading real time data on DAS No. 25.

- b) DAS No. 39 and 61, R1 & R2 Current Loops, respectively. Adjust current supply pots in current loops 1 & 2 as necessary to attain 200.00 ± 0.04 mV output. This adjustment may drift slightly beyond ± 0.04 mV with time and temperature. However, the University of Pennsylvania computer program corrects for this error during data analysis.

4.3.4 System Shut-Down & Power Failure

4.3.4.1 Placing System On-Line After Power Shut-Down

Turning the instrument power-off erases the on-line program that was entered in memory via the keyboard. When turning the power-on, the system automatically reverts to the program from Program Bank Data File 0, however, "TIME" and "NEXT SCAN" need to be input.

- a) Verify power supply to all units, set ID, and Time in accordance with Sections 4.3.2.1, through 4.3.2.4 a) and b).
- b) Verify system and channel constants for Program Bank Data File 0, Section 4.3.1.1 c) Step 10. As necessary recall program from Program Bank (Section 4.3.1.5).
- c) Set the "NEXT SCAN" in accordance with Section 4.3.2.4 c).
- d) Verify that the system scan initiates at applicable time interval and that Decwriter and Magnetic tape recorder function as required. See Section 4.3.2.3 for placing magnetic tape recorder on-line.
- e) After verifying system operation, place the system on "AUTO".

4.3.4.2 Placing System On-Line After Power Failure

In the case of a general power failure or brown-out, system operation automatically reverts to the "Automatic Mode" with DC operating voltage supplied automatically from the microprocessor Memory Save feature. Operation in this mode is sustained for approximately 10 minutes by 3 batteries (two 6V and one 4V) which are kept fully charged from the AC power during normal operation. If it is desired to turn the instrument off or unplug the power cord, first shut-off power with the power switch in order not to needlessly discharge these batteries.

Within the approximately first 10 minutes, the system control functions as follows:

DC power is interrupted to output interface(s).

Display is blanked out.

Clock continues operating and central processing unit continues to function so that programs stored in RAMs are retained.

4.3.4.2 (cont'd)

Keyboard is functionally disabled and

- Channel scanning and data outputting operations are inhibited.

When AC power is restored, the power fail indicator light on the microprocessor display is activated, while the normal "on" lights for the Decwriter and magnetic tape recorder come back on. The system will be automatically programmed in accordance with Program Bank Data File 0, zero. Whenever the system is powered-on, this base program is automatically put into the operating memory. All key functions in the system constant and channel constant groups are stored in the Program Bank, except for the TIME and NEXT SCAN values.

a) Upon observing the power failure light proceed as follows:

1. Check Decwriter print-out and determine the duration of the power failure by reviewing the times of print-out.
2. Observe operation (data output or not) of the DAS. If the system is outputting data proceed with Section b), otherwise continue with Section c).

NOTE 1: After a power failure, the first data print-out from memory may be in error, however, subsequent scans will be correct.

NOTE 2: If the power outage was for 10 minutes or less, the system operation remains in the "Automatic Mode", resuming the programmed operations of scanning, measuring and outputting channel data while powering down between channel frame scans. Whenever the system is powered-on, the base program from the Program Bank File 0 is automatically put into the operating memory. Thus the Memory Save and Program Bank features combine to allow automatic resumption of data output, without the need of any reprogramming from the keyboard. Both the Decwriter and magnetic tape recorder automatically come back on-line.

b) DAS Operating - Both printer and magnetic tape recorder on-line and recording data.

1. Check magnitudes of typical channel data from print-out for correspondence with previous data before the power failure.
2. Press "INPUT" button; Read LLLLLLLL in display as the power fail indicator light goes off (This light remains on until "INPUT" mode button is pressed - Now system can be checked).
3. Verify "ID", "TIME" and "NEXT SCAN" as programmed in Section 4.3.2.4 a), b) and c), respectively. Reset as necessary.
4. Verify that system scan initiates at applicable time interval and that Decwriter and magnetic tape recorder function as required.
5. As necessary, verify channel and system constants by pressing "MINUS", "MAN RECORD" buttons (Section 4.3.1.1 c) Step 10).

6. After completing above check-out and determining correct system operation, place the system on "AUTO", Section 4.3.3.1 b).
- c) DAS Not operating - both printer and magnetic tape recorder on-line but not recording

For power failures lasting longer than 10 minutes, the Memory Save feature can no longer maintain the current time. When the Program Bank File 0 is called from memory, the time setting is zero and the Next Scan time is equal to the scan interval stored in the program bank. Determination of the Next Scan and Time parameters are pursued as follows:

STEP	PRESS	READ IN DISPLAY
1	INPUT	LLLLLLLL Engages initial load point. Power fail LED goes off.
2	TIME	Determine actual on-line TIME NEXT SCAN and ID.
3	NEXT SCAN	
4	ID	
5	MAN REC	Determine sample data output, check for format and general values.
6	MINUS	Determine channel and system constants on-line as per Program Bank File 0.
	MAN REC	
7	As necessary recall applicable operating program from Program Bank (Section 4.3.1.5) or set appropriate constants (Section 4.3.1.1).	
8	As necessary reset the applicable "ID", "TIME" and "NEXT SCAN" in accordance with Sections 4.3.2.4 a), b) and c), respectively. Also check manual [15] for additional details if required.	
9	Verify that system scan initiates at applicable time interval and that Decwriter and magnetic tape recorder function as required.	
10	After completing above check-out and verifying system operation, place the system on "AUTO", Section 4.3.3.1 b).	

4.3.5 Special System Operations

4.3.5.1 Flow Meter Calibration Testing

- a) In conjunction with the detailed calibration procedure for the flow meters, Section 4.4.1, operate the system as follows:

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
1	<input type="button" value="INPUT"/>	LLLLLLLL	As necessary press input to engage initial load point.
2			Recall Flow Meter Calibration Program as stored in Memory Bank File No. 2 in accordance with Section 4.3.1.5
<u>SCAN INTERVAL SYSTEM CONSTANT</u>			
3	<input type="button" value="SCAN INTVL"/>	500	Read scan interval between data scans, minutes and seconds as input in basic program.
4	<input type="button" value="1"/>	XXXXXXXX1	
	<input type="button" value="0"/>	XXXXXXXX10	
5	<input type="button" value="ENTER"/>	LLLLLLLL	Enter 10 second scan interval. Read load point.

NEXT SCAN SYSTEM CONSTANT

Set the next scan time in conjunction with the desired flow rate stabilization and start of test, Section 4.4.1.4 c).

<u>STEP</u>	<u>PRESS</u>	<u>READ IN DISPLAY</u>	
6	<input type="button" value="NEXT SCAN"/>	XXXXXXXX	Read time set for next scan.
7			Press the applicable day, hour, minute and seconds, as shown in Section 4.3.2.4 c).
8	<input type="button" value="ENTER"/>	LLLLLLLL	Read load point.
At the completion of Test Run			
9	<input type="button" value="HALT"/>		This stops next scan
10			Repeat steps 6-9 as necessary for each applicable run condition and test.

4.3.5.1 (cont'd)

- b) At the conclusion of flow meter calibration testing prepare the DAS for normal system recording as required in accordance with applicable steps in Section 4.3.4.1.

NOTE: Section 4.3.4.1 Step a) ID & TIME need not be set, however, Step b) requires recalling applicable program from Program Bank.

4.3.6 Tape Recorder Operating Procedures

Present system operation requires the data to be recorded at 5 minute intervals. Operate the system in accordance with the procedures as provided by [20], paragraph 2.2

During normal operation, the indicator lights are on for the following functions: "Write Status", "Write Enable", "On Line" and "Load", see Fig. 4-11. At the programmed NEXT SCAN time, the microprocessor display goes blank and 4-5 seconds later, the Decwriter starts to print-out the data. (Note that running the special "Dig AV with Continuous Scan" program of 4.3.1.7 will cause the display to be blank all the time, because the DAS is constantly "busy" scanning). At the conclusion of the print-out the "Data in Memory" indicator light goes on for an instant and then the magnetic tape moves. See Fig. 4-11, Tape Recorder Controls and Indicators, for a layout diagram and explanations.

4.3.6.1 Initial Start-up

Perform the preliminary procedures of paragraph 2.2.3, [20]. Use iso-propyl alcohol on cotton applicator to clean tape head and roller guides.

4.3.6.2 Tape Installation and Removal

- a) Perform tape threading, loading and placing unit on-line as defined in paragraphs 2.2.4, 2.2.5, and 2.2.6, respectively, [20].
- b) Annotate tape reel marker with Solar tape number, date and time of initial data recorded.
- c) Before the tape end, approximately 2 weeks, for 63 channels scanned each 5 minutes, press End of File (EOF) button on the magnetic tape recorder to write this (EOF) on the tape.
- d) Then rewind and unload [20] tape as defined in paragraph 2.2.7.
- e) Repeat steps a) through d) for the new tape.
- f) Annotate tape reel marker with the date and time of last data recorded.

NOTE: In general, the tape changes are performed in between scans without loss of data. When the tape head and guides are cleaned, however, one five minute reading may be missed as necessary.

4.3.6.3 Power Failure & PD2064 Shutdown

In order to allow automatic restart of the tape recorder when power is restored after a power failure, an Auto Power Restart (APR) option was added to the basic unit. This feature automatically powers up, loads and sets the deck on-line following a power failure or brown out (if the unit was previously in an on-line state). See Section 4.3.4.2 If the restart option does not function proceed as follows:

- a) Following a system shut-down when the tape recorder was on-line, pressing the PD2064 start button will power the tape recorder. The electronics involved restart the recorder as during the tape loading condition. Specifically, the tape advances, looking for the beginning of tape (BOT) marker. Since this has already been passed, the unit will continue to run until completely out of tape. If this occurs proceed as follows:
 - 1) Wrap at least 5 or 6 turns on the original reel. Rethread the tape as usual.
 - 2) Press Load button - the reel starts to turn forward - immediately Press rewind.
 - 3) This tape may be removed as usual or replaced back on-line for a second file.
- b) Placing a second file on tape, proceed as follows:
 - 1) Unwrap enough tape to pass initial load point (BOT) and thread tape as usual, (or use a black card under the light sensor as the BOT tape foil whizzes by)
 - 2) Press Load Button - reel starts to move forward and continues, since the BOT marker was bypassed. Allow reel to advance to clear area on tape (past previous recorded data). Insert a white card across first light sensor simulating BOT marker. This causes tape to stop. Note approximate footage on reel.
 - 3) Place on-line.

NOTE: Upon start-up when the tape starts to advance initially, step a) above, the white card can be used as defined in Step 2 above.

4.3.7 Printer Terminal Operating Procedures (LA36 Decwriter)

Operate the system in accordance with the procedures as provided by [21] pages 1-11, and provided in the following section.

4.3.7.1 Normal Start-up

Refer to Fig. 4-12 for a layout diagram and definitions of the keys and controls.

- a) Load paper, described in Section 3 (3-1 to 3-3) of [21] .
- b) Set LINE/LOC switch to LOC
Set POWER ON/OFF switch to ON
- c) Select FDX/HDX switch to FDX or HDX
- d) Not Applicable.
- e) Not Applicable.
- f) Select baud rate (BAUD RATE switches) to 300.
- g) Set the LINE/LOC switch to LINE.

The LA35 is now on-line and ready to receive data.

4.3.7.2 Normal Operation

During normal operating conditions, the printer will be initiated by the DAS at 5 minute intervals to print-out the data. If the solar heating system is not operating, then it may be desirable to leave the printer in the power Off position and not print the data. When desired, start printer operation by setting the power switch to ON. Otherwise operate the system in accordance with the program stored in Program Bank 1, Section 4.3.1.2.

During normal operation, the Decwriter may be placed in the LOCAL position between print-outs to annotate the data with typed messages. After using the Decwriter in the local position, remember to switch back to LINE. Otherwise the Decwriter will not print-out the data.

In general when the Decwriter is on-line, the paper supply will last approximately 45 days. Paper loading is routinely performed as described in Section 3 (3-1 to 3-3) of [21] . Another routine task is to change the ribbon when necessary. See Section 3 (3-7 to 3-9) of [21] for the detailed procedure.

4.3.7.3 Placing System On-Line After Power Failure or Shut-Down

After a power failure or PD-2064 shut-down, the Decwriter will automatically start printing when power is restored at the direction of the microprocessor.

4.3.8 Environmental Control of the DAS Room

The temperature in the DAS room is maintained below 80°F as necessary by an air conditioner which is rated at 13,600 BTU/hr, 115V, 60Hz and 12 amps. This window unit is hooked to a 20 amp circuit breaker adjacent to the window.

The unit is normally run by pressing the Master Control "NORM" button. For extremely hot days when maximum cooling is required the "SUPER" setting is used. In order to reduce the rate of cool air delivered to the room the "QUIET" setting is used. Generally the air control is in the "CLOSE" position. As desired to exhaust stale air, the air control is placed in the "OPEN" position.

The air conditioner is equipped with an energy saving, two position switch. When placed in the "FAN-ON" position, the air circulating fan runs continuously, while in the "FAN-AUTO" position the unit shuts off whenever cooling is not required. The degree of cooling is attained by adjusting the temperature dial between 1-7 (max cooling). Normally a setting between 3-4 maintains the temperature between 75-79°F. During the summer months the FAN-ON position is generally used, while for cooler weather the FAN-AUTO position is recommended. The applicable temperature settings are adjusted accordingly to keep the room temperature from exceeding 80°F. For circulating and filtering indoor air, a "FAN ONLY" setting is provided on the Temperature dial.

Press the "OFF" button for shutting the unit. Always remember to wait 3 minutes before restarting.

For additional details including trouble shooting procedures, refer to manufacturer's manual [30].

4.4 Detailed Calibration Procedures

4.4.1 Water Flow Meter Calibration

The objective of this flow calibration test procedure is to calibrate simultaneously and insitu the three flow meters utilized in the water supply line to the SDHWS, the demand heating system and the solar collector system, respectively W300, W400 and W100. They happen to be in the same flow rate range. The water used for the calibration comes from the city mains, and its pressure upstream of the flow meters is kept constant by a water pressure regulator. The city water is switched through the regulator by-pass branch only during calibration, to avoid the associated pressure drop during normal operation. The water coming through the meters during calibration is collected in two tanks and then drained by hose to the main drain pipe. The flow calibration set-up is illustrated in Fig. 4-13.

4.4.1.1 Valve Line-Up

Line-up the valves in the respective systems to isolate the flow meters as follows:

a) Solar Collector Loop: "Ramapo" Flow Meter, W100

1. Open flow meter bypass valve, V-141 (N.C.)
2. Close flow meter inlet isolation valve V -138 (N.O.)
3. Close flow meter outlet isolation valve, V-140 (N.O.)

b) Demand Loop: Invalco Flow Meter, W400

1. Turn power off at circuit breaker for demand pump.
2. Check closed flow meter bypass valve V-406 (N.C.), and close flow meter inlet isolation valve, V-404 (N.O.)
3. Check for open outlet valve V-405 at outlet of W-400.
4. Close return line globe valves at inlet to storage tanks, V-407, V-408 and V-409, respectively for tank numbers 1, 2 & 3.
5. Close Thermoflo balancer flow meter valves for W-404, W-405, and W406, also at inlet to storage tanks 1, 2 & 3, respectively.

c) SDHWS: "Flow Technology" Flow Meter W300

1. Check that flow meter bypass valve is closed, V-303 (N.C.),
2. Open inlet & outlet isolation valves, V-312 and V-314, to the pressure regulation valve V-313.
3. Close inlet valve V-301 to flow meter W300.
4. Check open outlet valve V-302 at outlet of W300.
5. Close outlet valves V-304 and V-305 from SDHWS.
6. Close Thermoflo balancer flow meter valves for W-302 and W-303 at inlet to SDHWS.

4.4.1.2 Interconnecting Systems

Two hoses are utilized to interconnect the three flow meters and a third hose directs the water downstream of the third flow meter to the flow stabilization or weighing tank. These rubber hoses have female pipe thread end connectors which are of the swivel type. A 40 foot long, 3/4 inch diameter hose connects the SDHWS to the demand loop, a 30 foot long, 1 inch diameter

hose connects the demand system to the solar collection loop and a 8 foot long, 1 inch diameter hose directs the flow to the discharge tanks. See Fig. 4-13 for the complete calibration flow path.

- a) Verify closed (by opening slightly & then closing) all calibration hose connections, V-162, -163, -315, -411 and -412.
- b) Hook-up hoses between systems as shown in Figs. 4-13, 2-2 and 2-3.
 1. Hook-up 1" hose to V-163 (collector loop)
 2. Hook-up 1" hose from V-162 (collector loop) to V-412 (demand loop)
 3. Hook-up 3/4" hose from V-411 demand loop to V-315 (SDHWHS).
- c) Valve Line-up
 1. Leave closed flow rate control globe valve V-163.
 2. Open flow calibration hose valves, V-162, -315, -411 and -412.

4.4.1.3 Pre-Test Preparations

- a) Adjacent to the flow calibration control valve, V-165, place the weighing tank and flow stabilization tank. The weighing tank is set-up on the pre-calibrated scale (Howe Richardson Scale Co., Model 2141, Capacity 300 lbs. or equivalent).
- b) Set-up the DAS to print-out the three flow meter readings at 10 second intervals on the printer. This program is stored in Program Bank File #2. The three applicable DAS channel numbers are 6, 25 and 58, respectively for flow meters, W400, W100 and W300. Recall the specific program from Program Bank File No. 2 in accordance with Section 4.3.1.5.
- c) Close the cold water cutout valve, V-310.
NOTE: This valve is to be closed just prior to the start of testing, since it cuts-off cold water supply throughout the house.

4.4.1.4 Testing: Record results on Data Sheet No. 12, Appendix A.

- a) Record the pre-test weight of the weighing tank and contents.
- b) Open the flow control valve V-163 and direct the flow to the flow stabilization tank. Set the nominal desired flow rate as read on the DAS console mounted flow meters for W300 and/or W400 by adjusting V-163.

- c) After flow stabilization is established, prepare the DAS on-line printer by setting applicable "Next Scan" time (time to start the run) Section 4.3.5.1 Steps 6-8. Synchronize the start of a print-out with the start of test run and start a stop watch as the flow is directed to the weighing tank.
- d) During the test, monitor the flow meter readings at a few instances for W300 and W400 and record directly on the print-out.
- e) At the conclusion of the desired run time as observed on the stop watch, immediately switch the flow from the weighing tank to the flow stabilization tank and press the "Halt" button, Section 4.3.5.1 Step 9. Then shut or adjust the flow at V-163 for the next run. See Fig. 4-13.
- f) Record the weight of the tank and its contents and note the end of test on the print-out sheet.
- g) Repeat steps a) through f) for each of the desired flow rates as necessary to cover the flow range of the meters.

4.4.1.5 Returning the systems to normal operation

- a) Disconnecting Systems
Close hose isolation valves and disconnect system interconnecting hoses. Return all valves to the normal operating positions as shown in Figs. 2-2 and 2-3.
- b) Placing the DAS back on-line
At the conclusion of testing, return the DAS to the normal operating mode, as defined in Section 4.3.5.1 b).
- c) Placing System On-Line
Place systems back on-line as specified in Section 4.1.3.

4.4.2 Other Instrumentation and Equipment

For detailed calibration procedures of the other instrumentation, follow the instructions provided in the applicable sections of the referenced documents.

The RTD's were originally calibrated in the laboratory, using the same constant current supply and DAS operating now at Solarow. It is planned that future RTD calibrations would be performed at the site of each unit, by removing it from its operating location and placing it into a constant temperature environment, at two or more temperatures, and reading the results on the DAS. During calibration, the wire connections of the RTD are exactly the same as during operation.

Pyranometers are sent for calibration to a certified laboratory, such as Eppley.

5. MAINTENANCE

5.1 General

General maintenance practices are to be performed for all applicable elements of the systems. For specified detailed procedures of individual pieces of equipment, refer to the maintenance section of the appropriate equipment manual.

During normal operation perform the items as follows:

- a) Observe all systems for leaks.
- b) Check for general equipment, instrumentation and system malfunctions by observing DAS print-out for typical values and by noticing any unusual items.
- c) Check insulation for deterioration.
- d) Normal maintenance as outlined in the following parts of this section.

In conjunction with the normal maintenance requirements, a monthly maintenance schedule is utilized to summarize the specific times for performing maintenance functions. A typical monthly schedule is shown in Table 5-1. These records are transferred to an ongoing maintenance chart comprised of Tables 5-2 through 5-5.

5.2 Pumps, Fans, Air Conditioner & Associated Motors

The overall maintenance schedule for the pumps, fans, air conditioner, and associated motors is provided in Table 5-2. This table notes the applicable reference documents which defines the maintenance instructions in detail.

5.3 Filters and Strainers

The overall maintenance schedule for the filters and strainers is provided in Table 5-3. In addition, the specific filter elements replacement units are identified. For the strainers, the flushing frequency is defined, while there are no replacement elements required.

During normal system operation or as convenient, change the filter elements as follows:

- a) Isolate filter by opening applicable bypass valve and closing applicable upstream and downstream cutout valves.

<u>SYSTEM</u>	<u>BYPASS VALVE</u>	<u>CUTOUT VALVES</u>
Demand	V-406	V-404 & V-405
SDHWH	V-303	V-301 & V-302
Fuel Oil	V-415	V-413 & V-414

- b) Place bucket under filter and remove air vent at top of unit.
- c) Unscrew cover unit and remove filter shell tube guide assembly and filter.

- d) Install new filter element, as required, and reassemble cover and air vent.
- e) Place filter back on-line by opening applicable upstream and downstream cutout valve and closing applicable bypass valve. Refer to step a) above for specific valve numbers.

5.4 Flow Meters and Associated Indicators

The overall maintenance schedule for the flow meters and associated indicators is provided in Table 5-4. In general the water meters are calibrated annually as defined in Section 4.4.1 of this report.

5.5 Glass Cleaning

The various glass elements subject to fouling are defined and cleaned as shown in Table 5-5.

5.6 Spare Parts Inventory

Various spare parts are on-hand for immediate use as necessary. A list of these items is shown in Table 5-6. Also contained in this table is a fuse inventory.

5.7 System Drain-down & Flush

Annually drain-down the storage tank system and associated systems and flush out completely. This should be performed as convenient during the summer months. See detailed operating procedures as shown in Section 4.1.8 of this report. Specifically flush out heat exchangers in SDHHS and Demand System.

5.8 Miscellaneous

5.8.1 Furnace Servicing

During summer months have oil furnace undergo regular cleaning and service by fuel oil supply company, with a project representative on site during the service to inspect the work and answer questions.

5.8.2 Shadowband for Diffuse Insolation Radiometer

Recoat the inner surface of the shadow band with Parsons' optical black lacquer or equivalent as required.

5.8.3 Memory Save Battery Life for PD-2064

Power consumption of the memory elements is provided by two 3 volt lithium organic batteries which have an operating life of 5 years. The original batteries dated 7/1/77 were faulty and were replaced 5/22/79. The new batteries were dated 2/21/79 and thus should be replaced 2/84. In addition, a battery drain resistor was added to the memory bank board by the service representative when

replacing the batteries. In the event the PD-2064 is shut down for a period of 3 months or more, the unit should be turned on at least once every 3 months for a period of 12 hours, so that the internal batteries are kept recharged and in a chargeable condition.

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44. Hersey Products Inc., "Niagara Liquid Meters",
Industrial Measurement Division, Old Valley Falls Road, Spartanburg, S.C. 29303
45. Air Monitor Corporation, "Fan-E and D.A.M.D. Design & Installation Guide",
P.O. Box 6358 Coddington Station, Santa Rosa, California 95406
46. Gould Incorporated, "Operating Manual Type 590 Barocel", dated 7/77,
Control & Systems Division, 340 Fordham Road, Wilmington, Massachusetts 01887
47. Conameter Corporation, "Analog Low Flow Transmitters, Instructions & Parts List",
No. DP-4, Jan. 1977
Box 383, Haddonfield, NJ 08033
48. American Meter Division Singer Co., "American AL-175 Aluminumcase Meter",
Bulletin 305.3, 6/75
13500 Philmont Avenue, Philadelphia, PA 19116
49. Disc Instrument Co., "Rotaswitch Incremental Shaft Encoders 820 Series",
Bulletin 820
102 E. Baker Street, Costa Mesa, California 92626

TABLE 2-1: SOLAR ENERGY COLLECTION LOOP VALVE LIST (FIGURE 2-2)

VALVE			
No.	Nominal Size Inches	Type	Location
V 100	3/8	Gate	Strainer drain at collector pump suction
V 101	1	Gate	Pump suction line from storage tank #1
V 102	1	Gate	Pump suction line from storage tank #2
V 103	1	Gate	Pump suction line from storage tank #3
V 104 (S3)	1-1/4	Solenoid Control	Collector pump discharge line
V 105-V111	1/2	Globe	Outlet from respective collectors on 1st row
V 112-V118	1/2	Globe	Outlet from respective collectors on 2nd row
V 119-V125	1/2	Globe	Outlet from respective collectors on 3rd row
V 126-V132	1/2	Globe	Outlet from respective collectors on 4th row
V 133-V137	1/2	Globe	Outlet from respective collectors on 5th row
V 138	1-1/2	Gate	Upstream of "Ramapo" flow meter, W100
V 139	1-1/2	"Amtrol" Air Purger	Upstream of W100
V 140	1-1/2	Gate	Downstream of W100
V 141	1-1/2	Gate	Bypass line of W100
V 142 (S2)	1-1/4	Solenoid Control	Upstream of Manifold to storage tanks
V 143	1	Globe	Inlet to storage tank #1
V 144	1	Globe	Inlet to storage tank #2
V 145	1	Globe	Inlet to storage tank #3
V 146-V149 (S1A-D)	1-1/4	Solenoid Control	Drain line from inlet manifold to collectors, respectively for rows 2-5
V 150-V154	3/4	Air Vent/ Vacuum Breaker	Top of collector outlet manifold, respectively for rows 1-5
V 155-V159	1/4	Air Vent	Top of collector outlet manifold, respectively, for rows 1-5
V 160	1/2	Pressure Relief	Top of collector outlet manifold for row 1; setting psig
V 161	3/8	Gate	Strainer drain upstream of W100
V 162	1	Gate	Upstream of W100: flow meter calibration- from demand system V 412
V 163	1	Globe	Downstream of W100: flow meter calibration- to weighing tank
V 164 (S1)	2	Solenoid Control	Collector return line downstream of S1A-D

TABLE 2-2: THERMAL STORAGE SYSTEM VALVE LIST (FIGURE 2-3)

VALVE			
No.	Nominal Size Inches	Type	Location
V200	1/4	Ball	Storage tank No. 2, T200 cutout
V201	1/4	Ball	Storage tank No. 2, T201 cutout
V202	1/4	Ball	Storage tank No. 2, T202 cutout
V203	1/4	Ball	Storage tank No. 2, T203 cutout
V204	1/4	Ball	Storage tank No. 2, T204 cutout
V205	1/4	Ball	Storage tank No. 2, T205 cutout
V206	1/4	Ball	Storage tank No. 2, T206 cutout
V207	1/4	Ball	Storage tank No. 1, T207 cutout
V208	1/4	Ball	Storage tank No. 1, T208 cutout
V209	1/4	Ball	Storage tank No. 1, T209 cutout
V210	1/4	Ball	Storage tank No. 1, T210 cutout
V211	1/4	Ball	Storage tank No. 1, T211 cutout
V212	1/4	Ball	Storage tank No. 1, T212 cutout
V213	1/4	Ball	Storage tank No. 1, T213 cutout
V214	1/2	Gate	Outlet from storage tank No. 1 to gage glass level indicator
V215	1/2	Gate	Outlet from Storage Tank No. 2 to gage glass level indicator
V216	1/2	Gate	Outlet from Storage Tank No. 3 to gage glass level indicator
V217	1/2	Gate	Inlet at bottom of gage glass level indicator
V218	1/2	Gate	Inlet at top of gage glass level indicator
V219	1	Automatic Make- Up Feed	"McDonnell" No. 25A Cold water supply between Storage Tanks No. 2 and No. 3
V220	1/2	Gate	Drain line from V-219
V221	1/2	Gate	Drain line at bottom of Storage Tank No. 1
V222	1/2	Gate	Drain line at bottom of Storage Tank No. 2
V223	1/2	Gate	Drain line at bottom of Storage Tank No. 3
V224	3/4	Check	Drain outlet line adjacent to main drain pipe
V225	1/4	Ball	Storage Tank No. 2, cutout above V-200 (extra)
V226	1/4	Ball	Storage Tank No. 1, cutout above V-207 (extra)
V227	1/2	Relief	Manifold at top of Storage Tank No. 2

TABLE 2-3: SOLAR DOMESTIC HOT WATER HEATING LOOP VALVE LIST
(FIGURE 2-3)

VALVE			
No.	Nominal Size Inches	Type	Location
V 300	1	Gate	City water supply inlet
V 301	3/4	Gate	Upstream of "Flow Technology" flow meter W300
V 302	3/4	Gate	Downstream of "Flow Technology" flow meter W300
V 303	3/4	Gate	Bypass of "Flow Technology" flow meter W300
V 304	3/4	Globe	Outlet from SDHWH in Storage Tank No. 2
V 305	3/4	Globe	Outlet from SDHWH in Storage Tank No. 3
V 306	3/4	Ball	Inlet to Domestic Hot Water Heater (DHW)
V 307	3/4	Gate	Inlet to DHW, Bypass from city water supply
V 308	3/4	Gate	Outlet from DHW
V 309	3/4	Tempering	Outlet from DHW, downstream of V-308 & flow meter W301
V 310	3/4	Gate	Cutout valve to cold water accessories
V 311	3/4	Gate	Inlet to storage system make-up feed valve V-219
V 312	3/4	Ball	Inlet to pressure regulator, V313, by pass line to V301 for pressure regulation during flow meter calibration
V 313	3/4	Regulator	Upstream of "Flow Technology" flow meter by pass line to V301 for pressure regulation during flow meter calibration
V 314	3/4	Ball	Outlet from pressure regulator by pass line to V301 for pressure regulation during flow meter calibration
V 315	3/4	Gate	Inlet header to SDHWHs; flow meter calibration - outlet from W300 to Demand System V 411

TABLE 2-4: SPACE HEATING SYSTEM VALVE LIST (FIGURE 2-2)

VALVE			
No.	Nominal Size Inches	Type	Location
V 400	1	Gate	Demand Pump suction drain line strainer
V 401	1	Gate	Outlet from Storage Tank No. 1
V 402	1	Gate	Outlet from Storage Tank No. 2
V 403	1	Gate	Outlet from Storage Tank No. 3
V 404	1	Gate	Inlet to "Invalco" flow meter W 400
V 405	1	Gate	Outlet from "Invalco" flow meter W400
V 406	1	Gate	Bypass to "Invalco" flow meter W400
V 407	1	Globe	Inlet to Storage Tank No. 1
V 408	1	Globe	Inlet to Storage Tank No. 2
V 409	1	Globe	Inlet to Storage Tank No. 3
V 410	1	Check	Demand pump outlet
V 411	1	Gate	Inlet to flow meter W400: flow meter calibration from SDHWS, V315
V 412	1	Gate	Outlet from heat exchanger: flow meter calibration from W400 to Solar Collection Loop, V164
V 413	1/4	Ball	Inlet to "Conameter" oil flow meter, F400
V 414	1/4	Ball	Outlet from "Conameter" oil flow meter, F400
V 415	1/4	Cock	Bypass line to "Conameter" oil flow meter, F400

TABLE 2-5: CONTROLLER & SENSOR LIST

CONTROLLER LIST

No.	Type	Manufacturer	Model No.	Controls	Ref.
<u>Comfort Heating System</u>					
1	FixFlo Control with Frost Override & Adjustable Turn-on Differential	Hawthorne Industries Solar Energy Division	H-1506-A	Collector Pump, S1, S2 & S3	9,10
2	Two-Stage Room Thermostat	Barber-Colman Co. Controls Division	TC-154	Demand Pump, Air Blower & Furnace	11,12
3	Aquastat	Honeywell	L4008 B	Demand Pump & Air Blower	13
4	Protectorelay Oil Burner	Honeywell	RA 117A	Oil Pump & Air Blower	14
5	Make-up Water Feeder	McDonnell & Miller	McDonnell No. 25A	Storage Tank Water Level	15
<u>Marine Domestic Hot Water Heating System</u>					
6	Unitrol Total Regulation	Robertshaw Controls Co.	R110-RT-P	Gas Flow to Heater	16
7	Tempering Valve	Watts	70A	Hot Water to House	17

TE: See Figure 2-1 for Controller Locations

TABLE 2-5: CONTROLLER'S SENSOR LIST

SENSOR LIST			
Controller No.	Description	Model No.	Measurement No. (See Fig. 2-1)
C-1	Air frost (set @ 38°F)	H-1521	T002(C)
C-1	Collector absorber frost set @ 38°F	H-1521	T003(C)
C-1	Storage Tank Immersion	H-1526	T112(C)
C-1	Collector Absorber Outlet Immersion	H-1526	T113(C)
C-2	2 Air Temperature Bimetal Elements inside Thermostat		
C-3	Remote Bulb Immersion @ Demand Pump Discharge		T405(C)
C-4	Stack Temperature		
C-5	Ball Float Level Actuation		Integral with unit
C-6	Thermocouple Energy cut off (E.C.O.) switch Pressure regulator		Integral with DHW
C-7	Temperature Sensing Element (Thermostat), Range 120-160°F	SA70A3	

TABLE: 2-6: Solar Heat Collection Loop Control Logic, [2] (Table 1)

Temperature at Hottest Collector	Temperature at Coldest Collector, or Ambient	PI	S1=A thru S1=D	S2, S3	Operation
$\geq (T_s + \Delta Th_1)$	any	on	closed	open	solar heat collection
$< (T_s + \Delta Th_2)$	$> T_d$	off	open	closed	none, system full
$< (T_s + \Delta Th_2)$	$\leq T_d$	off	open	open	drainage

ΔTh_1 and ΔTh_2 are temperature differences of value:
 Turn-off temperature difference $\left\{ \begin{array}{l} < (\Delta Th_1, \Delta Th_2) \leq \end{array} \right\}$ Turn-on temperature difference
 [here typically $3^\circ\text{F}(1.7^\circ\text{C})$] [here typically $16^\circ\text{F}(8.9^\circ\text{C})$]
 T_s Temperature of water at bottom of storage tanks
 T_d Drain-down temperature limit (here $38^\circ\text{F}, 3.3^\circ\text{C}$)

TABLE 2-7 DIFFERENTIAL TEMPERATURE CONTROLLER 12 POSITION SWITCH CONTROL VALUES

With Storage Temperature of 81.05°F (8963Ω)

Switch Position	Hysteresis Resistor Value	ΔT_{on}	ΔT_{off}	Hysteresis $\Delta T_{on} - \Delta T_{off}$
No.	KΩ	°F	°F	°F
1	∞	3.0	3.0	-0-
2	391.0	3.45	3.0	0.45
3	274.1	3.81	3.0	0.81
4	218.8	4.53	3.0	1.53
5	149.3	5.02	3.0	2.02
6	120.7	5.93	3.0	2.93
7	99.21	6.55	3.0	3.55
8	81.94	7.52	3.0	4.52
9	56.10	9.46	3.0	6.46
10	46.81	10.97	3.0	7.97
11	38.97	12.23	3.0	9.23
12	33.02	13.76	3.0	10.76

NOTE: Due to the non-linearity of the thermistor sensors, the amount of hysteresis (except at position #1) will increase as temperature increases (storage sensor value decreases). For example, at a storage temperature of 135°F, position 10 will produce a hysteresis of approximately 13°F.

All the above information was provided with Controller C-1 by its manufacturer.

TABLE No. 3-1: TOTAL INSTRUMENTATION (GROUPED BY SYSTEMS) SOLAR HEATED ROW HOME

1 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Climatological:</u>				
H001	17	Outdoor humidity	0 to 100% RH	WEATHERMEASURE HM111
I001	13	Total insolation	0 to 1150 W/m ² (0 to 365 Btu/hr.ft ²)	EPPLEY PSP 15678F3
I002	12	Diffuse insolation	0 to 500 W/m ² (0 to 158 Btu/hr.ft ²)	EPPLEY PSP 14537F3, shadowband SBS 5402
P001	18	Outdoor barometric pressure	91.4 to 106.7 kN/m ² (27" to 31.5" Hg)	YSI-SOSTMAN 2014-HA-3-WH, 14315
T001	10	Outdoor dry-bulb temperature	-40 to 50°C (-40 to 122°F)	ARI [†] , 4810
T002 (C)	--	Air Frost temperature		H-1521
T003 (C)	--	Collector absorber frost temperature		H-1521
V001	14	Wind velocity, U component North-South	0 to 36 m/s (0 to 80mph) 0 to 360°	R.M. YOUNG Anemometer 27004
V002	15	Wind velocity, V component East-West		Propeller 21282
V003	16	Wind velocity, W component Up-Down		Ind. Translator 27503R
<u>Collector System:</u>				
EP600	21	Electrical power to circulation pump	0 to 1500 W	SCI Hallitipler #2100, 700301-14632

† ARI R-50172-6F100-12 Platinum RTD (C) -Control

TABLE No. 3-1. 2 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Collector System:</u> <u>contd.</u>				
P100 (L)	--	Circulation pump discharge	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge, Indicating gauge
P101	19	Inlet to first collector row	0 to 172.4 kN/m ² gauge (0 to 25 psig)	BELL & HOWELL CEC 4-312-0002
P102	20	Outlet from last collector row	0 to +68.9 kN/m ² gauge (0 to + 10 psig)	BELL & HOWELL CEC 4-312-0002
P103 (L)	--	Inlet to storage tanks	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge, Indicating Gauge
P104 (L)	--	Circulation pump suction	0 to 103.4 kN/m ² gauge (0 to 15 psig)	Ashcroft, Indicating Gauge
T100	00	Outlet from thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI [†] , 4782
T101	01	Outlet from thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI [†] , 4805
T102	02	Outlet from thermal storage tank #3	-10 to 110°C (14 to 230°F)	ARI [†] , 4800
T103	03	Inlet to first collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4787
T104	04	Inlet to second collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4813
T105	05	Inlet to third collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4786
T106	07	Inlet to fourth collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4791
T107	08	Inlet to fifth collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4783
T108	09	Outlet from fifth collector row	-10 to 110°C (14 to 230°F)	ARI [†] , 4802
T109	11	Inlet to flow meter W100	-10 to 110°C (14 to 230°F)	ARI [†] , 4808
T110 (L)	--	Thermal storage inlet manifold	-7 to 116°C (20-240°F)	Weston, Indicating gauge

(L) - Local

(C) - Control

† ARI R-50172 - 6F100-12 Platinum RTD

TABLE No. 3-1, 3 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Collector System:</u> <u>contd.</u>				
T111 (L)	--	Circulation pump suction	-7 to 116°C (20-240°F)	Weston, Indicating gauge
T112 (C)	--	Storage tank immersion		H-1526
T113 (C)	--	Collector absorber outlet immersion		H-1526
W100	25	Collector Loop	0.09 to 0.9 x 10 ⁻³ m ³ /s (1.4 to 14 GPM)	RAMAPO 1 in. Mark V-1-J02, 5122
W101 (L)	--	Outlet from storage tank #1	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
W102 (L)	--	Outlet from storage tank #2	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
W103 (L)	--	Outlet from storage tank #3	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
W104 (L)	--	Inlet to storage tank #1	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
W105 (L)	--	Inlet to storage tank #2	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
W106 (L)	--	Inlet to storage tank #3	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB - 1"
<u>Thermal Storage System:</u>				
L200 (L)	--	Gage Glass Level indicator between storage tanks #1 and #2	0 to 74.93 cm. of water (0 to 29.5 in. of water)	

TABLE No. 3-1. 4 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Thermal Storage System: contd.</u>				
P200 (L)	--	Pressure manifold at top of storage tanks	101.6 kN/m ² Vac-0-103.4 kN/m ² (30" Hg Vac-0-15 psig)	Ashcroft, Indicating gauge
T200	40	Temperature distribution in thermal storage tank #2 (top)	-10 to 110°C (14 to 230°F)	ARI ††, 4828
T201	41	Temperature distribution in thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI ††, 4831
T202	42	Temperature distribution in thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI ††, 4819
T203	43	Temperature distribution in thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI ††, 4829
T204	44	Temperature distribution in thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI ††, 4823
T205	45	Temperature distribution in thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI ††, 4818
T206	46	Temperature distribution in thermal storage tank #2 (bottom)	-10 to 110°C (14 to 230°F)	ARI ††, 4826
T207	47	Temperature distribution in thermal storage tank #1 (top)	-10 to 110°C (14 to 230°F)	ARI ††, 4824
T208	48	Temperature distribution in thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI ††, 4820
T209	49	Temperature distribution in thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI ††, 4833
T210	50	Temperature distribution in thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI ††, 4832

††ARI R-50171 - 24E100-12 Platinum RTD (L) - Local

TABLE No. 3-1, 5 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Thermal Storage System: cont'd.</u>				
T211	51	Temperature distribution in thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI ++, 4822
T212	52	Temperature distribution in thermal storage tank #1	-10 to 110°C (14 to 230°F)	ARI ++, 4830
T213	53	Temperature distribution in thermal storage tank #1 (bottom)	-10 to 110°C (14 to 230°F)	ARI ++, 4827
<u>Domestic Hot Water System:</u>				
F300	63	Gas flow rate to DHW gas-fired heater	$0.59 \times 10^{-3} \text{ m}^3/\text{s}$ (0 to 75 ft ³ /hr)	AMERICAN METER AL-175 S2114956 with Rotaswitch Incremental Shaft Encoder, 821-125- DALP
F301 (L)	--	Gas flow rate upstream of F300		AMERICAN METER S M 200 4429569
P300 (L)	--	City Water Supply to SDHWH System	0 to 689.5 kN/m ² (0-100 psig)	Ashcroft Indicating gauge
P301 (L)	--	Inlet to SDHWH Storage Tanks #2 & #3	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge Indicating gauge
P302 (L)	--	Outlet from SDHWH in storage tank #2	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge Indicating gauge
P303 (L)	--	Outlet from SDHWH in storage tank #3	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge Indicating gauge

++ ARI R-50171 - 24E10)-12 Platinum RTD (L) - Local SDHWH- Solar Domestic Hot Water Heater

TABLE No. 3-1. 6 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Domestic Hot Water System:</u> <u>contd.</u>				
P304 (L)	--	Outlet from gas-fired heater, downstream of tempering valve	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge Indicating gauge
P305 (L)	--	Outlet from pressure regulator	0 to 413.7 kN/m ² gauge (0 to 60 psig)	US Gauge Indicating gauge
T300	54	Inlet to manifold SDHWH storage tanks #2 & #3	-10 to 40°C (14 to 104°F)	ARI †, 4806
T301	55	Outlet from SDHWH in storage tank #3	-10 to 110°C (14 to 230°F)	ARI †, 4811
T302	56	Outlet from SDHWH in storage tank #2	-10 to 110°C (14 to 230°F)	ARI †, 4798
T303	57	Outlet header from storage tanks #2	-10 to 110°C (14 to 230°F)	ARI †, 4797
T304	59	Outlet from gas heater	-10 to 110°C (14 to 230°F)	ARI †, 4784
T305	60	Outlet from gas heater downstream of tempering valve	-10 to 110°C (14 to 230°F)	ARI †, 4790
W300	58	Into SDHWH	0.095 to .95 x 10 ⁻³ m ³ /s (.15-15 GPM)	FLOW TECHNOLOGY FT-10N15-LJ turbine meter #10229
W301	62	Tempering Cold Water Supply	Positive Displacement Rotating Disk	Hersey, Domestic water meter pulsing with magnetic reed switch MD 1215122
W302 (L)	--	Inlet to SDHWH in storage tank #2	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB-1"

† ARI R-50172-6 F100-12 Platinum RTD (L) - Local; SDHWH- Solar Domestic Hot Water Heater

TABLE No. 3-1, 7 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Domestic Hot Water System:</u> contd.				
W303 (L)	--	Inlet to SDHWH in storage tank #3	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 GPM)	BELL & GOSSETT TB -1"
W304 (L)	--	City Water Supply (Existing Meter)		Badger 190122
<u>Space Heating System:</u>				
EP601	30	Electrical power to demand loop pump		SCI Halltiplier 2100, 7309-2
EP602	31	Electrical power to warm air fan		SCI Halltiplier 2100, 700311-059
F400	35	Oil flow rate to furnace	0 to 2.1 x 10 ⁻⁶ m ³ /s (0 to 2 gph)	CONAMETER Model No.13-101 Output 1000 mvdc Range 6 gph Series 13 Oscillating piston meter S/N S771144
P400 (L)	--	Demand loop pump discharge pressure	0 to 103.4 kN/m ² gauge (0 to 15 psig)	US Gauge Indicating gauge
P401 (L)	--	Demand loop pump suction pressure	0 to 103.4 kN/m ² gauge (0 to 15 psig)	Ashcroft Indicating gauge
P402 (L)	--	Demand loop return manifold to storage tanks	101.6 kN/m ² Vac-0-103.4 kN/m ² (30" Hg Vac-0-15 psig)	US Gauge Indicating gauge

(L) - Local

SDHWH-Solar Domestic Hot Water Heater

TABLE No. 3-1, 8 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Space Heating System: contd.</u>				
P403 (L)	--	Oil supply upstream of fuel oil flow meter	0 to 413.7 kN/m ² gauge (0-60 psig)	US Gauge Indicating gauge
P404 (L)	--	Oil supply downstream of fuel oil flow meter	101.6 kN/m ² Vac-0-103.4 kN/m ² (30 in. Hg Vac-0-15psig)	Ashcroft Indicating gauge
PD400 (L)	--	Pressure difference between fan inlet and discharge	0-250 N/m ² (0 to 1" w.c.)	DWYER MAGNEHELIC 2001
T400	22	Demand loop water exit from thermal storage tank #3	-10 to 110°C (14 to 230°F)	ARI [†] , 4804
T401	23	Demand loop water exit from thermal storage tank #2	-10 to 110°C (14 to 230°F)	ARI [†] , 4781
T402	26	Demand loop water at inlet to water-to-air space heater	-10 to 110°C (14 to 230°F)	ARI [†] , 4794
T403	27	Demand loop water at exit from water-to-air space heater	-10 to 110°C (14 to 230°F)	ARI [†] , 4799
T404	29	Return air temperature	-10 to 50°C (14 to 120°F)	ARI [†] , 4788
T405 (C)	--	Remote bulb immersion at demand pump suction in storage tank #2		
T600	28	Basement air temperature	-10 to 50°C (14 to 120°F)	ARI [†] , 4815
T601	36	First floor air temperature	-10 to 50°C (14 to 120°F)	ARI [†] , 4796
T602	37	Second floor air temperature	-10 to 50°C (14 to 120°F)	ARI [†] , 4807
T603	38	Third floor air temperature	-10 to 50°C (14 to 120°F)	ARI [†] , 4792

† ARI R-50172-6 F100-12 Platinum RTD

(L) Local (C) Control

TABLE No. 3-7, 9 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Space Heating System contd.</u>				
TD400	32	Air temperature difference across water-to-air exchanger	0-20°C(0-68°F)	10-junction type K thermopile
TD401	33	Air temperature difference across air heating furnace	0-50°C(0-120°F)	10-junction type K thermopile
W400	6	Total flow rate through demand loop	0.082 to 0.82 x 10 ⁻³ m ³ /s (1.3 to 13 gpm)	INVALCO W3/0750 turbine meter
W401 (L)	--	Demand loop water outlet from thermal storage tank #1	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB - 1" Indicator
W402 (L)	--	Demand loop water outlet from thermal storage tank #2	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB-1" Indicator
W403 (L)	--	Demand loop water outlet from thermal storage tank #3	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB -1" Indicator
W404 (L)	--	Demand loop water inlet to thermal storage tank #1	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB - 1" Indicator
W405 (L)	--	Demand loop water inlet to thermal storage tank #2	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB - 1" Indicator
W406 (L)	--	Demand loop water inlet to thermal storage tank #3	0.13 to 0.63 x 10 ⁻³ m ³ /s (2 to 10 gpm)	BELL & GOSSETT TB-1" Indicator

(L) Local

TABLE No. 3-1, 10 of 10

MEASUREMENT	DAS CHANNEL NUMBER	DESCRIPTION	RANGE	SENSOR MODEL S/N
<u>Space Heating System: contd.</u>				
W407	34	Warm Air total flow rate	0 to 0.75 m ³ /s, 0 to 5.6m/s (0 to 1600 cfm, 0 to 1100 fpm)	AIR MONITOR 10" x 22" FAN-E/
<u>Current Supply Loops</u>				
R1	39	Standard Resistor for 1st Current Loop NBS-Type	100.0001 ohms @ 25°C	LEEDS & NORTHRUP 4030-B S/N 1854057
R2	61	Standard Resistor for 2nd Current Loop NBS-Type	100.0001 ohms @ 25°C	LEEDS & NORTHRUP 4030-B S/N 1854069

TABLE NO. 3-2: DAS INSTRUMENTATION LIST (CHANNEL NUMBER ORDER)

Data Acquisition System (DAS)			Measure- ment No.	Description (See Note)	RTD Current Supply Loop Nos./ or Signal Conditioning Devices
Channel No.	Connector No.	Pin Nos.			
00	S1	4-5	T100	Outlet S.T. 1	C.S. #2
01	S1	6-7	T101	Outlet S.T. 2	C.S. #2
02	S1	8-9	T102	Outlet S.T. 3	C.S. #1
03	S1	10-11	T103	Inlet 1st C.R.	C.S. #2
04	S1	12-13	T104	Inlet 2nd C.R.	C.S. #2
05	S1	14-15	T105	Inlet 3rd C.R.	C.S. #2
06	S1	16-17	W400	Demand Loop	Flow Rate Indicator (Invalco) W-370 @ DAS
07	S1	18-19	T106	Inlet 4th C.R.	C.S. #2
08	S2	4-5	T107	Inlet 5th C.R.	C.S. #2
09	S2	6-7	T108	Outlet 5th C.R.	C.S. #2
10	S2	8-9	T001	Outdoor Air	C.S. #2 Digital Meter (Analogic) AN2559LP @ DAS
11	S2	10-11	T109	Inlet W100	C.S. #1
12	S2	12-13	I002	Diffuse	Direct to DAS
13	S2	14-15	I001	Total	Digital Meter (Analogic) AN2553LP @ DAS
14	S2	16-17	V001	North-South	Dual Range Meter (Young) @ DAS
15	S2	18-19	V002	East-West	Dual Range Meter (Young) @ DAS
16	S3	4-5	V003	Up-Down	Dual Range Meter (Young) @ DAS
17	S3	6-7	H001	Outdoor Humidity	HM-111-1PS (Weather Measure) @ DAS
18	S3	8-9	P001	Outdoor Barometric	Digital Meter (Analogic) AN2559LP @ DAS
19	S3	10-11	P101	Inlet 1st C.R.	Bridge Input Digital Indicator (Action) @ DAS
20	S3	12-13	P102	Outlet 5th C.R.	Bridge Input Digital Indicator (Action) @ DAS
21	S3	14-15	EP600	Circulation	Direct to DAS
22	S3	16-17	T400	D.L. Exit S.T. 3	C.S. #1
23	S3	18-19	T401	D.L. Exit S.T. 2	C.S. #1
24	S4	4-5	short		Not applicable
25	S4	6-7	W100	Collector Loop	No direct readout meter Strain Gauge Adapter (Ramapo) SGA-101B
26	S4	8-9	T402	D.L. Inlet H.Ex.	C.S. #2
27	S4	10-11	T403	D.L. Exit H. Ex.	C.S. #1
28	S4	12-13	T600	Basement Air	C.S. #2
29	S4	14-15	T404	Return Air	C.S. #1
30	S4	16-17	EP601	Demand	Direct to DAS
31	S4	18-19	EP602	Warm Air Fan	Direct to DAS

Note: Abbreviations - S.T.: storage tank, C.R.: collector row

D.L.: demand loop, H.Ex.: heat exchanger, C.S.: current supply

TABLE NO. 3-2: DAS INSTRUMENTATION LIST (CHANNEL NUMBER ORDER)

Data Acquisition System (DAS)			Measurement No.	Description (See Note)	RTD Current Supply Loop Nos./ or Signal Conditioning Devices
Channel No.	Connector No.	Pin Nos.			
32	S5	4-5	T0400	Air/H.Ex.	Direct to DAS
33	S5	6-7	T0401	Air/Furnace	Direct to DAS
34	S5	8-9	W407	Warm Air	Gould 590-10T-208-VIX-41D Integral Borocel Pressure Transducer Internal Tachometer (Conameter)
35	S5	10-11	F400	Oil to Furnace	
36	S5	12-13	T601	1st Floor Air	C.S. #1
37	S5	14-15	T602	2nd Floor Air	C.S. #2
38	S5	16-17	T603	3rd Floor Air	C.S. #2
39	S5	18-19	R1	Std. Resistor	C.S. #1
40	S6	4-5	T200	Temp. Profile	C.S. #2
				S.T.2	
41	S6	6-7	T201	Temp. Profile	C.S. #2
				S.T.2	
42	S6	8-9	T202	Temp. Profile	C.S. #2
				S.T.2	
43	S6	10-11	T203	Temp. Profile	C.S. #2
				S.T.2	
44	S6	12-13	T204	Temp. Profile	C.S. #1
				S.T.2	
45	S6	14-15	T205	Temp. Profile	C.S. #1
				S.T.2	
46	S6	16-17	T206	Temp. Profile	C.S. #2
				S.T.2	
47	S6	18-19	T207	Temp. Profile	C.S. #1
				S.T.1	
48	S7	4-5	T208	Temp. Profile	C.S. #1
				S.T.1	
49	S7	6-7	T209	Temp. Profile	C.S. #1
				S.T.1	
50	S7	8-9	T210	Temp. Profile	C.S. #1
				S.T.1	
51	S7	10-11	T211	Temp. Profile	C.S. #1
				S.T.1	
52	S7	12-13	T212	Temp. Profile	C.S. #1
				S.T.1	
53	S7	14-15	T213	Temp. Profile	C.S. #1
				S.T.1	
54	S7	16-17	T300	SDHWH Inlet	C.S. #1
				S.T.s.	
55	S7	18-19	T301	SDHWH Out S.T.3	C.S. #1
56	S8	4-5	T302	SDHWH Out S.T.2	C.S. #1
57	S8	6-7	T303	SDHWH Out S.T.s.	C.S. #2
58	S8	8-9	W300	SDHWH	Range Extending Amplifier (Flow Tech) Freq. Input Digital Indicator (Action) @ DAS
59	S8	10-11	T304	Out Gas Heater	C.S. #1
60	S8	12-13	T305	To Appliances	C.S. #2
61	S8	14-15	R2	Std. Resistor	C.S. #2
62	S8	16-17	W301	Tempering Supply	Pulse Generator & Converter
63	S8	18-19	F300	Gas to DHWH	Rotaswitch Encoder (Disc) Series 820: Pulser & Converter

Note: Abbreviations - H.Ex.: heat exchanger, S.T.: storage tank, C.S.: current supply
 DHWH: Domestic hot water heater, SDHWH: solar DHWH

TABLE NO. 3-3: DAS INSTRUMENTATION LIST WITH CABLE CODE AND HOOK-UP LOCATIONS
(Measurement Types in Alphabetical Order)

Measurement No.	Description	DAS No.	Instrument S/N	Hook Up Location:	Cable	
				Junction Box Row ① & No.	Bundle No.	Individual Wire Color ②
<u>Electric Power</u>						
EP 600	Circulation	21	700311-020	A 22-24	2	Green
EP 601	Demand	30	7309-2	A 13-15	2	Red
EP 602	Warm Air	31	700311-059	A 19-21	2	Orange
<u>Flow</u>						
F 300	Gas to DHWH	63	S 2114956	A 31-33	3	White Stripe
F 400	Oil to Furnace	35	S 771144	A 4-6	1	Blue
<u>Humidity</u>						
H 001	Outdoor Humidity	17	1047	Direct to Indicator @ DAS Console	11	Gray
<u>Insolation</u>						
I 001	Total	13	15678 F 3	H 8-10	9	Red
I 002	Diffuse	12	14537 F 3	H 5-7	9	Red Stripe
<u>Pressure</u>						
P 001	Outdoor Barometric	18	14315	H 1-4	8	Black; White Stripe
P 101	Inlet 1st C.R.	19	37606	L 12-16	8	Red; Red Stripe
P 102	Outlet 5th C.R.	20	37929	L 11, 17-20	8	Orange; Green
<u>Resistance</u>						
R 1	#1 Current Loop	39	1854057	In DAS Console	--	---
R 2	#2 Current Loop	61	1854069	In DAS Console	--	---
<u>Temperature</u>						
T 001	Outdoor Air	10	4810	H 15-17	9	White Stripe
T 100	Outlet S.T.1	00	4782	B 10-12	4	Black
T 101	Outlet S.T.2	01	4805	C 4-6	5	Blue
T 102	Outlet S.T.3	02	4800	D 4-6	5	White Stripe
T 103	Inlet 1st C.R.	03	4787	K 10-12	10	Orange
T 104	Inlet 2nd C.R.	04	4813	K 4-6	10	Red Stripe

NOTES: ① A-G, Basement / H-L, Roof: See Figures 3-1/3-2, respectively.

② Any Color Stripe means that color with a black stripe.

Abbreviations: DHWH - domestic hot water heater

C.R. - collector row

S.T. - storage tank

TABLE NO. 3-3: DAS INSTRUMENTATION LIST WITH CABLE CODE AND HOOK-UP LOCATIONS
(cont'd 2 of 3) (Measurement Types in Alphabetical Order)

Measurement No.	Description	DAS No.	Instrument S/N	Hook Up Location:	Cable	
				Junction Box Row ① & No.	Bundle No.	Individual Wire Color ②
<u>Temperature (cont'd)</u>						
T 105	Inlet 3rd C.R.	05	4786	K 16-18	10	Green
T 106	Inlet 4th C.R.	07	4791	J 16-18	10	Red
T 107	Inlet 5th C.R.	08	4783	J 10-12	10	White Stripe
T 108	Outlet 5th C.R.	09	4802	J 4-6	10	Black
T 109	Inlet W 100	11	4812	G 16-18	7	Red
T 200	Profile S.T.2	40	4828	B 28-30	4	Red Stripe
T 201	Profile S.T.2	41	4831	B 22-24	4	Red
T 202	Profile S.T.2	42	4819	C 22-24	1	Red
T 203	Profile S.T.2	43	4829	B 16-18	4	White Stripe
T 204	Profile S.T.2	44	4823	F 16-18	6	Blue
T 205	Profile S.T.2	45	4818	D 16-18	5	Red Stripe
T 206	Profile S.T.2	46	4826	C 16-18	1	White Stripe
T 207	Profile S.T.1	47	4824	G 28-30	7	Orange
T 208	Profile S.T.1	48	4820	D 28-30	5	Green
T 209	Profile S.T.1	49	4833	F 10-12	7	Blue
T 210	Profile S.T.1	50	4832	F 4-6	7	Green
T 211	Profile S.T.1	51	4822	E 4-6	6	Red Stripe
T 212	Profile S.T.1	52	4830	E 28-30	5	Black
T 213	Profile S.T.1	53	4827	D 10-12	5	Red
T 300	SDHWH Inlet S.Ts.	54	4806	G 22-24	7	Red Stripe
T 301	SDHWH Out S.T.3	55	4811	D 22-24	5	Orange
T 302	SDHWH Out S.T.2	56	4814	E 22-24	6	Blue
T 303	SDHWH Out S.Ts.	57	4797	C 28-30	1	Red Stripe
T 304	Out Gas Heater	59	4784	E 10-12	6	Orange
T 305	To Appliances	60	4790	B 4-6	1	Orange
T 400	D.L. Exit S.T.3	22	4804	F 28-30	6	Red
T 401	D.L. Exit S.T.2	23	4781	E 16-18	6	Green
T 402	D.L. Inlet H.Ex.	26	4794	C 10-12	1	Black
T 403	D.L. Exit H.Ex.	27	4799	F 22-24	6	White Stripe
T 404	Return Air	29	4788	G 4-6	7	Blue
T 600	Basement Air	28	4815	B 35-37	4	Orange
T 601	1st Floor Air	36	4796	G 10-12	7	Blue Stripe
T 602	2nd Floor Air	37	4807	Direct to DAS	13	Gray
T 603	3rd Floor Air	38	4792	Direct to DAS	14	Gray

NOTES: ① A-G, Basement / H-L, Roof: See Figures 3-1/3-2, respectively.

② Any Color Stripe means that color with a black stripe.

Abbreviations: S.T. - storage tank D.L. - demand loop
SDHWH - solar domestic hot water heater
H.Ex. - heat exchanger C.R. - collector row

TABLE NO. 3-3: DAS INSTRUMENTATION LIST WITH CABLE CODE AND HOOK-UP LOCATIONS
(cont'd 3 of 3) (Measurement Types in Alphabetical Order)

Measurement No.	Description	DAS No.	Instrument S/N	Hook-Up Location:	Cable	
				Junction Box Row ① & No.	Bundle No.	Individual Wire Color ②
<u>Temperature Difference</u>						
TD 400	Air/H.Ex.	32	---	A 1-3	1	Green
TD 401	Air Furnace	33	---	A 7-9	2	Black
<u>Velocity</u>						
V 001	North-South	14	27004	Direct to Indicator @ DAS Console	16	Gray
V 002	East-West	15	27004			
V 003	Up-Down	16	27004			
<u>Flow</u>						
W 100	Collector Loop	25	5122	A 34-38	3	Red; Red Stripe
W 300	SDHWH	58	10229	B 32-34	3	Orange
W 301	Tempering Supply	62	5433953	A 25-27	2	Blue
W 400	Demand Loop	06	---	A 10-12	2	White Stripe
W 407	Warm Air	34	5795	A 16-18	2	Red Stripe
				A 28-30	3	Black
<u>Miscellaneous Items</u>						
H001	Air Blower Power	--	---	Direct to Roof Outlet	12	Orange
(Humidity) F300	Blower Alarm	--	---	H18-19	9	Black
	Encoder Power	--	---	C32-34	3	Green
Differential Temperature Controller	5th C.R. Temp.	--	---	L1-2	} Cable to Basement	White Stripe
	Ambient Air	--	---	L3-4		
	Collector Plate	--	---	L5-6		
					15	Blue Orange
NOTES: ① A-G, Basement / M-L, Roof: See Figures 3-1/3-2 respectively.						
② Any Color Stripe means that color with a black stripe.						
Abbreviations: SDHWH - solar domestic hot water heater H.Ex. - heat exchanger						

TABLE NO. 3-4: INSTRUMENT CABLE CONNECTIONS TO JUNCTION BOX, DAS OR INDICATOR DEVICE

Item No.	Instrument Type	Quantity	Belden Wire*			Description of Hook-Up		
			Type No.	AWG Gage No.	Conductor No.	Belden Cable Details		Instrument
1	<u>Temperature</u> RTDs See Table 3-3 for specific units	40	9873	20	3 pairs	Pair No. 1:	Black/Red	Orange/Orange'
						Pair No. 2:	Black/White	Nothing
						Pair No. 3:	Black/Green	Orange/Orange'
2	<u>Flow Meters</u> Demand Loop Invalco, DAS 6	1	8422	22	2	Shielded	Clear, Black	Connector Adaptor
3	Solar Collection Loop Ramapo, DAS 25	1	8407	16	4	Shielded	White, Black, Red, Green	
4	Solar Collection Loop Ramapo, DAS 25	1	8761	22	2	Shielded Twisted	Black/Clear	
5	SDPHW Loop Flow Tech, DAS 58	1	8761	22	2	Shielded Twisted	Black/Clear	Connector Adaptor
6	Hersey, DAS 62	1	8428	18	2	Shielded	Black/Clear	
7	DHW, Gas Disc Encoder, DAS 63	1	8428	18	2	Shielded	Black/Clear	Black, White
8	Disc Encoder, DAS 63	1	8428	18	2	Shielded	Black/Clear	Red

Notes:

* The wire model numbers refer to those of Belden Corporation [50]

' Orange' represents orange with a black stripe

7 pair cables, #18 gage, connect junction box connections to DAS

TABLE NO. 3-4: INSTRUMENT CABLE CONNECTIONS TO JUNCTION BOX, DAS OR INDICATOR DEVICE (CONT'D)

Item No.	Instrument Type	Quantity	Selden Wire*			Description of Hook-Up		
			Type No.	AWG Gage No.	Conductor No.	Belden Cable Details	Instrument	
9	Furnace Fuel Conameter, DAS 35	1	8422	22	2	Shielded	Clear/Black	Connector Adaptor
10	Warm Air Gould, DAS 34	1	8760	18	2	Shielded	Black/Clear	
	<u>Temperature Difference</u>							
11	Thermopiles	2	8760	18	2	Shielded Twisted	Black/Trans	Brown-Yellow
	<u>Pressure</u>							
12	Pressure Transducer	2	8407	16	4	Shielded	White, Black Red, Green	Connector Adaptor
	<u>Climatological</u>							
13	Anemometer	1	8456	22	10		Black, White Red, Green Brown, Blue Orange, Yellow Purple, Gray	Connector Adapter
14	Total and Diffuse Insolation	2	83393	20	2	Shielded Twisted	Black, Red	
15	Humidity	1			5 pin DIN41524	No Shield	Connector Adapter	Brown, White Violet, Yellow Green
16	Barometer	1	9953	16	3	Shielded	White, Black Red	

Note: * The wire model numbers refer to those of Belden Corporation [50]

TABLE 3-5: STANDARD DESIGNATIONS FOR SENSORS & SUBSYSTEMS, [5]

Letter Designations

C = Specific Heat
 D = Direction or Position
 EE = Electric Energy
 EP = Electric Power
 F = Fuel Flow Rate
 I = Incident Solar Flux (Insolation)
 M = Performance Parameter
 P = Pressure
 PD = Differential Pressure
 Q = Thermal Energy
 T = Temperature
 TD = Differential Temperature
 V = Velocity
 W = Heat Transport Medium Mass Flow Rate
 TI = Time

Subsystem Designations

<u>Number Sequence</u>	<u>Subsystem/Data Group</u>
001 to 099	Climatological
100 to 199	Collector and Heat Transport
200 to 299	Thermal Storage
300 to 399	Hot Water
400 to 499	Space Heating
500 to 599	Space Cooling
600 to 699	Building/Load

TABLE 3-6: RTD SEQUENTIAL (SERIES) HOOK-UP ORDER FOR CURRENT SUPPLY LOOPS 1 & 2

SECTION 3.5

Sequence for Current Supply Loop No. 1				Sequence for Current Supply Loop No. 2			
Junction Box Position*	RTD No.	DAS Channel No.	RTD S/N	Junction Box Position*	RTD No.	DAS Channel No.	RTD S/N
G5	T207	47	4824	C5	T303	57	4797
G4	T300	54	4806	C4	T202	42	4819
G3	T109	11	4808	C3	T206	46	4826
G2	T601	36	4796	C2	T402	26	4794
G1	T404	29	4788	C1	T101	01	4805
F1	T210	50	4832	B1	T305	60	4790
F2	T209	49	4833	B2	T100	00	4782
F3	T204	44	4823	B3	T203	43	4829
F4	T403	27	4799	B4	T201	41	4831
F5	T400	22	4804	B5	T200	40	4828
E5	T212	52	4830	B7	T600	28	4815
E4	T302	56	4798	Δ	T603	38	4792
E3	T401	23	4781	Δ	T602	37	4807
E2	T304	59	4784	H8	T001	10	4810
E1	T211	51	4822	J3	T106	07	4791
D1	T102	02	4800	J2	T107	08	4783
D2	T213	53	4827	J1	T108	09	4802
D3	T205	45	4818	K3	T105	05	4786
D4	T301	55	4811	K2	T103	03	4787
D5	T208	48	4820	K1	T104	04	4813

NOTE: * A-G Basement Junction Box, N-L Roof Junction Box
 Δ Direct to DAS Pin Connection

TABLE 3-7: DECMRITER PRINTOUT DATA LAYOUT & IDENTIFICATION

0505 07 16:17:53	HR					
C000 T100 Out S.T.1	C001 T101 Out S.T.2	C002 T102 Out S.T.3	C003 T103 In 1st C.R.	C004 T104 In 2nd C.R.	C005 T105 In 3rd C.R.	
C006 W000 Demand Loop	C007 T106 In 4th C.R.	C008 T107 In 5th C.R.	C009 T108 Out 5th C.R.	C010 T001 Outdoor Air	C011 T109 In W100	
C012 I002 Diffuse Insola.	C013 I001 Total Insola.	C014 V001 N - S	C015 V002 E - W	C016 V003 Up-Down	C017 H001 Outdoor Humidity	
C018 P001 Barometer	C019 P101 In 1st C.R.	C020 P102 Out 5th C.R.	C021 EP000 Circulation	C022 T400 Demand Out S.T.3	C023 T401 Demand Out S.T.2	
C024 Short	C025 W100 Collector Loop	C026 T402 Demand In H. Ex.	C027 T403 Demand Out H. Ex.	C028 T600 Basement Air	C029 T404 Return Air	
C030 EP601 Demand Pump	C031 EP602 Warm Air Fan	C032 T0400 Air/H. Ex.	C033 T0401 Air/Furnace	C034 W407 Warm Air	C035 F400 Oil to Furnace	
C036 T601 1st Floor Air	C037 T602 2nd Floor Air	C038 T603 3rd Floor Air	C039 R1 Current loop #1	C040 T200 Profile S.T.2	C041 T201 Profile S.T.2	
C042 T202 Profile S.T.2	C043 T203 Profile S.T.2	C044 T204 Profile S.T.2	C045 T205 Profile S.T.2	C046 T206 Profile S.T.2	C047 T207 Profile S.T.1	
C048 T208 Profile S.T.1	C049 T209 Profile S.T.1	C050 T210 Profile S.T.1	C051 T211 Profile S.T.1	C052 T212 Profile S.T.1	C053 T213 Profile S.T.1	
C054 T300 SDHWH In	C055 T301 SDHWH Out S.T.3	C056 T302 SDHWH Out S.T.2	C057 T303 SDHWH Out S.Ts.	C058 W300 SDHWH	C059 T304 Out Gas Heater	
C060 T305 Out Tempering	C061 R2 Current loop #2	C062 W301 Temper. Supply	C063 F300 Gas to DHWH			

Key For Instrument Letter Designations

EP Electric Power
 F Fuel Flow Rate
 H Relative Humidity
 I Incident Solar Flux (Insolation)
 P Pressure

R Current Thru Standard Resistor
 T Temperature
 TD Differential Temperatures
 V Velocity
 W Heat Transport Medium Flow Rate

KEY FOR ABBREVIATIONS

S.T. - Storage Tank
 C.R. - Collector Row
 H. Ex. - Heat Exchanger

DHWH - Domestic Hot Water Heater
 SDHWH - Solar DHWH
 Insola. - Insolation
 Temper. - Tempering

TABLE 3-8:
ELAPSED TIME METER MODEL IDENTIFICATIONS & OVERALL SYSTEM
DISPLAY BOX LAMP ON REPRESENTATION

Engler 60 Hz A.C. Hour Meter Types, Model	Voltage	SOLENOIDS		Warm Air Fan	Demand Loop Pump	Solar Collection Pump	DHW Gas	Furnace Oil Burner
		S2 & S3	ST A-D					
11SG7*	115	✓	✓		✓			✓
21SG2	230			✓		✓		
91SG2	24						✓	
Overall System Display Box Lamp "ON" Designations		Power on Valves Closed (No Drain Down)		Motor On	Motor On	Motor On	Flame On	Motor On
Lamp Color		Red		Orange	Orange	Orange	Red	Red

* 200 Series

TABLE 4-1

NORMAL OPERATING SWITCH POSITION IDENTIFICATION FOR
BASEMENT CONTROL BOARD & VICINITY

Switch No.	Normal Position	Service Description	Notes (See Figure for location of Switches 1-10)
1	"Operate"	Differential Temperature Controller, C1	Power light is always on. Pump & frost lights are on as applicable
2	12	Differential Temperature Controller, C1 12-position Dial	Regulates temperature differential for starting collector circulation pump
3	80°F	Aquastat, C3: Storage Tank Temperature	As marked on temperature scale dial
4	"On"(Up)	Solenoid Valves S1-A,-B,-C &-D	Valves closed with power, "OFF" position opens valves to bypass flow upstream of collector rows 2-5
5	"Off"	Demand Pump 24v Bypass	"On" position automatically starts demand pump
6	2.2	Delay Circuit for Solenoid Valves S2 and S3	Adjustable dial to vary time
7	0.6	Delay Circuit for Demand Pump	Adjustable dial to vary time
8	Up(On)	Collector Circulation Pump Power	Circuit Breaker
9	Up(on)	Air Fan Power	Circuit Breaker
10	Up(on)	Demand Pump Power	Circuit Breaker
11	Up(on)	Furnace Emergency	Power on. In off position power to furnace is shut down. Switch located at top of stairs (1st floor) on left side when going down - opposite light switch.

TABLE 4-2: SHADOWBAND DECLINATION ANGLE SETTINGS FOR DIFFUSE INSOLATION METER

TABLE 4-2: SUN DECLINATION ANGLE, Degrees												
DAY	MONTH											
	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	-23.12	-17.30	-7.35	4.77	14.85	21.95	23.17	18.20	8.55	-2.90	-14.20	-21.68
2	-23.02	-17.00	-7.17	4.65	15.14	22.07	23.08	17.94	8.18	-3.29	-14.51	-21.82
3	-22.90	-16.71	-7.08	5.03	15.43	22.19	23.00	17.67	7.81	-3.67	-14.82	-21.95
4	-22.77	-16.41	-6.70	5.41	15.72	22.31	22.91	17.41	7.44	-4.06	-15.13	-22.09
5	-22.67	-16.11	-6.32	5.79	16.01	22.42	22.83	17.14	7.07	-4.44	-15.44	-22.22
6	-22.56	-15.81	-5.94	6.17	16.30	22.54	22.74	16.88	6.71	-4.83	-15.75	-22.36
7	-22.44	-15.52	-5.55	6.55	16.59	22.66	22.66	16.61	6.34	-5.22	-16.06	-22.50
8	-22.33	-15.22	-5.17	6.93	16.88	22.78	22.57	16.35	5.97	-5.60	-16.37	-22.63
9	-22.18	-14.89	-4.78	7.30	17.14	22.85	22.44	16.05	5.59	-5.98	-16.65	-22.72
10	-22.02	-14.56	-4.38	7.66	17.39	22.92	22.31	15.76	5.21	-6.36	-16.92	-22.80
11	-21.87	-14.23	-3.99	8.03	17.65	22.99	22.18	15.46	4.83	-6.73	-17.20	-22.89
12	-21.71	-13.91	-3.60	8.40	17.91	23.07	22.04	15.17	4.45	-7.11	-17.47	-22.97
13	-21.56	-13.58	-3.21	8.77	18.17	23.14	21.91	14.87	4.07	-7.49	-17.75	-23.06
14	-21.40	-13.25	-2.81	9.13	18.42	23.21	21.78	14.58	3.70	-7.87	-18.03	-23.15
15	-21.25	-12.92	-2.42	9.50	18.68	23.28	21.65	14.28	3.32	-8.25	-18.30	-23.23
16	-21.05	-12.57	-2.02	9.85	18.90	23.30	21.47	13.96	2.93	-8.61	-18.54	-23.26
17	-20.84	-12.21	-1.63	10.20	19.12	23.33	21.30	13.64	2.54	-8.98	-18.78	-23.29
18	-20.64	-11.86	-1.23	10.55	19.34	23.35	21.12	13.32	2.15	-9.34	-19.02	-23.32
19	-20.44	-11.51	-0.84	10.90	19.57	23.38	20.95	12.97	1.76	-9.71	-19.26	-23.36
20	-20.23	-11.16	-0.44	11.25	19.79	23.40	20.77	12.67	1.38	-10.07	-19.50	-23.39
21	-20.03	-10.80	-0.05	11.60	20.01	23.43	20.60	12.35	.99	-10.43	-19.74	-23.42
22	-19.83	-10.45	+0.35	11.95	20.23	23.45	20.42	12.03	.60	-10.80	-19.98	-23.45
23	-19.58	-10.08	+0.74	12.27	20.40	23.42	20.20	11.68	+0.21	-11.14	-20.17	-23.42
24	-19.32	-9.71	+1.13	12.59	20.57	23.39	19.98	11.33	-.18	-11.48	-20.36	-23.39
25	-19.07	-9.34	+1.53	12.92	20.75	23.36	19.75	10.99	-.57	-11.82	-20.55	-23.36
26	-18.82	-8.96	+1.92	13.24	20.92	23.33	19.53	10.64	-.96	-12.16	-20.74	-23.32
27	-18.57	-8.59	+2.31	13.56	21.09	23.29	19.31	10.29	-1.34	-12.50	-20.93	-23.29
28	-18.31	-8.22	+2.70	13.88	21.26	23.26	19.09	9.94	-1.73	-12.84	-21.11	-23.26
29	-18.06		+3.09	14.21	21.43	23.23	18.87	9.59	-2.12	-13.18	-21.30	-23.23
30	-17.81		+3.48	14.53	21.61	23.20	18.65	9.25	-2.51	-13.52	-21.49	-23.20
31	-17.55		+3.87		21.78		18.42	8.90		-13.86		-23.16

TABLE 4-3: DIFFUSE INSOLATION METER CORRECTION FACTORS

Shadow band corrective factors for average partly cloudy skies

Lat °N	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lat °S	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
0	1.17	1.21	1.24	1.22	1.19	1.16	1.17	1.20	1.23	1.21	1.19	1.16
10	1.15	1.19	1.23	1.23	1.20	1.18	1.19	1.21	1.23	1.20	1.16	1.14
20	1.13	1.16	1.21	1.23	1.21	1.19	1.20	1.21	1.22	1.18	1.14	1.12
30	1.11	1.14	1.19	1.22	1.21	1.20	1.21	1.21	1.20	1.15	1.12	1.10
40	1.09	1.12	1.17	1.20	1.21	1.20	1.21	1.21	1.18	1.13	1.10	1.08
50	1.07	1.10	1.14	1.18	1.20	1.20	1.20	1.19	1.15	1.11	1.08	1.06
60	1.05	1.07	1.11	1.15	1.19	1.20	1.19	1.17	1.13	1.09	1.06	1.04
70	-	1.05	1.08	1.13	1.18	1.21	1.19	1.14	1.11	1.06	1.04	-
80	-	-	1.06	1.11	1.19	1.22	1.20	1.14	1.09	1.04	-	-
90	-	-	1.05	1.11	1.20	1.23	1.21	1.15	1.07	-	-	-

The Eppley Laboratory, Inc.

Newport, Rhode Island

October 1966

TABLE 4-4: PROGRAMMING CONSTANTS STORED IN MEMORY BANK FILES 0 & 1 AND SAMPLE DATA SCAN

SYSTEM CONSTANTS FOR PROGRAM STORED IN FILE 0 (ZERO) OF MEMORY BANK

ID	Day	Hour	Minute	Seconds	
0512	18	15	03	03	HR
C***					00.00 MV
C000	3	0	.2	0	MV
C002	3	0	.2	0	MV
C004	3	0	.2	0	MV
C006	3	0	.1	0	MV
C008	3	0	.2	0	MV
C010	3	0	.2	0	MV
C012	3	0	.3	0	MV
C014	3	0	.1	0	MV
C016	3	0	.1	0	MV
C018	3	0	.1	0	MV
C020	3	0	.1	0	MV
C022	3	0	.2	0	MV
C024	3	0	.3	0	MV
C026	3	0	.2	0	MV
C028	3	0	.2	0	MV
C030	3	0	.1	0	MV
C032	3	0	.3	0	MV
C034	3	0	.2	0	MV
C036	3	0	.2	0	MV
C038	3	0	.2	0	MV
C040	3	0	.2	0	MV
C042	3	0	.2	0	MV
C044	3	0	.2	0	MV
C046	3	0	.2	0	MV
C048	3	0	.2	0	MV
C050	3	0	.2	0	MV
C052	3	0	.2	0	MV
C054	3	0	.2	0	MV
C056	3	0	.2	0	MV
C058	3	0	.1	0	MV
C060	3	0	.2	0	MV
C062	3	0	.1	0	MV

Reference channel
 Channel interval sec
 Channel pair
 Correction function code
 Input-Output code
 Units
 Units code
 Range code

SYSTEM CONSTANTS STORED IN FILE 1 (ONE) OF THE MEMORY BANK

0512	18	15	03	26	HR
C***					00.00 MV
C000	2	0	.2	0	MV
C002	2	0	.2	0	MV
C004	2	0	.2	0	MV
C006	2	0	.1	0	MV
C008	2	0	.2	0	MV
C010	2	0	.2	0	MV
C012	2	0	.3	0	MV
C014	2	0	.1	0	MV
C016	2	0	.1	0	MV
C018	2	0	.1	0	MV
C020	2	0	.1	0	MV
C022	2	0	.2	0	MV
C024	2	0	.3	0	MV
C026	2	0	.2	0	MV
C028	2	0	.2	0	MV
C030	2	0	.1	0	MV
C032	2	0	.3	0	MV
C034	2	0	.2	0	MV
C036	2	0	.2	0	MV
C038	2	0	.2	0	MV
C040	2	0	.2	0	MV
C042	2	0	.2	0	MV
C044	2	0	.2	0	MV
C046	2	0	.2	0	MV
C048	2	0	.2	0	MV
C050	2	0	.2	0	MV
C052	2	0	.2	0	MV
C054	2	0	.2	0	MV
C056	2	0	.2	0	MV
C058	2	0	.1	0	MV
C060	2	0	.2	0	MV
C062	2	0	.1	0	MV

SAMPLE DATA SCAN

0512	18	15	05	00	HR
C000	200.31	MV	C001	207.76	MV
C002	206.64	MV	C003	198.94	MV
C004	198.25	MV	C005	198.68	MV
C006	-0007.2	MV	C007	0198.9	MV
C008	198.75	MV	C009	197.88	MV
C010	-197.98	MV	C011	211.35	MV
C012	01.157	MV	C013	07.521	MV
C014	0047.4	MV	C015	-0073.8	MV
C016	-0001.7	MV	C017	-0435.0	MV
C018	-2447.4	MV	C019	0000.3	MV
C020	0001.4	MV	C021	0006.4	MV
C022	210.75	MV	C023	211.03	MV
C024	00.003	MV	C025	00.059	MV
C026	213.76	MV	C027	215.17	MV
C028	211.70	MV	C029	216.34	MV
C030	-0001.4	MV	C031	-2638.9	MV
C032	00.492	MV	C033	15.098	MV
C034	049.88	MV	C035	-265.61	MV
C036	215.28	MV	C037	217.46	MV
C038	218.16	MV	C039	-198.88	MV
C040	211.38	MV	C041	209.83	MV
C042	209.18	MV	C043	208.71	MV
C044	206.83	MV	C045	206.38	MV
C046	207.61	MV	C047	211.63	MV
C048	209.68	MV	C049	208.53	MV
C050	207.81	MV	C051	207.46	MV
C052	207.40	MV	C053	207.34	MV
C054	214.65	MV	C055	208.62	MV
C056	209.28	MV	C057	213.00	MV
C058	0004.2	MV	C059	0233.1	MV
C060	230.26	MV	C061	-200.08	MV
C062	0001.3	MV	C063	0165.4	MV

109

0612 19 15:08:22 HR																																			
C*** 00.00 H																																			
C000	0	0	.2	0	MV	C002	0	0	.2	0	MV	C004	0	0	.2	0	MV	C006	1	0	.1	0	MV	C008	0	0	.2	0	MV	C010	0	0	.2	0	MV
C012	0	0	.3	0	MV	C014	0	0	.1	0	MV	C016	0	0	.1	0	MV	C018	0	0	.1	0	MV	C020	0	0	.1	0	MV	C022	0	0	.2	0	MV
C024	1	0	.3	0	MV	C026	0	0	.2	0	MV	C028	0	0	.2	0	MV	C030	0	0	.1	0	MV	C032	0	0	.3	0	MV	C034	0	0	.2	0	MV
C036	0	0	.2	0	MV	C038	0	0	.2	0	MV	C040	0	0	.2	0	MV	C042	0	0	.2	0	MV	C044	0	0	.2	0	MV	C046	0	0	.2	0	MV
C048	0	0	.2	0	MV	C050	0	0	.2	0	MV	C052	0	0	.2	0	MV	C054	0	0	.2	0	MV	C056	0	0	.2	0	MV	C058	1	0	.1	0	MV
C060	0	0	.2	0	MV	C062	0	0	.1	0	MV	C064	0	0	.2	0	MV	C066	0	0	.2	0	MV	C068	0	0	.2	0	MV	C070	0	0	.2	0	MV
C072	0	0	.2	0	MV	C074	0	0	.2	0	MV	C076	0	0	.2	0	MV	C078	0	0	.2	0	MV												

C0612	-18.15408112 HR
C006	-0007.1 MV C007
	0199.0 MV C024
	-00.003 MV C025
	00.059 MV C058
	0004.1 MV C059
	0233.1 MV

FD-2054 SYSTEM CONFIGURATION	I-O TABLE	CORRECTION FUNCTION TABLE	RANGE TABLE	UNITS TABLE
	Code Input Output	Code CF	Code Range	Code Units
Power <u>120V 60Hz</u>	0 Analog SKIP	0 None	0	0 MV
Analog Channels <u>64</u>	1 Analog Device 1	1	1 4000 MV	1 V
Digital Channels	2 Analog Device 2	2	2 400 MV	2 OF
Output 1 <u>DECHRI TER</u>	3 Analog Devices 1 & 2	3 DIGITAL AVEs	3 40 MV	3 OC
Output 2 <u>MAG TAPE9832</u>	4 Digital SKIP	4 DUSCAN	4	4 PSI
Serial No. <u>990470A</u>	5 Digital Device 1	5	5	5 P/M
	6 Digital Device 2	6	6	6 R/M
	7 Digital Devices 1 & 2	7	7	7 P/S
	8 STOP SCAN	8 N/A	8 N/A	8 HZ
	9 STOP OUTPUT	9 N/A	9 N/A	9 HR

TABLE 5-1: TYPICAL MONTHLY MAINTENANCE SCHEDULE

Date	Month
1	Change ID, TIME & NEXT SCAN
2	Change Mag Tape: Solar # ____ Last Reading ____; Solar # ____ 1st Reading ____ Clean Tape Head & Roller Guides
3	
4-5	
6	Check Decwriter Paper Supply
7	
8	Change Decwriter Paper Supply, Change Decwriter Ribbon, Vacuum inside Decwrite As Convenient Check Flowmeter Calibration Ramapo @ Zero Flow Check DAS 39 & 61 for 200 ± 1 mv Reading
9	
10	
11-12	
13	
14	Change Mag Tape: Solar # ____ Last Reading ____; Solar # ____ 1st Reading ____
15	
16	
17	
18-19	
20	
21	
22	Check & Change as necessary Filter Elements Upstream of Demand System W400, SDHWS W300 & Fuel Oil F400 in conjunction with annual furnace cleaning.
23	Oil demand pump, Collector pump doesn't require oiling
24	
25-26	
27	Change Mag Tape: Solar# ____ Last Reading ____; Solar # ____ 1st Reading ____
28	
29	
30	
31	

TABLE 5-2: MAINTENANCE SCHEDULE FOR PUMPS, FANS, AIR CONDITIONER
& ASSOCIATED MOTORS

PUMPS, FANS & ASSOCIATED MOTORS					MAINTENANCE			
SYSTEM	ITEM	MANUFACTURER	MODEL	SIZE	ITEM	FREQUENCY	REF.	S/N
Solar Collection	Pump	Goulds	3642	1"	None Required		31 & 6	624-11846
	Motor	Marathon Elec.	CUJ56	2HP	None Required			—
	Demand Pump Motor (1)	Bell & Gosset Bell & Gosset	P941G		Every 4 months Every 4 months	Lubrication (2)	32 & 7	102208
Fuel Oil	Oil Burner	Wayne Home Equipment Co.	OEA		{ Clean & Check System	{ Annually- Regular Furnace Service	33	—
	Pump	Sunstrand	A1VA- 7012	3GPH				—
	Motor	Marathon Electric	EPM	1/12hp				48S17S113
Warm Air	Fan	Baldor	RL	1/2HP	Quarterly	Lubrication (3)	34	12442
	Motor		1304-A		Quarterly	Pulley System (4)		
Meteoro- logical	Fan Motor		443	14 w	None Required None Required			
DAS Room	Air Condi- tioner	Emerson	14EDIE-L	13,600 BTU/hr	Biweekly (5)	Clean Air Filter	30	862220
	Motor Condensor Coil				None Required Annually (6)	Clean Coil		

- Notes: (1) Built-in thermal overload protection
 (2) SAE #20 non-detergent motor oil, 1 oil cup on pump, two on motor
 (3) Mobilux EP-2 or Lithium base grease [34]
 (4) Alignment: Check for tightness the belt and pulley set screw to motor shaft
 (5) During cooling season-Wash in warm water and mild detergent, Rinse and shake dry.
 (6) Start of cooling season-Use soft brush or vacuum cleaner with brush attachment

TABLE 5-3: MAINTENANCE SCHEDULE FOR FILTERS AND STRAINERS

FILTERS & STRAINERS					MAINTENANCE		
SYSTEM	ITEM	MANUFACTURER	MODEL	SIZE	ITEM (1)	FREQUENCY	REF.
Demand	Filter	Carborundum	BRX20-	3/4	{ Every 4 months	(Change Element) W11R10G	35,37
SDHWH	Filter	Carborundum	BRX20-	3/4		W11R10G	35,37
Fuel Oil	Filter	Carborundum	B4		Annually (2)	E15R4	36,37
Warm Air	Filter	Owens/Corning		20x25x1	Quarterly	Fiberglass	
Solar Collector	Strainer (V100)			1-1/2	Monthly	Flush (3)	
	Strainer (V161)			1-1/2	Monthly	Flush	
Demand	Strainer (V400)			1	Monthly	Flush	
SDHWH	Strainer (V313)	Watts	223S	3/4	Annually	Flush	38

Notes: (1) Replace as necessary
 (2) During regular furnace service
 (3) Refer to flush procedure, Section 5.3

TABLE 5-4: MAINTENANCE SCHEDULE FOR
FLOW METERS & ASSOCIATED INDICATORS

FLOW METERS & ASSOCIATED INDICATORS						MAINTENANCE				
WATER	INSTR. DAS									
SYSTEM	NO.	NO.	MANUFACTURER	MODEL	SIZE	FREQUENCY	ITEM	REF	S/N (1)	
WATER										
Demand	W400	6	Invalco	W3/0750	3/4"	Annually	Inspect & Clean (2)	39		
			Invalco	W-370		Annually	Calibration	40		
Collector Loop	W100	25	Ramapo	Mark V-1	1"	Annually	Calibration	41		
			Ramapo	5GA-100B		Annually				
SDHW	W300	58	Flow Techno-	FT-10N15-LJ		Semi-Annually	Inspect & Clean (3)	42		
			logy							
			Flow Tech.	LFA300						43
			Action Pak	5070						
SDHW	W301	62	Hersey			None Required		44		
AIR										
Space Heat- ing	W407	34	Air Monitor Gould	FAN-E		None Required		45		
				590-10T-2Q8 VIX-41D		None Required		46		
OIL										
Space Heat- ing	F400	35	Conameter	13-101 Series	13	None Required		47		
GAS										
SDHW	F300	63	American Meter	AL-175		None Required		48		
			Disc, Rota- switch	Series 820		None Required		49		

NOTES: (1) Refer to Tables 3-1 for serial numbers

(2) Inspect internal parts for damage & wear. Clean with solvent (Rear rattle normal)

(3) Inspect internal parts for corrosion & fouling. Clean with solvent or alcohol.

TABLE 5-5: MAINTENANCE SCHEDULE FOR GLASS CLEANING

TABLE 5-5: GLASS CLEANING			MAINTENANCE		
ITEM	MANUFACTURER	MODEL	FREQUENCY	DESCRIPTION	REF.
Total Insolation	Eppley	PSP	Weekly	Wipe Hemisphere with lint free soft cloth. As necessary remove frozen snow, ice by using warm cloths.	26
Diffuse Insolation	Eppley	PSP with Shadowband	Weekly		
Thermoflo Balancer Flow Meters	Bell & Gossett	1" Size	As Necessary	Use glass cleaner and tube brush	23
Gage Glass			As Necessary	Use glass cleaner and tube brush	—
Solar Collector	International Environment Corp.	SolarTherm II	In general no cleaning necessary		
	Pittsburgh Plate Glass	Std. Copper Collector	In general no cleaning necessary		

TABLE 5-6: SPARE PARTS INVENTORY

<u>No.</u>	<u>COMPONENT</u>	<u>No. of UNITS</u>	<u>SPARE PART</u>
1	Relative Humidity, DAS # 17, H001 Weather Measure Corp.	(1)	Replacement Sensor Element HMP - 14UE, W/M No. 600252
2	Tempering Valve, V-309 Watts	(1)	Replacement Thermostat Assembly No. 70 A.
3	Flow Meter, DAS #6, W400 C.E. Invalco	(1)	Repair Kit 3/4" TFM w/carbide No. 81001904
4	Thermoflo-Balancer Flow Meters Bell & Gossett	(3)	Repair Kits, Glass & Spring Assembly No. 118822
		(4)	Glass No. G-91904
		(9)	Rubber Washers F-67200
5	Solenoid Control Valve Magnetrol	(1)	Model PTF - 18GR25, 1½"

FUSE LIST

<u>Quantity</u>	<u>Description</u>	<u>Manufacturer</u>	<u>Use</u>
3	6A 3AG (312)	Littel Fuse	Hawthorne Controller
5	4A AGC 4	Buss Fuses	Hawthorne Controller
*	3A 3AG (312)	Littel Fuse	Kennedy Tape Recorder
5	2A 3AG (312)	Littel Fuse	Spare
5	1A 3AG (312)	Littel Fuse	PD - 2064 DAS
4	1/2A 3AG (312)	Littel Fuse	Young Anemometer Indicator
8	1/4A 3AG (312)	Littel Fuse	Humidity Indicator
*	2A MDL 2	Buss Fuses	Decwriter
*	3A MDL 3	Buss Fuses	Decwriter
*	2/10 A	Micro Fuse	*Action-Pak" DVMs

* Items on order

FIGURE 2-1: OVERALL SYSTEM FLOW DIAGRAM

University of Pennsylvania SolaRow House - Philadelphia

FIGURE 2-2: COMFORT HEATING SYSTEM DIAGRAM: SOLAR COLLECTION, HEAT DEMAND & WARM AIR LOOPS

FIGURE 2-3: SOLAR DOMESTIC HOT WATER HEATING SYSTEM & THERMAL STORAGE SYSTEM DIAGRAM

FIGURE 2-4: THERMAL STORAGE TANKS (PRIOR TO INSULATION) AND ASSOCIATED PIPING PHOTOGRAPH

FIGURE 2-5: OVERALL VIEW OF COLLECTOR ROWS & ROOF LOCATION PHOTOGRAPH

FIGURE 2-6: SOLAR THERMAL STORAGE TANK DETAIL DRAWING

3642-3742 • Size 1" • 3500 RPM

Note: Pump Impeller diameter, 5 3/8"
2 hp motor yields 1.07 bhp

FIGURE 2-7: CIRCULATION PUMP PERFORMANCE CURVES, GOULD MODEL 3642
from [6] page 4

IRON AND BRONZE BOOSTER PUMP

*Performance characteristics are based on using 1½" or 1½" flanges. When using ¾" or 1" flanges performance will be slightly reduced.

DIMENSIONS & WEIGHTS

MODEL NO.	FLANGE SIZE - NPT INCHES (specify size)	STANDARD 60 CYCLE MOTOR CHARACTERISTICS (special motors available on request)			DIMENSIONS IN INCHES (open drip-proof)					*ELEC. BOX ARRGMT.	APPROX. SHPG. WT. LBS.	
		HP	"	VOLTAGE	A	B	C	D	E		IRON BODY	BRONZE
Series 100	¾	1/12			15	6½	12½	¾	—	1	26	26
	1 & 1¼							¾	—			
	1½							1½	—			
SC-75	Sweat	¼	1	115 With Built-in Overload Protection	16½	8½	13½	¾	—	1	40	40
	¾							¾	—			
	1 & 1¼							1½	—			
Series PR	1½	¾	1	115 With Built-in Overload Protection	16½	8½	13½	¾	—	1	36	39
	1							¾	—			
	1½ & 1½							¾	—			
Series HV	1	¾	1	115 With Built-in Overload Protection	16½	8½	13½	¾	—	1	45	49
	1½ & 1½							¾	—			
	1							¾	—			
Series 1½	1½ & 1½	¾	1	115 With Built-in Overload Protection	16½	8½	13½	¾	—	1	60	66
	1							¾	—			
	1½ & 1½							¾	—			
2	2	¾	1	115 With Built-in Overload Protection	17½	10	14½	¾	—	2*	75	78
	2½							¾	—			
	2½							¾	—			
LD3	2½	¾	1	115 With Built-in Overload Protection	18½	10	15½	1½	—	2*	78	84
	2½							1½	—			
	2½							1½	—			
HD3	2½	¾	1	115 With Built-in Overload Protection	18½	10	15½	1½	—	2*	82	91
	2½							1½	—			
	2½							1½	—			
PD35-S	2½	¾	1	115/230	20½	12	16½	1½	—	3	130	147
	2½							1½	—			
	2½							1½	—			
PD37-S	2½	¾	1	115/230	20½	12	17½	1½	—	3	132	149
	2½							1½	—			
	2½							1½	—			
PD37-T	2½	¾	1	208-230/460	20½	12	17½	1½	—	3	140	153
	2½							1½	—			
	2½							1½	—			
PD38-S	2½	¾	1	115/230	24	14½	19½	1½	—	4	145	158
	2½							1½	—			
	2½							1½	—			
PD38-T	2½	¾	1	208 or 230/460	24	14½	19½	1½	—	4	145	158
	2½							1½	—			
	2½							1½	—			
PD40-S	2½	¾	1	115/230	24	14½	20½	1½	—	4	145	158
	2½							1½	—			
	2½							1½	—			
PD40-T	2½	¾	1	208 or 230/460	25½	14½	20½	1½	—	4	145	158
	2½							1½	—			
	2½							1½	—			

*Fractional 3/8 motors are available with electrical box arrangement #3.

How to select a B&G Booster Pump

Required: 10 GPM at 6 ft. head. Look first at the bottom of the Booster Pump Capacity Chart where pump delivery is shown. Run a line straight upward from the 10 gallon point until it intersects a horizontal line from the 6 ft. head on scale at left. The nearest pump curve, or one slightly above this intersection is the proper selection. The Series 100 Booster pump should be used. It is not advisable to select a Booster pump with a head under 2½ ft.

FIGURE 2-8: DEMAND PUMP PERFORMANCE DATA, BELL & GOSSETT, SERIES PR

CERTIFIED CORRECT DIMENSIONS*

ON 2 ROW COIL
CONNECTIONS SHOWN FOR
AIR FLOW LEFT TO RIGHT.
FOR AIR FLOW RIGHT TO LEFT
ROTATE COIL 180°

TABLE 1 — 12, 15, 18, 21 and 24 Tube Face

Nominal Tube Length	3'-0"	3'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"
A	2'-4 1/2"	2'-10 1/2"	3'-4 1/2"	3'-10 1/2"	4'-4 1/2"	4'-10 1/2"	5'-4 1/2"	5'-10 1/2"	6'-4 1/2"	6'-10 1/2"	7'-4 1/2"	7'-10 1/2"	8'-4 1/2"	8'-10 1/2"	9'-4 1/2"	9'-10 1/2"	10'-4 1/2"
B	22 1/2"	28 1/2"	34 1/2"	40 1/2"	46 1/2"	52 1/2"	58 1/2"	64 1/2"	70 1/2"	76 1/2"	82 1/2"	88 1/2"	94 1/2"	100 1/2"	106 1/2"	112 1/2"	118 1/2"

TABLE 2

Tube Face	1 Row	2 Row	D
12	2 1/2"	2 1/2"	4 1/2"
15	2 1/2"	2 1/2"	3 1/2"
18	2 1/2"	2 1/2"	2 1/2"
21	2 1/2"	2 1/2"	4 1/2"
24	2 1/2"	2 1/2"	2 1/2"

Note: Standard 2 row coil is full circuit.
Standard 1 row coil is 1/2 circuit.
Coils can be used for horizontal or vertical airflow.
Install with casing level.
Hand not required—see note on end view for airflow.
Drain from bottom of both headers.

AEROFIN CORPORATION
LYNCHBURG, VIRGINIA

TITLE:
TYPE "CH" COILS FOR HOT WATER
1 & 2 Row—12, 15, 18, 21 & 24 T.F.

SCALE:

NONE

5-1-72

DWG. NO. CA-72-CH

*Actual dimensions are subject to AeroFin Coil fabrication tolerances and will approximate the design dimensions shown.

FIGURE 2-9: WATER TO AIR HEAT EXCHANGER COIL LAYOUT DRAWING

FIGURE 2-10: PHOTOGRAPH OF AIR BLOWER MOTOR & PULLEY DRIVE SYSTEM

FIGURE 2-11: PHOTOGRAPH OF SOLAR DOMESTIC HOT WATER HEAT EXCHANGER

FIGURE 2-12: COMFORT HEATING SYSTEM CONTROL WIRING DIAGRAM, [2] Fig. 7

FIGURE 2-13: BASEMENT CONTROL PANEL PHOTOGRAPH

Differential
Temperature
Controller, C-1
Hawthorne Model No.H-1506-A

120
V.A.C.

FIGURE 2-14: CONTROL SCHEMATIC FOR COLLECTOR CIRCULATION LOOP PUMP AND SOLENOID VALVES

BARBER-COLMAN TC-154

2 STAGE THERMOSTAT

(VIEW FROM REAR)

Located in 2nd Floor Hallway
Outside of DAS Room

BROWN CABLE

2nd Floor

Through Window in DAS Room

FIG. 2-16

Basement

To DEMAND
PUMP
CONTROL

FIG. 2-17

FURNACE

RESET
BUTTON

HOOK-UP
DETAILS ON
FIG. 2-20

Located at Rear of Furnace

NOTE: ▲ - Wire Not Hooked-up

FIGURE 2-15: THERMOSTAT WIRING DIAGRAM WITH CONNECTIONS TO DEMAND PUMP AND FURNACE

FIGURE 2-16: DAS ROOM OVERALL WIRING & EQUIPMENT LAYOUT

H. Two Stage Thermostats (units with one dial) —

Calibration is similar to the Duplex units described above except as follows

Figure 6

Duplex Thermostats: TA and TC 160 to 179. These thermostats have two adjusting dials which individually adjust the control point of each bimetal element. Each dial may be set at any control point within its scale range without affecting the control point of the other element.

Two-Stage Thermostats: TA and TC 150 to 159. These thermostats have a single adjusting dial which simultaneously adjusts the control points of both bimetal elements. The calibrating screw on the left hand element is used to set the differential between stages. See Calibration for factory differential settings.

Calibration: All thermostats are calibrated at the factory and normally will not require further attention. However, if recalibration ever becomes necessary, proceed as follows:

A. Duplex Thermostats (units with two dials)

1. Turn off power to thermostat. On thermostats with heaters, be sure they are deenergized also. See Figure 6.
2. Set both Dials at room temperature as determined by an accurate thermometer near the thermostat.
3. Remove thermostat cover (loosen two cover mounting screws, swing cover away from wall at bottom and unhook at top). Be careful not to affect the Bimetal Elements with heat from your hands or breath.
4. Remove Contact Covers. See Figure 6.
5. If Contact Blade is made to right (R) side, slowly turn Calibration Screw in CW until Blade makes to left (L) side. Use a 3/16" open end wrench. (Each complete turn of the screw changes calibration about 30 F° on pilot duty thermostats or 6 F° on motor control units.) Now turn Calibration Screw out very slowly (CCW) until Blade just makes right (R) side.
6. If Contact Blade is originally made to the left (L) side, turn Calibration Screw out slowly (CCW) until Element just makes the right (R) side. Repeat procedure for other element. Thermostat is now properly calibrated.
7. Replace Contact Cover and thermostat cover.
8. Recheck calibration about 30 minutes later.

Figure 7

1. Perform steps 1 through 4 as described above. See Figure 7.
2. Calibrate right hand Bimetal only as described in step 5 above for SPDT thermostat and step 6 above for SPST thermostat.
3. Temporarily replace cover (don't tighten cover screws) and reset adjustment dial an amount equal to

the desired differential between stages. See table below for factory settings of standard models. Note: Dial should be lowered on TC 153 and TC 154 thermostats used on heating/cooling applications and raised on TA 151 thermostat for two stage heating only applications. Note that these calibration instructions oppose one another due to the calibration of the SPST and SPDT thermostats.

4. Remove cover and calibrate left hand Bimetal as follows: If Contact Blade is made to right (R) side, turn Between Stage Differential Calibration Screw in (CW) until Blade makes to left (L) side. Now turn Screw very slowly out (CCW) until Blade just makes the right (R) side.
5. If left hand Contact Blade is originally made to left side (as on TA 151 units), turn Between Stage Differential Calibration Screw slowly out (CCW) until Blade just breaks contact.
6. Replace Contact Cover and thermostat cover and recheck calibration again about 30 minutes later.

Part Number	Differential Between Stages	Calibrate 2nd Stage Dial Change from Room Temp to	Application
TA 151	2 F°	2 F° Higher	Heating
TC 153		2 F° Lower	Heating & Cooling
TC 154			

Replacement Parts: When ordering replacement parts, give as complete a description of the part as possible together with the part number of the thermostat from which it is taken. For example, one cover for a TC 153 0.4 thermostat.

Barber-Colman Company
ENVIRONMENTAL SYSTEMS DIVISION

1300 Rock Street, Rockford, Illinois, USA, 61101

FIGURE 2-18: TWO STAGE THERMOSTAT DETAIL LAYOUT PHOTOGRAPH & SETTING INSTRUCTIONS FOR TC 154 FROM [12]

FIGURE 2-20: FURNACE CONTROL CIRCUIT DIAGRAM

FIGURE 2-21: MAKE-UP FEED VALVE, CONTROLLER C-5, DETAILS

MCDONNELL No. 25A

Make-up Water Feeder for Receiving Tanks

The McDonnell No. 25A is a dependable float-operated feeder used to add make-up water to condensate receiving tanks whenever necessary. Its use is in keeping with the accepted modern practice of mounting a McDonnell pump controller on the boiler to keep the boiler water line within the prescribed limits for maximum efficiency. The No. 25A makes sure there is an adequate minimum supply of water in the receiver at all times to answer any demand from the boiler.

The No. 25A is mounted right along side the receiving tank, and feeds water into it through a separate feed line. It combines large feeding capacity with heavy-duty construction to meet the rugged demands of receiver tank service. Triple-feature valve design assures positive seating, as illustrated at right. Valve stem seating area is made of high temperature composition, valve seat of monel. Valve is protected by a large strainer.

The bottom flange of this strainer housing has a removable plug. If feeder is mounted on receiver before shipment to job site, this plug permits draining water from housing after testing as a precaution against freezing; it can also be used afterward to clean out any dirt trapped by strainer.

Maximum Body Pressure, 35 psi.
Maximum Water Supply Pressure, 100 psi.

TRIPLE-FEATURE VALVE DESIGN

1. Cam and roller design provides straight thrust action.
2. Valve guides support valve stem at both top and bottom.
3. Stem articulates at seating area for positive valve closing.

Dimension Details No. 25A

MCDONNELL & MILLER **ITT**
3500 N. Spaulding Avenue, Chicago, Illinois 60618

FIGURE 3-1: BASEMENT JUNCTION BOX LAYOUT DETAILS

FIGURE 3-2: ROOF JUNCTION BOX LAYOUT DETAILS

NOTE: For lead wire color identification at terminal connectors, See Fig. 3-1.

NOTE: For lead wire color identification at terminal connectors, See Figure 3-2.

FIGURE 3-5: FUNCTIONAL ELEMENTS OF PD-2064 DATA SYSTEM, [18] FIG. 1-1

DAS CONSOLE

Decwriter-
Printer

Room
Air
Conditioner

FIGURE 3-6: DATA ACQUISITION SYSTEM CONSOLE PHOTOGRAPH

CONNECTOR NUMBER

FIGURE 3-7: DAS CONSOLE CONNECTOR & PIN HOOK-UP DIAGRAM

KEY	
B	BLUE
BK	BLACK
G	GREEN
O	ORANGE
R	RED
R'	RED WITH BLACK STRIPE
S	SILVER
T	TRANSPARENT
W	WHITE

FIGURE 3-8: TERMINAL STRIP CONNECTIONS IN DAS CONSOLE

FIGURE 3-9: PULSE ACCUMULATORS HOOK-UP DIAGRAM

FIGURE 3-10 ELAPSED TIME METERS CONNECTION BOARD DIAGRAM, DAS ROOM
(not to scale)

FIGURE 3-11 ELAPSED TIME METERS CONNECTION BOX DIAGRAM (BASEMENT CONTROL BOARD)

CALEX 415-215

THESE CONNECTIONS ARE PRE-WIRED;
 THEY ARE EXPOSED ON THE FRONT FACE OF
 THE MONITOR BOX FOR TEST PURPOSES ONLY.
 (REFER TO SCHEMATIC DIAGRAM FIG. 3-14).

FIGURE 3-12:

CONNECTION DIAGRAM OF DHWH FLAME
 DETECTOR & RELATIVE HUMIDITY FAN
 ALARM MONITOR BOX

FIGURE 3-13: PHOTOGRAPH OF DHWH FLAME DETECTOR
& RELATIVE HUMIDITY FAN ALARM
MONITOR BOX

*TEST SW	FUNCTION
"1"	makes green off & red on
"OPERATION"	normal operation
"2"	makes red off & green on
"FAN"	makes green off & red on

FIGURE 3-14:

SCHEMATIC DRAWING OF DHWH FLAME DETECTOR & RELATIVE HUMIDITY FAN ALARM CIRCUITS

FIGURE 4-1: FLOW RATE VERSUS MV/V EXCITATION
 RAMAPO FLOW METER, W100, DAS 25
 ⊙ IN SYSTEM FLOW CALIBRATION DATA 12/7/78 (U. of P.)

Figure 4-2: FLOW RATE VERSUS MILLIVOLTS

INVALCO FLOW METER, W400, DAS 6

MODEL No. W3/0750 : TURBINE TYPE

1.3 to 13 GPM }
.1 to 1 Volt } SOLID LINE

⊙ IIR SYSTEM FLOW CALIBRATION DATA 12/7/78 (U of P)

Figure 4-3: FLOW RATE VERSUS HERTZ

FLOW TECHNOLOGY, INC. FLOW METER, W300, DAS 58

MODEL No FT-10H15-LJ, SIZE 5/8 S/N 10229

♦ BALLISTIC FLOW CALIBRATION DATA 8/23/77 (By MFG.)

○ IN SYSTEM FLOW CALIBRATION DATA 12/7/78 (U of P)

153

FIGURE: 4-4: PHOTOGRAPH OF SHADOWBAND ASSEMBLY INSTALLATION,
September 12, 1979, 11 AM.

FIGURE 4-5: PHOTOGRAPH OF SHADOWBAND & SUPPORT STRUCTURE ASSEMBLY

FIGURE 4-6: SHADOWBAND BASEPLATE & SUPPORT STRUCTURE ASSEMBLY DRAWING

FULL SIZE SCALE

NOTES:

One side bar slot 12 7/32 & 4 1/2" dimension reduced to 4 9/32 to suit

Subdivision scale marks added in full size drawings

SIDE BAR DRAWING

FIGURE 4-7: SHADOWBAND DECLINATION ANGLE SCALE DRAWING AS SHOWN ON SIDE BAR

UVW INDICATOR-TRANSLATOR UNIT MODEL 27503

GENERAL ASSEMBLY & REPLACEMENT PARTS

R. M. YOUNG COMPANY

2801 AERO PARK DRIVE, TRAVERA CITY, MICHIGAN 49084

FIGURE 4-8: GENERAL ASSEMBLY DRAWING OF ANEMOMETER INDICATOR UNIT [28]

GILL UVW ANEMOMETER

MODEL 27004

CABLE & WIRING DIAGRAM

8/1/75

GENERATOR OUTPUT:
±500mV @1800 rpm (ALL SENSORS)
(ARMATURE RESISTANCE 32 OHMS)

NOTE: UNITS WITH 230V BLOWERS HAVE
NEUTRAL SIDE OF 115V RECEPTACLE
WIRED TO PIN B (FOR SUPPLY FROM
STEP DOWN TRANSFORMER).

SENSOR CABLE

BELDEN NO. 8456 (10 CONDUCTOR, 22 AWG)

FIGURE 4-9: ANEMOMETER CABLE & WIRING DIAGRAM [28]

FIGURE 4-10: SIMPLIFIED PROGRAMMING FLOW CHART -
from Fig. 3-2 of ref. [18], Sh. 2 of 2

END OF FILE PUSHBUTTON/INDICATOR

A momentary pushbutton, which is used to generate an end of file sequence before rewinding the tape if these commands are not generated from the customer interface.

ON LINE PUSHBUTTON/INDICATOR

A momentary pushbutton, which functions as alternate action. When first activated the tape unit is placed in an on-line condition; when the tape unit is on line it can be remotely selected and will be ready if tape is loaded to or past the load point. When activated again it takes the unit off line. The LED indicator is illuminated in the on-line condition. A short time lag is built in between closure and action to prevent accidental operation.

LOAD PUSHBUTTON/INDICATOR

The momentary pushbutton activates the reel servos (tensions tape) and starts the load sequence. The LED indicator is illuminated when the reel servos are activated and tape is tensioned.

REWIND PUSHBUTTON/INDICATOR

The momentary pushbutton activates a rewind operation. This control is enabled only when tape is tensioned and unit is off line. The LED indicator is illuminated during either a local or remote rewind operation.

WRITE STATUS INDICATOR

This indicator is illuminated whenever tape unit is on line, selected, and write status is selected.

DATA IN MEMORY INDICATOR

Illuminated whenever there is data in the memory which has not been transferred to tape.

WRITE ENABLE INDICATOR

Illuminated whenever a reel with a write enable ring is mounted on the supply (file) hub.

LOAD and REWIND pushbuttons are disabled when the tape unit is on line.

FIGURE 4-11: TAPE RECORDER CONTROLS AND INDICATORS [17] FIG. 1-4

TYPEWRITER KEYBOARD — LA36

The keyboard of the LA36 Series is built to a universally accepted standard — the office typewriter (ANSI standard). The key layout, stroke, and touch are familiar to any typist. This means that training and familiarization time can be kept to a minimum, and maximum throughput can be achieved quickly. DECwriter II's keyboard is user-proven, having undergone vigorous testing since the fall of 1973.

Three-key rollover protection is incorporated in the design to eliminate multiple-keying errors. Up to three keys can be depressed at one time but the input will be correct if one of the first two keys struck is released before the third.

Switches adjacent to the keyboard allow the operator to power-up, select transmission rate, choose on-line or local operation, half- or full-duplex operation, and to activate optional features. In the local mode DECwriter II functions as a typewriting device allowing operators to add information to the printout.

An optional 14-key numeric keypad is available for those applications that require extensive numeric data entry. The keypad fits in the keyboard bezel to the right of the main keys.

digital

DIGITAL EQUIPMENT CORPORATION

STANDARD FEATURES — LA36 KEYBOARD

- POWER-ON/OFF** — Turns power on or off.
- LINE/LOC** — Connects the LA36 to the host computer (LINE) or, when depressed in the locked position, to itself (LOCAL).
- FDX/HDX** — Selects either full-duplex or half-duplex (when depressed, in the locked position) with local copy operation.
- BAUD RATE** — Selects clock frequency for transmission/reception at one of the following rates:
 300 (normal) 30 characters/second at 10 bits/character
 150 15 characters/second at 10 bits/character
 110 10 characters/second at 11 bits/character
 For 300 BAUD operation:
 Depress and lock only the key labeled 300
 For 110 BAUD operation:
 Depress and lock only the key labeled 110
 For 150 BAUD operation:
 Depress and lock both keys
- CTRL** — In combination with other keys, causes some "control" (nonprinting) action to take place at the host computer. See Table I.
- ESC(SEL)** — Directs the host computer to treat the next received character as a command.
- TAB** — Directs the host computer to advance the print head the programmed number of spaces.
- LINE FEED** — Sends a line feed command in the data sent to the host computer.
- BACK SPACE** — Sends a BS code to the host computer. Moves the printed head one space to left in half-duplex mode.
- BREAK** — Causes reception of data from the host computer to be interrupted (in half-duplex operation).
- DELETE** — Transmits a DELETE code to host computer.
- RETURN** — Sends a carriage return command in the data sent to the host computer.
- REPEAT** — Repeats to the host computer any character being pressed simultaneously.
- CAPS LOCK** — Generates all upper-case characters plus numerals and eliminates lower-case alphas.

OPTIONAL FEATURES — LA36 KEYBOARD

- ALT CHAR SET** — When depressed and in the locked position selects the Alternate Character Set to be printed.
- CHAR SET LOCK** — When depressed in the locked position determines whether the operator or a remote device controls changes between ASCII and APL or other alternate character sets.
- STD/ALT CHARACTER SET** — These Light Emitting Diodes light to signify which character set has been selected. Either the one above STD or ALT will be illuminated.
- AUTO LF** — When depressed in the locked position AUTO LF inserts a local line feed after each carriage return whether typed locally or received from the host.
- HERE IS** — When depressed will send up to a 20 character message down the communication line.
- PAPER OUT** — Will light when the terminal is out of paper.
- DEVICE SELECT** — Will light when the terminal has been remotely selected to transmit. SELECT AVAIL will then be extinguished.
- SELECT AVAIL** — Will light when the terminal is available for remote selection.

FIGURE 4-12: DECWRITER KEY AND CONTROL LOCATIONS AND FUNCTIONS

FIGURE 4-13: INTERCONNECTING SYSTEMS FLOW DIAGRAM FOR FLOW METER CALIBRATION TESTING

DATA SHEET NO. 1: OVERVIEW OF OPERATIONS IN BASEMENT AREA

[illegible]

SECTION 4.1

[illegible]

DATA SHEET NO. 3: SOLAR COLLECTION LOOP OPERATIONAL PARAMETERS
Section 4.1.3.2

[illegible]

DATA SHEET NO. 4: COLLECTOR BALANCED FLOW DISTRIBUTION
Section 4.1.3.3

Total System Flow, W100 _____

Row No. _____

Date: _____

Initial

[illegible]

DATA SHEET NO. 5: DEMAND LOOP OPERATIONAL PARAMETERS
Section 4.1.3.5

[illegible]

DATA SHEET NO. 6: WARM AIR LOOP OPERATIONAL PARAMETERS
Section 4.1.3.6

[illegible]

DATA SHEET NO. 7: SDHWS OPERATIONAL PARAMETERS
Section 4.1.3.9

[illegible]

DATA SHEET NO. 8: TEMPERING VALVE TEMPERATURE SETTING
& MAKE-UP FEED VALVE OPERATION

SECTIONS 4.1.3.10, 4.1.3.13

Section 4.1.3.10

Date	Time	Tempering Valve	Outlet DHWH Temperature		Flow Initiation	Initial
		Temp. Setting °F	T304	T305	W301	

Section 4.1.3.13

Date	Time	Gage Glass Level			Indicator System	Reading L-200		Initial
		One	Both	None		Make-up Flow		
					Drained	Starts	Stops

DATA SHEET NO. 9: THERMOSTAT DATA

Section 4.1.5.6

[illegible]

DATA SHEET NO. 10: CORRELATION OF THERMOSTAT DATA WITH
INTERFACING UNITS, Section 4.7.5.5

[illegible]

SECTION 4.2.1

[illegible]

NOTE: * As viewed facing front of meter

176

Water Density:

[illegible]

*8.341 lb/gal based on water density of 67.4 lbs/ft³

▲ Avg. mv - average millivolts determined from decwriter printout values

APPENDIX B: DETAILED WIRING DIAGRAMS

WIRING DIAGRAM NO. 1: TYPICAL RTD CIRCUITRY, DAS CHANNEL 0, ETC.

WIRING DIAGRAM NO. 2:
INVALCO FLOW METER, W400, DAS CHANNEL 6

WIRING DIAGRAM NO. 3:
OUTSIDE AIR TEMPERATURE RTD, T001, DAS CHANNEL 10

WIRING DIAGRAM NO. 4:

TOTAL INSOLATION, I001 & DIFFUSE INSOLATION, I002, PYRONOMETERS, DAS CHANNELS 13 AND 12.

WIRING DIAGRAM NO. 5:

WIND SPEED U, V, W ANEMOMETER, V001 N-S, V002 E-W & V003 UP-DOWN DAS CHANNELS 14-16.

WIRING DIAGRAM NO. 6:
RELATIVE HUMIDITY, H001, DAS CHANNEL 17

WIRING DIAGRAM NO. 7:
BAROMETER, H001, DAS CHANNEL 18

WIRING DIAGRAM NO. 8: PRESSURE TRANSDUCERS, P101 & P102, DAS CHANNELS 19 & 20

WIRING DIAGRAM NO. 9: RAMAPO MARK V FLOW METER, W100, DAS CHANNEL 25

THERMOPILE ACROSS AIR HEAT EXCHANGER & AIR HEATING FURNACE

DAS CHANNEL 32, TD 400
(DAS CHANNEL 33, TD 401)

NOTE: ALL DESIGNATIONS IN PARENTHESIS
IS FOR TD 401, CHANNEL 33

WIRING DIAGRAM NO. 10:

THERMOPILES ACROSS AIR HEAT EXCHANGER & AIR HEATING
FURNACE, TD 400 & TD 401, DAS CHANNELS 32 & 33

WIRING DIAGRAM NO. 11:

GOULD BAROCEL WARM AIR FLOW, W407, DAS CHANNEL 34

WIRING DIAGRAM NO. 12: CONAMETER FUEL FLOW METER, F400, DAS CHANNEL 35

WIRING DIAGRAM NO. 13: FLOW TECHNOLOGY FLOW METER, W300, DAS CHANNEL 58

APPENDIX C: EQUIPMENT SUPPLIER CATALOG

EQUIPMENT SUPPLIER CATALOG

COMPANY INFORMATION

1 of 4

NAME	ADDRESS	TELEPHONE NO.	SALESMAN/ENGR. ASSISTANCE
AGM Electronics Inc. Pulse Accumulator	P.O. Box 6089 Tucson, AZ 85733	(602)795-4000	John Vermaes Dave Nelson
Action Instruments Co., Inc. Action Pak-Flow Meter, GPM & Press. Reading, PSI (Local Rep: Powell Pendergraph)	8601 Aero Drive San Diego, CA 92123	(714)279-5726 (215)657-0330	Scott Bradfield/ Bruce Fuller, Customer Serv. Jerry Bessey
Airco Welders Supply MAPP Industrial Gas	4501 N. Howard Street Philadelphia, PA	(215)DA9-0350	
Arbonite Corporation Storage Tank Lining	P. O. Box 888 Doylestown, PA 18901	(215)348-2950 (215)343-0242	Ralph L. Terry
Barber Colman 2 Stage Thermostat	4667 C Sumnerton Road Trevose, PA 19047	(215)322-8400	Frank Hopkins
188 Bell & Howell CEC Division	360 N. Sierra Madre Villa Pasadena, CA 91109	(213)796-9381	Bob Hull/Repair Dept.
Bell & Howell Local Representative	5 Perina Boulevard Cherry Hill, NJ 08034	(609)424-4416 (215)922-0564	Joseph W. Ashley
R. D. Bitzer Company Thermoflo Balancer Flow Meter, 1" Size, Bell & Gossett	1330 Willow Avenue Melrose Park Philadelphia, PA 19126	(215)224-2112	John Nowak
Bradford-White Corporation BWHH	24th & Ellsworth Streets Philadelphia, PA 19146	(215)PE5-6250	J. Bonocore, Service Manager

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NAME	ADDRESS	TELEPHONE NO.	SALESMAN/ENGR. ASSISTANCE
Cole-Parmer Nalgene Tank with spigot & cover	7425 North Oak Park Ave. Chicago, IL	1-(800)323-4340	Joann McGowen
Delva Associates, Inc. Magnetic tape	2274 Jenkintown Road Glenside, PA 19038	(215)WA7-4348	Frank Sweich
Digital Accessories & Supplies Decwriter Supplies	Cotton Road Nashua, NH 03060	1(800)258-1710	
Elbow Industrial Supply Company Miscellaneous fittings & valves McDonnell & Miller Make-up Feed Valve No. 25A Watts Tempering Valve No. 70A	305 North 6th Street Philadelphia, PA 19106	(215)WA5-7720	George P. Devers/Bernie Gross Peter J. McCann
L. C. Electric A/C installation		(215)425-1754	Don Thompson Lou Carpenter
Electronic Marketing Assoc., Inc. Kennedy Magnetic Tape Recorder: APR, Auto Power Restart	11716 Parklawn Drive Rockville, MA	(301)881-5300	Martin F. Hooper, Serv. Mgr.
Electronic Marketing Assoc., Inc. Kennedy Magnetic Tape Recorder Flow Tech. Flowmeter & Indicator	210 Goddard Boulevard King of Prussia, PA 19406	(215)248-5050(PHila) or (215)265-1600(K of P) or (215)828-7400(Conshohocken)	Ed Birochak
Esterline Angus Corporation PD-2064 DAS Pulse Accumulator	P.O. Box 24000 Indianapolis, IN 46224	(317)244-7611 (317)244-7611	Greg Harker Dave Burns
Esterline Angus Corporation (local rep.) Pulse Accumulator	Gwynedd Plaza, Beth. Pike Springhouse, PA 19477	(215)628-4211	E. P. Adams, Sales Engineer John Kondrach, Service Engineer

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COMPANY INFORMATION

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NAME	ADDRESS	TELEPHONE NO.	SALESMAN/ENGR. ASSISTANCE
John Hack Company, Inc.	P.O. Box 339 Woodbury, NJ	(215)845-2700 (215)WA5-3605	James A. DeSantis, Jr. Nevin Trach
Hawthorne Industries, Inc. Solar Energy Division	3114 Tuxedo Avenue W. Palm Beach, FL 33405	(800)327-7300 (305)684-8400	Mr. J. B. Carr
Herbach & Rademan, Incorporated	401 East Erie Avenue Philadelphia, PA 19131	(215)426-1700	
Leecraft Mfg. Co., Inc. Indicator Lights			
C. E. Invalco Invalco Flow Meter Local Rep: Test Equipment Sales Company	1305 N. Louisville Tulsa, OK 74115	(918)932-5671 X122 (215)379-5431	Steve Mathews Jeff Randolph, Engr/ Carolyn Zabel/Dave Hoad Bob Frankhouser
Kennedy Company APR costs (Local Rep: Electronic Marketing Assoc., Inc.)	540 West Woodbury Road Altadena, CA	(213)798-0953	Dale Fink
Kunkel Oil	638 Market Street Upper Darby, PA	(215)476-9400	
Magnetrol Valve Corporation Solenoid valves	67 Fifth Avenue, P.O.Box 17 Hawthorne, NJ 07507	(201)427-4341	Raymond A. Kretschmer
Pace Associates, Inc. Relative Humidity Indicator	1750 Costner Circle Paul Valley Industrial Park Warrington, PA 18976	(215)343-1781	Herb Pollack

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COMPANY INFORMATION

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NAME	ADDRESS	TELEPHONE NO.	SALESMAN/ENGR. ASSISTANCE
Pacor Incorporated Insulation material	P.O. Box 3549 Philadelphia, PA 19122	(215)978-1900	C. Finnegan
Parker Brass Tube Fittings & Valves	649 Long Lane Upper Darby, PA	(215)SA7-3000	J. S. Aber
Philadelphia Electric Company Watt transducers (SCI)	23rd & Market Streets Philadelphia, PA 19103	(215)841-4899	Jack Howsare
Powell Pendergraph Inc. Digital Indicator (Local Rep: Action Instruments)	801 Easton Road Willow Grove, PA 19090	(215)657-0330	Jerry Bessey
191 Ramapo Instrument Co., Inc. Ramapo Flow Meters (Local Rep: Stover Assoc.)	2 Mars Court, P.O. Box 428 Montville, NJ 07045	(201)263-8800	Garry Anderson/Larry Killian
Singer-American Meter Division Gas Flow Meter, DHWH	13500 Philmont Avenue Philadelphia, PA 19116	(215)673-2100	John P. O'Hara, Sales Mgr.
James R. Stover & Assoc., Inc. Ramapo Flow Meter	P.O. Box 4 Quakertown, PA 18951	(215)538-0106	
Test Equipment Sales Company Invalco Flow Meter	P.O. Box 142 Cheltenham, PA	(215)379-5431	Herb Hawkins
R.M. Young Company Wind Anemometer	2801 Aero-Park Drive Traverse City, MI 49684	(616) 946-3980	David G. Kipley, Joan Campbell Bob Young
Weather Measure Corporation Relative Humidity Indicator	3213 Orangegroove Avenue N. Highlands, CA 95660	(800)824-5811 (916)481-7565	Walt Stewart, Bill Galvin Joan Schmitt X258 (ship.info.)