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**PADONIA ELEMENTARY SCHOOL SOLAR HEATING AND
COOLING PROJECT**

Final Report

August 1979

Work Performed Under Contract No. EY-76-C-02-2738

**AAI Corporation
Baltimore, Maryland**

MASTER

U.S. Department of Energy

Solar Energy

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SOLAR CONCENTRATOR
ON
PADONIA ELEMENTARY SCHOOL

AAI Corporation
P.O. Box 6767
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FINAL REPORT

August 1979

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Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the United States Department of Energy.

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I. INTRODUCTION

AAI Corporation was selected by the U.S. Department of Energy to develop a Solar Heating and Cooling System and to install it on the Padonia Elementary School. AAI Corporation installed the system with the permission of the Baltimore County Board of Education. The artist's sketch in figure 1-1 presents an overall view of the installation. Figure 1-2 shows the system with all three collectors in focus.

This report describes the Padonia Installation, its Operational Procedures and Maintenance Requirements.

The System Design and Performance data are presented in appendices A and B. Operational Logic and Construction Drawings are presented in appendices C and E.

Appendix D lists the E-Cube computer run to determine the heating and cooling requirements for the Padonia Elementary Cafetorium, Library, and Administrative Suite.

Figure 1-1. 8/1 Solar Concentrator on Padonia Elementary School

Figure 1-2. Padonia Elementary School Solar Concentrator
With 3 Collectors in Focus

A Corporation

II. SOLAR HEATING AND COOLING SYSTEMS

A. Description

The solar heating and cooling system installed in the Padonia Elementary School utilizes solar collectors (concentrating type) to collect radiant energy from the sun and transfer it to the cafetorium, library, and administrative suite of the school for space heating and cooling. This arrangement requires the solar piping circuits to be hydraulically interfaced with the school's existing system, as shown on AAI Drawing 57607-40032. This allows utilization of the existing distribution units (MZ-1 and MZ-2) and the automatic temperature controls which serve those areas. If the solar system cannot meet the school's energy requirements, or in the event of a solar system malfunction, the school's system is automatically programmed to supply the energy for that portion of the building.

The system collects energy by pumping the cooler water from the bottom of the hot water storage tank to the solar heated collectors and returning the water thus heated to the top of the hot water tank. The heated water is then pumped from the storage tank or directly from the collectors through the school's hot water distribution units (MZ-1 and MZ-2) which transfer the energy by conditioned air to the school areas.

Cooling is accomplished by utilizing the solar heated water to power the absorption type chiller. The chill water output of the chiller is also interfaced with the school's distribution system.

1. General Arrangement (see Appendix E DWG 57607-40032)

The solar concentrator system consists of the following elements:

- o roof-top reflector - 3400 ft.²
- o collector - 350 ft.²
- o collector control mechanism
- o a heating and cooling system including an absorption chiller and hot and chill water storage
- o instrumentation and controls

2. Reflector (see Appendix E DWG 57607-40169 & 57607-40201)

The reflectors mounted on the roof are second-surface reflective glass mirror 0.100 inch thick, 4 feet long and 2 feet wide. The back of the mirror is coated with a thick coating of silver which is covered with layers of copper, tin, lead, and epoxy to protect the silver. The mirrors are mounted on the roof decking. The curvature of the deck is determined by the trusses (see figures 2-1 & 2-2). Two layers of asphalt building paper are laid over the wood decking to act as a cushion for the glass. The sheets of glass are secured to the building paper with an adhesive, (see figures 2-3 & 2-4). Metal hold-down strips mechanically ensure that the glass stays in place.

3. Collector

The collector is a movable container for selective coated copper pipes containing water. A heavy layer of fiberglass insulation behind and on the sides of the pipes reduces the heat loss. The insulation can

Figure 2-1. Wood Trusses and Collector Support Arms

Figure 2-2. Wood Deck Conforming to Truss Curvature

Figure 2-3. Wood Deck Covered with Asphalt Paper
Before Installing Glass Mirrors.

withstand 1000°F without degradation. A single glass cover is mounted beneath the pipes. An aluminum channel structure supports the long span of pipes. (See figure 2-5).

The collector consists of three sections, each independently driven and controlled. The physical movement of each section is accomplished by a motor driven screw jack capable of rotating the section thru 90 degrees. For safety reasons, each screw-jack motor is equipped with an integral brake and a separate hydraulic damper system to restrain the motion of the collector arms. (See figure 2-6, and Appendix E DWG 57607-40079).

Temperature sensors are mounted on the back side of the collector tubes. An electronic sun-sensing control mechanism is also mounted to each section of the collector. Movement of the collector is accomplished when the proper signal (forward or reverse) is received from the sun-sensing unit. The sun's position is checked every 30 seconds by the sun-sensing unit.

4. Collector Control System

The control system for the solar concentrator controls two basic functions:

1. The control of the water as a collection and transfer medium for capture and retention of solar heat energy.
2. The control of the three movable collector structures for proper positioning to obtain maximum concentration of the reflected rays of the sun.

The collection and storage of solar heat energy is dependent

Figure 2-4. Glass Mirrors and Retaining Strips Installed

Figure 2-5. View Showing Collector with Selective Coated Copper Tubing. (Single Glazing Removed.)

Corporation

Figure 2-6. Collector Drive Mechanism, Motor Driven Screw Jack With Brake Plus Hydraulic Damper for Additional Safety

on the presence of sufficient reflected solar radiation. The temperature of the tubing must be higher than the temperature of the water in the storage tank in order to collect heat by pumping water thru the tubing. A positive temperature differential (temperature of tubing higher than temperature of water in storage tank) with a factor for losses, initiates the pumping of water through the collector tubing. The control logic also requires the outlet water temperature from the collector to be greater than the inlet water temperature (storage tank temperature) in order to achieve an increase in the energy collected.

To monitor the temperature of the collector tubing, four surface temperature sensors are mounted at various locations along the collector length. The outlet water temperature from the collector is monitored by immersion type temperature sensors in the hot water return line.

A manual override of the collector pivot mechanism is utilized for manual positioning for check-out and testing, and for maintenance of the collector.

5. Instrumentation Room (See Appendix E DWG 57607-40039)

The instrumentation room houses the control console and instrumentation, the absorption chiller, the electrical power panel, the Johnson control panel, compressed air tank, hydraulic pumps, valves, and plumbing representing the heart of the hydronic system. (See Figures 2-7, 2-8, 2-9, 2-10, and 2-11).

All the water to and from the collectors, the cooling tower,

and the school is routed through this room.

A spiral staircase provides access to the roof deck from inside the instrumentation room.

Lighting is provided to view the underside of the roof deck, its trusses, and other construction features.

The majority of temperature sensors for the various piping flows, their flow meters, and flow switches are all located within the confines of this room. This provides easy accessibility for service and maintenance.

6. Heating and Cooling Equipment

a. General

The existing heating and air-conditioning system of the Padonia School consists of the following elements:

- o a hot water heating system using an oil-fired boiler
- o an electrically powered gas compression type air-conditioner
- o an integrated piping system for supplying either hot or cold water to the various heating/cooling unit ventilators throughout the building
- o an automatic dual temperature control system

Figure 2-7 . Solar System Control Console
Located in Instrumentation Room

Figure 2-8. Solar System Electrical Power
& Pneumatic Control Panels

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Figure 2-9. Internal View of Pneumatic Control Panel
For Johnson Control Valves

Figure 2-10. Internal View of Cabinet With Watt Transducers

Figure 2-11. Pumps and Flow Control Valves in Instrumentation Room

The Solar Concentrating System has been added to provide a supplementary source of energy for heating and cooling. The equipment for the solar heating and cooling subsystem is located in the instrumentation room. The heating equipment consists of the space heating piping circuits, controls, and pump interconnected with the hot water storage tank/collector and the school's existing multi-zone units #1 and #2. The cooling system consists of the piping circuits, pumps, hot water absorption chiller, and cooling tower. (See figures 2-12, & 2-13. Figure 2-14 presents the specifications for the MODEL WFB 300 Chiller).

The hot water input to the chiller is interconnected with the hot water storage tank/collector. The chill water output from the chiller is interconnected with the (1) chill water storage tank and (2) the school's existing MZ-1 and MZ-2 units. The cooling tower is installed on the collector mounting structure which is located on the roof of the school. (See figure 2-15).

The thermal energy storage tanks are located underground just south of the music room and recreation equipment storage area. The two tanks are steel, pressure tanks of 10,000 gallon capacity and insulated with 6 inches of polyurethane foam. The plumbing connections are located in an underground vault from where they run underground to the instrumentation room. One tank is utilized for hot water and the other tank is used for chill water storage. (See figure 2-12).

Corporation

Figure 2-12. Underground Insulated Storage Tanks & Vault
For Storage Tank Plumbing

Arkla Corporation

Figure 2-13. Arkla Absorption Chiller
Model WFB-300 (25 ton)

SPECIFICATIONS

MODEL WFB 300 (Absorption Chiller)

DESIGN DELIVERED CAPACITY, Btu/h..... 306,000¹

DESIGN DELIVERED CAPACITY, Tons I.M.E..... 25.5¹

ENERGY REQUIREMENTS

Design Hot Water Input, Btu/h..... 447,000
 Design Hot Water Inlet Temperature, °F..... 195
 Design Hot Water Outlet Temperature, °F..... 184.8
 Permissible Range of Inlet Temp..... 160 to 200
 Design Hot Water Flow, gpm..... 90
 Pressure Drop, Feet of Water, at 90 gpm..... 20.7
 Permissible Range of Flow, gpm..... 50 to 100
 Pressure Drop, Feet of Water, at 100 gpm..... 25.6
 Maximum Working Pressure, psig..... 100
 Electrical Voltage, 60 Hz, 1 Phase..... 115²
 Maximum Wattage Draw..... 150

CHILLED WATER DATA

Design Inlet Temperature, °F..... 55
 Design Outlet Temperature, °F..... 45
 Design Flow, gpm..... 60
 Pressure Drop, Feet of Water, at 60 gpm..... 9.8
 Permissible Range of Flow, gpm..... 30 to 100
 Pressure Drop, Feet of Water, at 100 gpm..... 26.9
 Maximum Working Pressure, psig..... 100
 Unit Water Volume, Gallons, Approx..... 12
 Fouling Factor..... .0005

CONDENSING WATER DATA

Design Heat Rejection, Btu/h..... 753,000
 Design Inlet Temperature, °F..... 85
 Design Outlet Temperature, °F..... 101.7
 Permissible Range of Inlet Temp..... 75 to 90
 Design Flow, gpm..... 90
 Pressure Drop, Feet of Water, at 90 gpm..... 22.9
 Permissible Range of Flow, gpm..... 50 to 110
 Pressure Drop, Feet of Water, at 110 gpm..... 33.5
 Maximum Working Pressure, psig..... 100
 Unit Water Volume, Gallons, Approx..... 20
 Fouling Factor..... .001

FOR COOLING TOWER SELECTION

Maximum Heat Rejection, Btu/h..... 853,000
 Range, °F..... 16 to 17
 Minimum Permissible Sump Temperature, °F..... 75³

SERVICE CONNECTIONS

Hot Water Inlet and Outlet..... 2" FPT
 Chilled Water Inlet and Outlet..... 2½" FPT
 Condensing Water Inlet and Outlet..... 2½" FPT

PHYSICAL DATA, APPROXIMATES

Operating Weight, Pounds..... 3,420⁴
 Shipping Weight, Pounds..... 3,145⁵
 Crated Size, Inches..... 114 W, 45 D, 69 H

- NOTES:** 1. Capacity at design conditions.
 2. Units equipped for operation on 230V-50Hz-1Ph available on special order.
 3. Thermostatic switch to control tower fan **MUST** be used. Set to "cut out" at 75°F.
 4. Includes circulating water weights.
 5. Units as shipped contain Lithium Bromide charge.

DIMENSIONAL VIEWS

WFB 300
2-20

FIGURE 2-14

Figure 2-15. Cooling Tower, Baltimore Aircoil Inc.
Model J0605 B-18

Corporation

7. Sprinkler System

A sprinkler system is installed underneath the deck to protect the wood trusses and deck from fire.

This system was installed in accordance with Baltimore County Fire Department Regulations.

The water supply originates in the school's boiler room where the control valves and pressurizing equipment are installed.

The plumbing is routed to the instrumentation room from where it radiates to the east and west wings of the deck. The sprinklers are positioned to properly protect the underside of the deck and the individual trusses.

In case of fire, the system can later be drained through a gate valve located near the ceiling at the northern wall of the instrumentation room.

Corporation

III SYSTEM OPERATING PROCEDURES

A. Solar Collection/Hot Water Storage System

The control system is designed to provide automatic operation with a manual override to allow for service and maintenance. The controls are located on the System Control Panel located in the equipment room (see Figure 3-1).

The solar concentrator is put into operation as follows:

1. Check that Main Power is "ON" to the Control Console. The panel contains separate power switches for the collector screw jack motors and for instrumentation in the control console. (The circuit breakers are located on the Electrical Power Panel.) See Figure 2-8.
2. Check to see that the console power switches for the screw jack motors and instrumentation are also "ON". These are located at rear of console (see Figure 3-2), also the three "Overload" circuit breakers (one for each collector) must be "ON". These are located underneath the counter top at the front of the console. See Figure 2-7.
3. The compressed air light must be "OFF" indicating availability of compressed air to operate the control valves. (System Monitor Panel Figure 3-3.)
4. Check the water level of the storage tank by observing the water level alarm lights on the control panel. This can also be checked manually at sight gauges located in the valve pit or vault.
5. Focus Collectors #1, #2, and #3.

a. Place the Sun Tracker switch of each collector to the "AUTO" position. Observe the Sun Tracker indicator lights. The collector moves in the direction of the light that is "ON". When neither the "NORTH" or "SOUTH" light is "ON", the collector is normally in focus.

The indicator lights marked "LIMIT" will light up when the collector is either extreme "NORTH" or extreme "SOUTH". If the collectors activate either of these limits, the power to the screw jack motors is cut off. The sun tracker will automatically back off the stops if the solar focus is anywhere between the north and south limits.

6. Place the collector pump control switch to "AUTO"

CAUTION - The collector pump control switch must be on "AUTO" (not manual) when the collectors are in focus or they will "overheat" for lack of water flow. This will activate an "overheat" circuit which automatically defocuses the collectors. If any collector "overheats", the "overheat" button on the control panel lights up indicating that the collector is defocused to prevent damage. Once the cause of overheating is determined and corrected, the collector can be focused by resetting the "overheat" button on the control panel.

7. The collector pump will start when the pump control "Command" light goes "ON".

Note: The command light goes on when the collector surface temperatures (Dry-no flow) are at least 10°F above the temperature of the bottom of the hot water storage tank. The pump will run for a predetermined 5 minutes until the system temperature is stabilized. A differential temperature between the flow into and out of the collectors of 3°F is necessary after that for the pump to continue running.

8. The "Collection System" flows are displayed on the system flow panel (see Figure 3-3). The schematic display includes indicator lights that light up as flow begins. There is an indicator light in the return line of each

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Figure 3-1. System Control Panel(Instrumentation Room)

Corporation

Figure 3-2. Power Switches For Instrumentation
& Collectors(Control Console)

Figure 3-3. System Monitor Panel (Compressed Air Indication and Digital Display For Solar System Parameters)

collector and in the suction line of the collector pump. The total return flow from the collectors goes to the hot water storage tank or it is divided between the school circulating pump and the storage tank.

9. The following "Collection System" data can be monitored from the "System Monitor" panel (see Figure 3-3).

- o Total collector flow T.^oF
- o Total collector flow rate in GPM.
- o Hot water storage tank temperatures.
- o Collector return water temperature for each collector.
- o Collector inlet temperature-total flow of 3 collectors.
- o Collector surface temperature when flowing or when dry-
(4 sensors to each collector.) See Note 1 below.

10. Shut Down of the "Solar Collection/Hot Water Storage System"

In the automatic mode of operation, the collector position control always maintains its collector position if clouds should suddenly blot out the sun or when the sun sets.

A built-in "Freeze-Prevention" circuit automatically moves the collectors to a vertical position for drainage of water from its banks of tubes when the collector surface temperatures drop below 40^oF. The collectors then remain in that position until the solar radiation reappears, refocusing the collectors, thereby reheating the collector tube banks to the temperature necessary to command water flow.

Note 1. Only two of the four sensors of each collector are

sampled for the collector pump operational logic. All four sensors are monitored, however, for the collector "Overheat" logic. Consequently, a situation may exist where the pump logic sensors may not be ready to activate the pump but the "Overheat" sensors have become hot enough to trigger the "Overheat" logic, thereby driving the collectors out of focus. This is a very unusual situation and if it occurs the system will not function automatically. To get the system to start pumping, focus the collectors manually, allow the collectors to approach to near "Overheat" temperature, but not up to 220°F, and then start the pump manually and maintain flow until a collector "IN" and "OUT" difference of about 2°F steadily exists. The collector pump and the collector tracking can then be set on "AUTO".

CAUTION: Never allow the collectors to sit in focus (Dry-no water) at the overheat temperature of 220°F for more than a few seconds. Serious overheating will cause the banks of copper tubing to twist, warp, or buckle causing leaks and changes in tubing slopes which could affect proper automatic draindown.

B. Solar Collection/Space Heating and Cooling System

There are two major loads supplied by the output of the solar collectors. These loads are supplied by splitting the return flow from the collectors. One route is to the circulating pump for school heating and the other route is to the hot water pump for the ARKLA chiller for cooling the school. The output of the ARKLA chiller can be directed to the school circulating pump or to a chilled water storage tank, or both.

The controls for selecting the summer/winter mode of operation or for directing energy flow are not completely automatic. Manually controlled gate valves are placed in the hot and chilled water supply lines to the school circulating pump. Manually controlled gate valves are also placed in the school return flow lines which branch off of the main trunk line return. One of these branches is to allow hot water return to the collectors or hot water storage tank when in the heating mode and the other branch is to allow chilled water return to the chiller or chilled water storage tank when in the cooling mode. Two of these four valves must be open depending upon the mode of operation.

In addition, the output of the circulating pump is regulated by two fixed flow control valves. One is set for 80 GPM flow to the school for summer operation and one is set for 40 GPM flow to school's distribution units for winter operation. The system operator must manually select the mode of operation by opening and closing the proper gate valves in the hydronic circuit in the discharge side of the circulating pump.

A summer/winter selector switch located on the test panel in the rear of the console must also be activated manually before the Solar Collection/Space Heating or Cooling System can be operated. (See figure 3-4).

The Pneumatic controls for automatically switching from solar to school heating/cooling were designed and installed by the control system contractor. These controls are interfaced with the electronic control system in the control console so that they can be remotely operated. The control system contractor is Johnson Controls*. These controls assure fail safe heating of the school if there is a power failure or for lack of solar energy.

1. The Solar Collection/Space Heating and Cooling System is put into operation as follows:

- a. Check that all power is "ON" to the console. Reference Section III A.
- b. In addition to Paragraph A above, the main power at the electrical control panel (Figure 2-8) must be on to the hot water pump (chiller), chilled water pump, cooling tower pump, and school circulating or load pump.
- c. Select summer or winter mode of operating by positioning manual switch on the test panel located in rear of control console. (See figure 3-4)

*Johnson Controls, Inc.
10221 S. Dolfield Rd.
Owings Mills, MD
Phone- (301) 363-6700

Corporation

Figure 3-4. Summer-Winter Selector Switch
(Located at Rear of Control Console)

d. Set the two manually controlled gate valves in the supply lines to the school circulating pump and the two valves in the return lines from the school distribution units MZ-1 and MZ-2. These valves are set according to the desired heating or cooling mode of operation and are located in the instrumentation room.

e. Activate the Solar Collection System as explained in Section III A.

f. Heating

For the school solar heating mode of operation, set the circulating pump switch on the system control panel to "AUTO" (see figure 3-1). Also select "Solar" heating as opposed to "School" heating by positioning the switch just to the right of the circulating pump switch.

g. The circulating pump control switch on the system control panel has a "MANUAL" position which overrides the system control logic and allows operation of the pump for service and maintenance purposes.

The selector switch for choosing "Solar" or "School" flow may also be set to "School". This isolates the solar flow from the school's distribution units and allows for service and maintenance of the solar system. (See Appendix C for Operational Logic)

h. Cooling

For the school's solar cooling mode of operation, the summer/winter switch in the back of the control console must be on "Summer" and the manually controlled gate valves in the circulating pump supply and

school return lines must be set so that the supply to the pump comes from the chiller or chilled water storage tank and the school return goes to the chiller or the chilled water storage tank.

i. Set the pump control switches for ARKLA hot water, cooling tower and chilled water pumps to "Automatic" (see Figure 3-1). These switches also have an "OFF" or manually "ON" position to allow individual operation or checkout of each pump for service or maintenance. The chiller will operate when the hot water storage tank temperature is 175°F or above.

j. Set the school circulating pump and the system selector switches to "AUTO" and "SOLAR" respectively.

k. Check water level in the chilled water storage tank by observing the water level alarm "High" or "Low" indicators located on the system control panel.

Note: The solar hydronic system is pressurized to approximately 8 psi and the storage tanks are pressurized accordingly. The storage tanks have the capability of automatic make up water to maintain the established water level at the 8 psi pressure. This equipment is located in the underground vault or valve pit situated between the two storage tanks. A sight gauge is also located there to manually check the water level in the tanks if the system control panel has indicated a high or low level alarm. (See figures 3-5, 3-6, & 3-7)

1. Chilled Water Production and Storage

Storage

During the cooling mode of operation, the ARKLA chiller will always run and produce chilled water provided a supply of hot water is available as measured in the hot water storage tank.

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The school circulating pump will continue to run with "ZERO" school load if the outside ambient is above 72°F and the water temperature in the chilled water storage tank is below 57°F.

Figure 3-5. Pressure Regulator & Backflow Preventer for Automatic Makeup of Water to Hot and Chill Water Storage Tanks

Figure 3-6. Storage Tank Water Level Float Valve With High and Low Level Alarm

Figure 3-7. Air Pressure Regulator and Relief Valve
For Water Storage Tanks (Located in
Instrumentation Room)

IV. MAINTENANCE - SOLAR SUBSYSTEMS

A. Collectors

The collector assembly consists of the drive mechanism, the absorber, the sun tracker, the temperature sensors, and the drain valves for automatic draining.

1. Drive Mechanism

The drive mechanism consists of an electrically driven screw jack. The motor, brake, and screw jack require periodic checks and service. Brake adjustment instructions are located inside the brake housing cover. The brake functioning must be checked every six months. Collector drifting after stopping of the drive motor indicates a necessity for a brake check and adjustment.

The screw jack itself should be checked for grease packing every 12 months. Do not overpack. The pivot bearings of the screw jack and torque tube must also be checked and lubricated annually.

2. Absorber

The absorber inside the collector housing consists of a bank of copper tubes silver soldered to a manifold at each end. Union type connections are made to the supply and return lines at the center strut. Clearance allowance is made at each end for expansion and contraction of the copper tubing. If leaks occur at the center strut, the union joints can be inspected and repaired thru an access door on the top side of the

housing.¹ If leaks occur at the opposite end where the solenoid valves are located, the connections can be inspected thru another access door on top of the collector housing. If leaks occur in between these ends, the tubing joints will have to be inspected and repaired by removing the glass cover plates of the affected section. The absorber also has temperature sensor connections at four points along the collector, two on each side of the strut. These connections are accessible thru access doors on the top of the collector. Connection repair or sensor replacement are the maintenance functions required for the components.

3. Sun Tracker

The sun tracker is the mechanical member mounted perpendicular to and on the collector. These mechanical housings contain slits for light to pass thru to solar cells. Wiring from the console is connected to these cells. Erratic movement of the collector indicates a possible faulty cell or circuitry. Correction of this malfunction should be referred to AAI Corporation, Cockeysville, MD.

4. Drain Valves (In Collectors)

An electrically operated drain valve is mounted on the outboard end of each half of a collector group. They are accessible thru

¹A maintenance platform designed to slide in a track at the northern end of the reflector is provided for servicing the collectors. See Drawing 57607-40195, Appendix E.

access doors on the top side of the collector. The drain valves are normally open.

The purpose of the drain valves in the collectors is to allow ambient air pressure into the collector as the water in the absorber drains back to the storage tank thru two dump valves located in the collector supply and return lines in the instrumentation room. All drain valves are opened for draining only when the collector pump has stopped running for one half hour and all collectors have moved to vertical. This is primarily to prevent freezing in cold weather. It is possible to visually check if the water is draining by examining the sight gage in the collector dumping line located in the instrumentation room. The air lines to the solenoid valves in the collector should be monitored during winter operation to see if they are filling with water. Since the air line is not insulated, it could fill up and freeze causing the collectors not to drain and freeze also.

B. Reflectors

The reflector for the solar concentrating system consists of the contoured deck (flame treated wood) covered with roofing paper. This surface is then coated with an adhesive upon which mirrors are placed. The edges of the mirrors are held down with metallic sealing strips and beads of mastic are placed along the upper and lower edges to prevent moisture from getting beneath the glass.

Defective or broken mirrors can be replaced individually by removing the hold down strips and lifting out the roofing paper

and mirror together. Cut thru to the basic wood along the edges of the mirror to be replaced.

C. Chiller and Cooling Tower

The absorption chiller used in the Padonia Solar Concentrator System is the Solaire 300 (WFB-300). This unit is manufactured by the ARKLA Industries, Inc., P.O. Box 534, Evansville, Indiana 47704. The installation, controls, adjustment, and service manual are supplied with the unit and should be consulted for all maintenance requirements.

The cooling tower is manufactured by Baltimore Air Coil, Ind., P.O. Box 7322, Baltimore, Maryland 21227. It is Model J0605-18, Serial No. 76-8587. It has a built in bleed-off line with a petcock type of valve for setting the bleed-off rate specified by ARKLA Industries for its chiller.

This is a jet spray tower whose jets will require periodic inspection to maintain maximum efficiency. The sump filters and the filter in the supply line will also require quarterly inspection. The makeup water float level control should also be inspected about every three months.

To prevent freezing during the winter months, the tower must be drained down. The sump is drained thru a drain line to a nearby school roofing drain. All filters should also be cleaned at this time to prevent contamination on the filter surfaces from blocking the filters. The copper makeup water line leading from the pump room to the tower is drained thru a hose bib valve located in the instrumentation room. The

3 inch supply and return lines are drained thru either clean outs or hose bibs located in the instrumentation room. All lines are sloped down to the heated instrumentation room where water could be allowed to remain in the lines without danger of freezing.

D. Hydronic System

1. Storage Tank Makeup Water

Make up water is added to the storage tanks automatically from a school domestic water line that leads from the instrumentation room, underground to the vault room, then to the McDonald makeup valves to the tanks. The portion of the line in the instrumentation room contains a filter screen, back flow preventer, and water pressure regulator (see Figure 3-5). Since the system operating pressure is 8 psi, the pressure regulator is set to 10 psi to allow flow if the McDonald valve demands it.

The major maintenance function would be to periodically check the filter screen for blockage and to check the pressure regulator setting of 10 psi to 12 psi. In addition, the water level of each storage tank (hot and cold) must be checked periodically by entering the vault and observing the water level sight gages. The proper water level must be maintained in order for the system pump suction lines to maintain priming. The pump suction connection at the storage tank must be constantly under water while the collector system pump is maintaining the collectors full of water. A storage tank water level alarm light is located on the control panel. If high level light is "ON", the storage tank may be too full, particularly if the light is "ON" when

collectors are running full. A high level also means that the system air is being replaced with water which may affect drain down of the collectors, especially in the winter when water in the collectors should be replaced with air in order to prevent freezing.

A "Low Level" indication could mean that the pump suction or return line ports are out of water causing pumps to lose their priming.

2. Compressed Air System

The source of compressed air for pressurizing the hydronic system is the school's air compressor. A supply line is run to the instrumentation room to a small tank (see Figure 3-7). This tank stores air at 50 psi from which the lines go underground to the storage tanks and out of the instrumentation room to the collector solenoid drain valves. The air from the small storage tank runs thru a regulator set to maintain 8 psi in the storage tanks and then thru a relief valve set for 8 psi. This is a small capacity relief for slow back pressure buildups. If a rapid back pressure occurs, due to a malfunction of the makeup water system, the full size water pressure relief valve will dump into the gravel pit in the instrumentation room. Air pressure gauges are installed in the lines to the storage tanks for monitoring the setting of the air regulator and for monitoring the storage tank pressure. The regulator, small capacity relief valve, pressure gauges, and tank shut off valves are all located in the instrumentation room for easy access and adjustment.

The air lines that run from the instrumentation room to the collector solenoid operated drain valves contain a master shut off valve near

the air storage tank and three individual shut off valves, one in each of the separate collector lines leading out of the instrumentation room. The valves allow shutdown of any one collector for service while still maintaining air pressure on the remainder of the system. The master shut off valve closes off the air to the entire system. This prevents water in the collectors from draining back to the storage tank to prevent freezing.

The control console contains a red indicator light which indicates a loss of air to the solar system when it is "ON".

3. Major Components

a. Collector Pump #5	Allis Chalmers, Model C-16, 3500 RPM,
230-460 V, 3 ϕ , 60 cycle, 5 HP, 70 GPM
@ 89 Ft. HEAD., N.H. Yates Co. (4 3/4" dia. Impeller)
b. Hot Water Pump to Chiller Generator #4	Allis Chalmers, Model C-16, 3500 PPM,
3 ϕ , 60 ~, 3 HP, 230-460 V, 70 GPM
@ 57 Ft. HEAD. N.H. Yates Co. (4 1/8" dia. Impeller)
c. Load Pump (Circulating Pump to School) #3	Allis Chalmers, Model C-16, 3500 RPM,
3 ϕ , 60 ~, 3 HP, 230-460 V, 80 GPM
@ 75 Ft. HEAD., 4 1/2" dia. Impeller
(N.H. Yates Co.)
d. Chilled Water Pump #2	Allis Chalmers, Model C-1, 3500 RPM,
230-460 V, 3 ϕ , 60 ~, 2 HP, 60 GPM
@ 71 Ft. HEAD., 4 7/8" dia. Impeller
N.H. Yates Co.
e. Condenser-Cooling Tower Pump #1	Allis Chalmers, Model C-1, 3500 RPM,
230-460 V, 3 ϕ , 60 ~, 2 HP, 90 GPM
@ 42 Ft. HEAD., 5" dia. Impeller,
N.H. Yates Co.

- f. Chiller (Absorption type) Solaire 300 (Model WFB-300) 25 Ton,
ARKLA Industries, Inc., P.O.Box 534,
Evansville, Ind. 47704
- g. Cooling Tower Model J0605 B-18 Serial No. 76-8587,
Mfg. by Baltimore Air Coil, Inc., P.O.
Box 7322, Baltimore, Md. 21227
- h. Ball Screw Jack Duff-Norton Co., P.O.Box 1719,
(Collectors) Charlotte, N.C. 28232, Part No. SK-3820-
R-4
- i. Limit Switch - Screw Jack Duff-Norton Co., P.O.Box 1719, Charlotte,
N.C. 28232, Part No. SK-6000-B
- j. Position Transducer- Duff-Norton Co., P.O.Box 1719, Charlotte
Screw Jack N.C. 28232, Part No. SK-6200-T
- k. Make Up Water Feeder McDonnell & Miller ITT, 3500 N. Spaulding
Hot & Cold Storage Tanks Ave., Chicago, Ill. 60618, Part No. 25A
- l. Low & High Water Level McDonnell & Miller ITT, 3500 N. Spaulding
Cut Off Switch Ave., Chicago, Ill. 60618, Part No. 150
(Hot & Cold Water Storage
Tanks)
- m. Flowmeters
Collector Flow
Ramapo
Flow Technology
Chiller Hot Water Flow
Chilled Water Flow
Load Flow
Cooling Tower Flow
- Mark V-3-CF (10-100 GPM 350 ohm)-Gov't
#4571
- Ramapo-Mark V-3-CF #4570
" " " #4572
" " " #4573
" " " #4574
- n. Precision Pyranometer Model PSP Ser. No. 15393F3
(to Measure Total The Eppley Laboratory Inc.
Radiation) Newport, R.I. 02840
- o. Precision Pyranometer Model PSP Ser. No. 15428F3
(used for Measuring The Eppley Laboratory Inc.
Diffuse Radiation Only) Newport, R.I. 02840

Corporation

p. Photovoltaic Pyranometer

Model 1008 Ser. No. 337
Calibration Constant 85.4
Rho Sigma Inc.
11922 Valerio St.
North Hollywood, Calif. 91605

q. Flow Control Valves

Chilled Water-School Load
Hot Water-School Load
Chiller Flow

Griswold-80 GPM Model 2-3284A Stock #3396
Griswold-40 GPM Model 2-3284A Stock #3396
Griswold-60 GPM Model 2-3284A Stock #3396
Griswold Controls(Irvine) Calif.

r. Pneumatic Control

All Temperature and Pressure Control
Valves are Supplied By:
Johnson Controls Inc.
10221 S. Dolfield Rd
Owings Mills, MD
Phone (301) 363-6700

1. Back Pressure Relief Valve #V5460-868(16-10595-35897)
2. Hot Water To Chiller Temperature Control #V5840-0476(16-13360-33870)
3. Collector Return Shut Off #V5460-868(16-10595-35897)
4. Hot Water Return From Chiller #V5460-868(16-10595-35897)
5. Load School By Pass #V5460-870(16-1915-36064)
6. Load Solar Supply #V5840-47A(16-21230-33885)
7. Load Solar Return #V5650-14(17-40-16)
8. Chilled Water Shut Off #5460-868(16-10595-35897)

s. Water Storage Tanks

10,000 Gallon (8ft. Outside
dia. x 28 ft. Long Steel $\frac{1}{2}$ in.
thick) Manufactured by Buffalo
Tank Division of Bethlehem
Steel Corp. Drawing #M-8017
Dated October 6, 1976

E. Electric Power and Controls

Electric Power for the Solar Installation is obtained from the School's utility power system. Total Power for this installation is divided into two branches, one for general utility, and the second for Solar System power. Each branch is monitored by separate Watt-Hour meters located in the school's boiler room. The solar and utility power branches are routed from the boiler room to the instrumentation room. Each branch has its main breaker and branch breakers located in separate junction boxes in the instrumentation room. The solar power junction box contains separate breakers for the Primary Power plus each pump, 208 V. Console Power, 115 V. Console Power, Arkla Chiller Power, Johnson Control Power and power for the Motor operated valve in the school return line. Primary power is 208 V. 3 - phase, 4 wire with 115 volt single phase distributed to various components except for the pumps, air conditioning and equipment rack which is 3 - phase.

Primary Solar Power is switched in the control console by solid state relays that are activated by Solar System logic. These relays control the pump motor starter control windings and the relay winding in the Johnson Control Panel that is used for controlling the Pneumatic - Electric Control Valves.

The Utility Power Junction Box contains the breakers for the instrumentation room lighting, heating, utility receptacles and 115 V. power in the underground vault. All other control wiring to the roof and underground vault and instrumentation room radiates from the control console.

F. Site Data Acquisition System

The Federal Government sponsors a National Program for the collection and dissemination of performance data of various Solar Heating and Cooling Systems.

The Padonia School is one of those projects monitored by the government.

To accomplish this, a federally owned Site Data Acquisition System has been installed on the northern wall of the instrumentation room. This is coupled by a telephone link to a Central Data Processing Center at Huntsville, Alabama. The data is monitored by means of government furnished sensors and flow meters spotted at appropriate places throughout the hydronic system. The Site Data Acquisition System and its related sensors and flow-meters are not the responsibility of the AAI Corporation, and in no way affect the control of and operation of the Solar System.

G. Solar System Hydronic Characteristics

1. Collector Flow Adjustment

The collector pump produces 70 GPM at a head of 89 feet of water.

Measurements indicate that the maximum total flow to all collectors is about 110 GPM.

The flow to each collector can be manipulated separately

by means of individual circuit setters located in each return line. These flow control valves are located near the screw jacks.

If any flow setting to the collectors creates an abnormal backpressure on the collector pump, it is relieved by a pneumatically controlled backpressure relief valve located across the pump suction and discharge lines. This is a Johnson Control Valve and its control unit is mounted on the pump room wall near the doorway.

The flow to the collectors is currently set to maintain approximately an equal flow to each collector with an absolute minimum backpressure on the pump. The total flow to the collectors can be modified by changing the setting of the pressure controller for the backpressure relief valve. If this is done, however, the individual flows to each collector will not remain identical. The circuit setters will have to be readjusted by means of a manometer for a given setting of the pressure controller.

2. Collector Pump - (Pump Priming-Unwanted Air)

During the normal course of operation, the solar system logic will start or stop the collector pump many times. When the pump stops, all the water in the collectors (upstream and downstream) will tend to return to the storage tanks. If this happens the pump will lose priming and the system will pick up air. To prevent this, a check valve is placed in the discharge side of the pump to block the return of water from the collectors on the upstream side and a pneumatically controlled shutoff

Corporation

valve is placed in the main collector return line (total flow) on the downstream side. This is a normally closed valve located in the instrumentation room and is opened by air pressure every time the pump starts.

The combination of these two valves minimizes pick up of air and prevents loss of pump priming during normal operation.

Note: The storage tank must be pressurized to about 8 PSI. This must occur after all the collector water is drained back to the tanks. If the pressure exceeds 12 psi with water drained back some residual water may not get back as far as the pump room to prevent freezing.

3. Hot Water Supply to the Hot Water and School Load Pumps

The suction line to both these pumps connects between the pneumatically controlled shut off valve described above in paragraph 2 and the hot water storage tanks. With the pneumatically controlled valve closed and the hot water tank pressurized to approximately 8 psi, this line will remain primed all the way to the hot water and school load pumps.

Note: It is mandatory that the water level in storage tank be above the collector return line entrance into the tank when the collectors are running and full of water. This will allow the storage tank pressure to maintain the necessary head to the hot water and school load pumps when the collectors are not running or the shut off valve is normally closed.

4. Cold Water Supply to the Chill Water or School Load Pumps. (Summer Mode of Operation)

The water to the suction side of the school load pump can come either solely from the chilled water storage tank connection at the bottom of the tanks or from the chilled water output of the chiller.

Note: Here again the chilled water storage tank must be pressurized to approximately 8 psi to maintain priming of the pump. The water level in the storage tank must also be above the school return line as it enters near the top of the tank because this line acts as the suction supply to the chill water pump for the absorption air conditioner.

When the load pump is "on" the water is pumped to school distribution units and returns through a motor driven shut off valve located in the instrumentation room and then to the chiller or storage tanks. As in the collector System, when the pump is off the water tends to drain back down to its lowest level and picks up air as it does it. To prevent this the motor driven shut off valve was included in the return line of the system. The valve is closed when the pump is off.

Note: This also prevents water from being forced into the chill water storage tanks due to school pressure forcing water by the Johnson Control Valves in the fan room.

A check valve in the discharge side of the pump prevents backdraining in the supply line to the distribution units.

Chill Water Pump - The water to the suction side of the chill-water pump comes either from the top outlet of the storage tank or the return line from the school's distribution units. The storage tank

must be pressurized to approximately 8 psi to maintain priming of the pump.

5. Condenser Water Pump.

The hydraulic loop for the condenser system consists of the pump, absorption chiller and cooling tower, and their associated valves and strainers. A domestic water line from the instrumentation room to the tower allows filling of the system. A hose bib and shut off valves located in the instrumentation room provide for draindown of the domestic water line to prevent freezing. The condenser pump draws water from the cooling tower sump, discharges it into the chiller from where it goes to the jets in tower and then returns to the pump. The maintenance of good flow is dependent upon proper bleeding of air from the loop. The "in" and "out" lines on the chiller contain petcocks for bleeding off air. Valves located in the water lines to and from the pump also provide for bleeding air from the system.

H. Outside Ambient Temperature and Shadow Band Adjustments

1. Ambient Temperature

One of the parameters for automatic control of the solar system is Outside Ambient Temperature. This device is located in the instrumentation room on the northern wall near the ceiling. The probe pierces the wall at this point to sense outside ambient temperature. It is set by means of a screw driver adjustment for 72° Fahrenheit. This data is fed into the system logic thru the "summer-winter" switch located at the rear of the control console.

2. Shadow Band

Another parameter for automatic control of the solar system is the "direct" component of Total Solar Radiation.

This is obtained by the use of two pyranometers and a metal shield or band. The band prevents the "total" sun from impinging on one of the pyranometers thereby recording only diffuse radiation. The second pyranometer is directly exposed to sunlight or "total" radiation. This includes both "diffuse" and "direct". The system logic subtracts the "diffuse" from the "total" to get the element of "direct" radiation that is usable by solar concentrators. The collectors are ordered to search for the "focus" when the direct component of radiation reaches 100 Btu/hr. Since the metal shield or shadow band is not programmed to move automatically as the earth revolves about the sun, its pyranometer would become partially exposed to the sun within 3 days time. Therefore the band must be manually adjusted approximately every 3 to 4 days to prevent this exposure and to maintain normal operation of the collector system. Perform the adjustment while the sun is shining and center the pyranometer in the shadow produced by the shield.

The pyranometer and shadow band installation is located on the walkway at the eastern end of the roof deck.

V. Data and Specifications

A. Design Data

1. The System Design Data and calculations are contained in Appendix A of this report. See data sheet figure 5-1.

B. Operational Data and Performance

1. The Federal Government sponsors a National Program for the collection, evaluation and dissemination of performance data of Selected Solar Heating and Cooling Projects.

The Padonia Elementary School was selected to participate in this program. To meet the above goals the government supplied the sensors and Site Data Acquisition System that is installed in the instrumentation room at the Padonia site. The data is monitored and coupled by telephone to a Central Data Processing Center located at the National Aerospace and Administrative Center in Huntsville, Alabama. There the information is reduced and analyzed.

Monthly Performance Reports are prepared from this data and they can be obtained from the National Solar Heating and Cooling Data Bank. The Department of Energy's Information Center at Oak Ridge, Tennessee is the distribution center for the information.

**PADONIA ELEMENTARY SCHOOL
SOLAR HEATING & COOLING PROJECT**

DATA SHEET

TYPE SYSTEM.....	RETROFIT: HEATING & COOLING, HYDRONIC SYSTEM
COLLECTOR.....	THREE 8/1 CONCENTRATING ROOF-TOP COLLECTORS, EACH 58 FT. BY 18 FT., AAI CORP. MFG.
REFLECTORS.....	3400 FT ² - SECOND-SURFACE REFLECTIVE GLASS MIRRORS
ABSORBER.....	350 FT ² ; COPPER TUBING, SELECTIVE COATED, SINGLE GLAZED
AREA HEATED & COOLED.....	10,000 FT ² (CAFETORIUM & LIBRARY)
PERCENT LOAD MET BY SOLAR.....	75% HEATING & COOLING PREDICTED
BELOW GROUND WATER STORAGE.....	20,000 GAL: 10,000 HOT 10,000 COLD
CHILLER.....	ARKLA MODEL WFB 300 (25 TON)
COOLING TOWER.....	BALTIMORE AIR COIL MODEL J0605
SYSTEM COST.....	\$670,000
SYSTEM DESIGN.....	AAI CORPORATION
GENERAL CONTRACTOR.....	C. J. SPALLITTA, INC.
OWNER/USER.....	BALTIMORE COUNTY SCHOOL SYSTEM

FIGURE 5-1

VI. Appendices

- A. Climatology, Heating and Cooling Loads, Concentrator Performance**
- B. Padonia Solar System Operational Logic**
- C. Heating and Cooling Loads for the Padonia Elementary School**
- D. The Padonia Solar System Construction Drawings**

APPENDIX A: Climatology, Heating, and Cooling Loads and Concentrator Performance

1. Climatology

This section treats the particular conditions that are presumed to pertain to the Padonia Elementary School in Cockeysville, Maryland, a community approximately 15 miles north of Baltimore.

At the present time we do not have sufficient data recorded at Cockeysville to predict average daily insolation and weather conditions. Therefore, the solar insolation data used to determine the amount of radiation collected was taken from values recorded at Washington, D. C. located about 50 miles southwest of Cockeysville. This data includes the average daytime temperatures and average daily insolation on a horizontal flat plate. [1] Also, graphical data of the sun's elevation and bearing was taken for a latitude of 40° north from reference [2], approximating Baltimore's latitude of $39^{\circ}17'26''$ north. The weather data which was used to calculate the heating and cooling loads was from U. S. Weather Bureau data for Philadelphia, Pa. which is located about 100 miles east-northeast of Cockeysville. The reason for not using Washington, D. C. weather data was due to the fact that the data which we have available for Washington shows March as being colder than January and February which we do not feel is typical of the weather for Cockeysville. We feel the Philadelphia weather

data which shows January, February and March as being consecutively milder is more typical of Cockeysville weather.

Figure A1 is a normalized distribution of the sun's radiant intensity for the months of June and December at a latitude 40 degrees north. [3]

Figure A2 is the graphical trajectory of the sun for 40° north latitude. [2]

Both of these figures are referred to in the subsequent calculation of the fraction of reflected radiation intercepted by the collector.

Figure A3 lists the daytime average daily temperatures and the daily insolation falling on a horizontal flat plate. [1] This data was used to determine the daily insolation on an inclined surface. Average night-time temperatures are assumed 2 degrees lower than average daytime temperatures.

Figure A4 lists the relation of diffuse radiation to the total radiation. [1]

2. Heating and Cooling Loads

The heat transfer coefficients for estimating heating and cooling requirements were taken from reference [3].

The computer program E CUBE[®] was used to calculate the heating and cooling requirements for a 10,000 ft² area of the Padonia Elementary School. E CUBE was developed by the American Gas Association and is available to AAI through our IBM 1130 computer terminal via the CDC Cybernet computer system. E CUBE is a series of programs which

Corporation

Normalized Distribution of Solar Radiation⁽³⁾

Figure A1

A-3

40°N LATITUDE

DECLINATION OF THE SUN

Date	Declination	Corresp. Date	Declination	Unified Calibr.
June 21	+23°27'		+23°27'	+23°27'
May 21	+20°09'	July 21	+20°31'	+20°20'
Apr. 21	+11°48'	Aug. 21	+12°12'	+12°00'
Mar. 21	+0°10'	Sep. 21	+0°47'	+0°28'
Feb. 21	-10°37'	Oct. 21	-10°38'	-10°38'
Jan. 21	-19°57'	Nov. 21	-19°53'	-19°55'
Dec. 21	-23°27'		-23°27'	-23°27'

Sun Path Diagrams: The earth's axis is inclined $23^{\circ}27'$ to its orbit around the sun and rotates 15° hourly. Thus, from all points on the earth, the sun appears to move across the skyvault on various parallel circular paths with maximum declinations of $\pm 23^{\circ}27'$. The declination of the sun's path changes in a cycle between the extremes of the summer solstice and winter solstice. Thus, the sun follows the same path on two corresponding dates each year. Due to irregularities between the calendar year and the astronomical data, here a united calibration is adapted. The differences as they do not exceed $41'$, are negligible for architectural purposes. The elliptical curves in the diagrams represent the horizontal projections of the sun's path. They are given on the 21st day of each month. Roman numerals designate the months. A cross grid of curves graduate the hours indicated in arabic numerals. Eight sun path diagrams are shown at 4° intervals from 24°N to 52°N latitude.

Figure A2

AIA Corporation

A-5

			Jan.	Feb.	Mar.	Apr.	May	June
Washington, D. C. (WBCO)	$\bar{H}$		632.4	901.5	1255	1600.4	1846.8	2080.8
	Lat. $38^{\circ}51'N$	$\bar{K}_t$	0.445	0.470	0.496	0.504	0.516	0.553
	El. 64'	t_o	38.4	39.6	48.1	57.5	67.7	76.2
			July	Aug.	Sept.	Oct.	Nov.	Dec.
Washington, D. C. (WBCO)	$\bar{H}$		1929.9	1712.2	1446.1	1083.4	763.5	594.1
	Lat. $38^{\circ}51'N$	$\bar{K}_t$	0.524	0.516	0.520	0.506	0.464	0.460
	El. 64'	t_o	79.9	77.9	72.2	60.9	50.2	40.2

$\bar{H}$: Monthly average daily total radiation on a horizontal surface BTU/Ft²/Day.

$\bar{K}_t$: Ratio of $\bar{H}$ to the extraterrestrial daily radiation on a horizontal surface, H_o .

t_o : Average daytime temperature.

Radiation and Other Data for Washington, D. C. - [Ref. 1]

Figure A3

Figure A4

Relation between Monthly-Average Daily Diffuse Radiation, $\overline{D}$, on a Horizontal Surface, and the Monthly-Average Daily Total Radiation, $\overline{H}$, on a Horizontal Surface. [Ref. 1]

$\overline{K}_T = \overline{H}/H_o$	0.3	0.4	0.5	0.7	0.7	0.75
$\overline{K}_d = \overline{D}/H_o$	0.178	0.183	0.188	0.174	0.149	0.125

(a) determines the heating and cooling requirements for a zone or building on an hourly, monthly and annual basis; (b) determines the relative energy consumption of the several different systems which may be considered; and (c) makes an economic comparison of the various systems based on first cost and operating costs.

The complete E CUBE computer run to determine the heating and cooling requirements for the Padonia Elementary cafeteria, library, and administrative suite is included as Appendix D. Two day types were used in this computation. Day type one represented a regular school day. At 7:00 a. m. the thermostat is turned up to 68°F in the winter and down to 76.5°F in the summer and the dampers are opened, giving a ventilation flow of 2990 cfm. People begin to arrive at 8:00 a. m. The peak energy input from people occurs from 11:30 a. m. to 1:00 p. m. when the cafeteria is serving lunch. The students begin to leave at 3:00 p. m. and essentially everyone is assumed to have left the building by 4:00 p. m. At 5:00 p. m. the ventilation dampers are closed and the thermostat is set back 8° in the winter and up 4° in the summer. Day type two represented a day when the school is unoccupied with no ventilation and the thermostat remaining at the overnight position. This day type is representative of weekends, holidays and vacation days.

With year-around usage of the school the school year was assumed to be composed of 229 school days of type one and the remainder was assigned to day type two. This allows 4 twelve-week sessions with a one-week vacation between each and a holiday for each month.

In the summer the moisture content of the air inside the school was assumed to be maintained at 50% relative humidity. No humidification was included during the heating season. Figure A5 shows the assumed transmission coefficients for the heat loss/gain from the exposed exterior surfaces of the zone under consideration. Weather data for Philadelphia, Pa. was used. The weather data is stored internally in E CUBE and is data which has been obtained from the U. S. Weather Bureau.

The resulting monthly heating and cooling requirements are plotted in Figure A6. The E CUBE hourly results show a peak heating load of 229 MBTU/Hr in January and a peak air-conditioning load in July to 28 tons.

Corporation

Transmission Loss/Gain Estimate Form for
Padonia Elementary School Cafetorium,
Library and Administrative Suite

Element	Parameter	Factor	Temperature Difference °F
Skylights	24 ft ²	0.50 Btu/Hr-Ft ² -°F	Δt
Floor Perimeter	35 Ft	0.60 Btu/Hr-Ft-°F	Δt
Floors	5300 Ft ²	0.05 Btu/Hr-Ft ² -°F	Δt
Walls	174 Ft ²	0.24 Btu/Hr-Ft ² -°F	Δt
	1112 Ft ²	0.15 Btu/Hr-Ft ² -°F	Δt
Roof	3328 Ft ²	0.10 Btu/Hr-Ft ² -°F	Δt
Windows	200 Ft ²	1.03 Btu/Hr-Ft ² -°F	Δt
Infiltration	54 cfm	1.08 Btu/Hr-cfm-°F	Δt

The product of the above factors results in the heat loss/gain for each element in Btu/hour.

Figure A5

Monthly Heating and Cooling Loads Required as Output from the Heating System
And the Air Conditioner for the Padonia Elementary Cafetorium, Library,
and Administrative Suite. The Dips in Requirement in March, June and September
Correspond to Assumed Vacation Periods

Figure A6

AAI Corporation

3. Concentrator Performance

In this section we will determine the amount of useful energy available for heating and cooling from the solar collector. In considering overall system performance, there are three major areas to consider: transmission efficiency, thermal losses at the collector, and operating efficiency of the heating or cooling system.

Transmission Efficiency

The transmission efficiency is comprised of a number of factors and can be defined as follows:

$$N_T = [1 - 0.7R_D][e_r r][1 - D]^3 [N_G][e_s(1 - s)][e_f F_e] \quad (1)$$

where: R_D = average daily diffuse radiation as a fraction of the average daily total radiation. (A multiplier of 0.7 is used since it is assumed that 30% of the diffuse radiation comes from the part of the sky in the immediate vicinity of the sun and therefore can be collected.)

r = reflectivity of reflector

e_r = angle factor associated with the reflectivity

D = dust losses (these losses are cubed to account for losses entering and leaving the reflector and also entering the collector)

N_G = fraction of reflected radiation intercepted by the collector.

s = effective shade loss

e_s = angle factor associated with the shade factor

F_e = effective transmissivity-absorptivity product

e_f = angle factor associated with F_e

References and derivations of the above follow.

Figure A7 summarizes the values for the transmission efficiency of AAI's proposed concentrator system for each month of the year along with the applicable factors used to arrive at these efficiencies. To simplify this analysis angle factors e_r , e_s and e_f are evaluated at an incidence angle of 30° . This represents the approximate weighted average angle of incidence as predicted by the method shown in Figure A8. Curves for angle factors for several physical properties have been reproduced in Figure A9 versus incidence angle. Assuming the reflective angle factor is determined chiefly by the change in transmissivity of the plate glass mirror, the reflectivity angle factor can be assumed equal to the transmittance angle factor for two glass thicknesses which is shown in Figure A9.

Figure A10 shows the ratio of average daily diffuse radiation to average total daily radiation as a function of $\bar{K}_T$. Using values of $\bar{K}_T$ for Washington from Figure A3 in the climatology section, this ratio can be determined for each month of the year.

The value for reflectivity of .86 was supplied by the manufacturer of the plate glass mirror which will be used as the reflector.

Whillier^[1] indicates that glass which appears extremely dirty will transmit about 96% of the light that a clean glass transmits. Therefore, a good average number for the dust factor (1-D) would be .98.

Whillier^[1] also indicates that a good value for design purposes for the shade factor (1-S) is .97.

Energy Collected Before Subtracting Thermal Loss

Figure A7

$N_T = [1 - 0.7R_D] [e_r r] [1 - D]^3 [N_G] [e_s (1 - s)] [e_f F_e]$					
$e_r = .99 \quad r = .86 \quad A_R = 3,388 \text{ Ft}^2$					
$e_s = .96 \quad 1 - s = .97 \quad Q_A: \text{Available daily radiation}$					
$e_f = .96 \quad F_e = .806$					
$1 - D = .98$					
	$1 - 0.7R_D$	N_G	N_T	$(H_{ot}/H_{oh})_{avg.}$	$Q_A \times 10^6$
Jan.	.706	.678	.276	1.701	1.006
Feb.	.720	.660	.274	1.441	1.206
Mar.	.736	.642	.273	1.232	1.430
Apr.	.740	.623	.266	1.061	1.530
May	.747	.605	.261	.962	1.571
June	.767	.587	.260	.919	1.684
July	.752	.605	.263	.937	1.611
Aug.	.747	.623	.269	1.013	1.581
Sept.	.749	.642	.278	1.152	1.569
Oct.	.741	.660	.282	1.354	1.402
Nov.	.718	.678	.281	1.616	1.175
Dec.	.715	.696	.287	1.799	1.039

$$Q_A = N_T \Delta A_R \bar{H} \sum \frac{H_{ot}}{H_{oh}} \quad (\text{Btu/day})$$

Method for approximating the angle of incidence at the collector using a weighted average.

Figure A8

(a)

(b)

(c)

Figure A9. Angle Factors for Several Physical Properties Versus Angle of Incidence [Ref. 1]

Ratio of Average Daily Diffuse Radiation to Average
Total Daily Radiation R_D as a Function of K_T .

K_T is the Fraction of Extraterrestrial Radiation
Arriving at the Surface of the Earth [Ref. 1]

Figure A10

From reference [1] the transmissivity-absorptivity product is defined as follows for a single plate collector:

$$F_c = F_c + a_1(1 - e^{-KL}) \quad (2)$$

where: a_1 = empirical coefficient

K = extinction factor

L = path length

For normal incidence L equals the thickness of the glass.

$$F_c = 1.008 T\alpha \quad (3)$$

where: T = transmittance of the collector cover

α = absorptivity of the collector

$$T = e^{-KL} \frac{(1-r)}{(1+r)} \quad (4)$$

where: r = the reflectivity of the glass cover.

$$r = \left(\frac{n' - 1}{n' + 1} \right)^2$$

where: n' = refractive index

The refractive index for glass is 1.526 which results in a reflectivity of .04336. Substituting into equation (4) using $K=.2$ which is "good" window glass and $L=.1875$ for the glass thickness, the transmissivity is .883.

Returning to equation (2), Whillier gives a value of .9 for the absorptivity of a collector with a selective black coating and a corresponding value of .14 for a_1 for a single cover plate. The transmissivity-absorptivity product therefore becomes

$$F_e = 1.008 \times .883 \times .9 + .14 (1 - e^{-.2 \times .1875})$$

$$F_e = .806$$

The following equation can be used to define the fraction of reflected radiation intercepted by the collector.

$$N_G = \frac{Q_c}{Q_{TR}} = \frac{\int_t \int_{\theta} n_g I \cos \theta_t dA_R dt}{\int_t \int_{\theta} I \cos \theta_t dA_R dt}$$

where: Q_c = radiation intercepted by the collector

Q_{TR} = total reflected radiation

n_g = fraction of reflected radiation from area dA_R which is intercepted by the collector

I = incident radiation intensity at the reflector

θ_t = angle of incidence of the radiation at the reflector

t = time

If we assume that the curved reflector surface can be represented by a series of flat plates, the above equation can be rewritten as,

$$N_G = \frac{I_{\max} \sum_t \left(\frac{I}{I_{\max}} \right) \Delta t \left[\sum_{\theta} n_g \cos \theta_t \Delta A \right]}{I_{\max} \sum_t \left(\frac{I}{I_{\max}} \right) \Delta t \left[\sum_{\theta} \cos \theta_t \Delta A \right]}$$

$$= \frac{\sum_t \left(\frac{I}{I_{\max}} \right) \left(\sum_{\theta} n_g \cos \theta_t \right)}{\sum_t \left(\frac{I}{I_{\max}} \right) \left(\sum_{\theta} \cos \theta_t \right)}$$

The normalized hourly insolation curve is included in the climatology section as Figure A1 from which $I/I_{\max}$ can be obtained. The fraction of reflected insolation, n_g , intercepted by the collector from the reflector element ΔA can be determined by means of a layout or analytically using solar elevation and bearing angles from Figure A2. The angle of incidence is defined as follows:

$$\cos \theta_t = \cos (L - \beta) \cos \delta \cos (\omega - \varphi) + \sin (L - \beta) \sin \delta$$

where: L = latitude

β = tilt angle of the reflector toward the south from horizontal

δ = declination angle

ω = hour angle, angle between the meridian plane passing through the sun and the meridian plane passing through the location under consideration.

φ = bearing angle measured from south

Making use of the expression defined above, N_G was calculated for the months of June and December. The values shown in Figure A7 for the remaining months represent a straight line interpolation between the months of June and December. This would indicate that between 30% and 40% of the radiation incident upon the collector is not intercepted by the collector. More recent detailed analyses have indicated however that a straight line approximation between June and December is conservative and that in actuality the percentage radiation intercepted peaks at approximately 90% in March and September resulting in a 10% to 40% interception loss. It should be pointed out that AAI is currently in an advanced stage of development of a computer program which will accurately solve for the interception loss as a part of the overall performance of the solar concentration. Accurate calculations making use of this program to predict concentrator output performance will be made early in the proposed program and the required system adjustments, if any, will be made at that point.

With the transmission efficiency established in the preceding paragraphs, referring back to Figure A7, the available daily radiation at the collector is defined as

$$Q_A = N_T \Delta A_R \bar{H} \sum \frac{H_{ot}}{A_R H_{oh}}$$

where: N_T = transmission efficiency

H_{ot}/H_{oh} = ratio of radiation incident on a tilted plate to that incident upon a horizontal plate

ΔA_R = elemental area of the reflector

$\bar{H}$ = average daily solar radiation incident upon a horizontal surface.

The section on climatology includes $\bar{H}$ values for Washington, D.C., in Figure A3. The equation for H_{ot}/H_{oh} is as follows, (1)

$$\frac{H_{ot}}{H_{oh}} = \frac{\cos(L-\beta)[\sin \omega_s - \omega_s \cos \omega_s']}{\cos L[\sin \omega_s - \omega_s \cos \omega_s]}, \text{ if } \omega_s \leq \omega_s'$$

$$\frac{H_{ot}}{H_{oh}} = \frac{\cos(L-\beta)}{\cos L} \left[\frac{\sin \omega_s' - \omega_s' \cos \omega_s'}{\sin \omega_s - \omega_s \cos \omega_s} \right], \text{ if } \omega_s' \leq \omega_s$$

where: $\cos \omega_s = -\tan L \tan \delta$

$\cos \omega_s' = -\tan(L-\beta) \tan \delta$

Corporation

2. Thermal Losses from the Collector

The equation defining heat loss from the collector to the surroundings is,

$$Q_L = U_L A_c \Delta T t$$

where: U_L = heat transfer coefficient

A_c = collector frontal area

T = temperature

t = time

$$U_L = U_{UP} + U_{DOWN} + U_{EDGE} \frac{A_p}{A_c}$$

where: A_p = perimeter area

Figure A11 , taken from reference 1, shows calculated values of heat loss coefficient versus temperature differential for various flat plate collector configurations. It should be noted that the proposed concentrator collector is upside-down compared to the standard flat plate collector. From reference 4 we find that horizontal plates with the warm side facing upward transfer about twice as much heat as flat plates with warm side facing down. With this in mind, we will modify the heat losses in Figure A11 to fit our case by dividing the upward losses by 2 and multiplying the downward losses by two. The upward side of the collector in Figure A11 is the glass cover which in our case is facing downward. We

Corporation

Computed heat losses from large flat plate collectors.

30° tilt, 1" airgaps, ambient temperature 70°F

External heat loss coefficient 4 Btu. hr sq ft °F (10 mph wind)

Heat Loss Upwards ($q_r + q_c$)

Key: BG	Normal Black	E = 0.95	One Glass Pane
BGG	Normal Black	E = 0.95	Two Glass Panes
BFG	Normal Black	E = 0.95	One Glass, One Film
SG	Selective Black	E = 0.12	One Glass Pane
SGG	Selective Black	E = 0.12	Two Glass Panes
SFG	Selective Black	E = 0.12	One Glass, One Film

Heat Loss Downwards

$q_b(0.18)$ Rear Loss For $h_{rear} = 0.18$ (c 2" insulation)

$q_b(0.12)$ Rear Loss For $h_{rear} = 0.12$ (c 3" insulation)

(Film is assumed 83% transparent and 17% reflective to long wave radiation)

Figure A11
[Ref. 1]

will also assume that the heat loss coefficient for the sides is equal to the heat loss coefficient from the rear.

In determining the temperature difference between the water temperature and ambient air temperature it is assumed that the water will be maintained at 180° during the heating season and 220° during the cooling season. This will reduce the heat loss during the winter months. The curve SG will be used from Figure A11 which assumes a single glass pane cover with a selective black coated absorber. The resulting heat losses and net available heat is shown in Figure A12. These losses, Q_L , have been reduced by 35% to account for cloudiness. If the sky is cloudy the radiation is basically diffuse and since the diffuse radiation has already been subtracted, no losses need be considered during cloudy periods.

The amount of energy which can be supplied to the heating and cooling system is plotted in Figure A13 versus the required input to the heating and cooling system. The required energy input is determined by dividing the heating and cooling output as plotted in Figure A6 by the efficiency and coefficient of performance, respectively. The hot water heating system is assumed to have an efficiency of 85%. Based on manufacturer information, the coefficient of performance for the air-conditioning system is 66%. AAI's concentrator supplies 84% of the required energy input neglecting the excess energy supplied in March, April and September. However, because of variations in weather, and other losses, we expect to provide 75% of the heating and cooling energy.

Thermal Losses at the Collector & Daily Net Energy Collected
(19° Azimuth Orientation)

Figure A12

$$Q_{\text{Net}} = Q_A - .65 U_L A_c \Delta T \Delta t$$

$$A_c = 352 \text{ Ft}^2; A_p = 240 \text{ Ft}^2$$

Month	Q_A^* BTU x 10 ⁶	T_w °F	T_o^{**} °F	ΔT °F	$U_L \Delta T^{***}$ Btu/ft ² /hr	Δt^{****} Hrs.	Q_L Btu x 10 ⁶	Q_{net} Btu x 10 ⁶
Jan.	1.006	180	38.4	142	78.2	7.1	0.127	0.879
Feb.	1.206	180	39.6	140	77.0	7.8	0.137	1.069
Mar.	1.430	180	48.1	132	72.0	8.5	0.140	1.290
Apr.	1.530	180	57.5	122	65.6	9.4	0.141	1.389
May	1.571	220	67.7	152	84.5	10.3	0.199	1.372
June	1.684	220	76.2	144	79.5	10.3	0.187	1.497
July	1.611	220	79.9	140	77.0	10.2	0.180	1.431
Aug.	1.581	220	77.9	142	78.2	9.7	0.174	1.407
Sept.	1.569	220	72.2	148	81.9	8.9	0.167	1.402
Oct.	1.402	180	60.9	119	63.8	8.1	0.118	1.284
Nov.	1.175	180	50.2	130	70.6	7.3	0.118	1.057
Dec.	1.039	180	40.2	140	77.0	7.0	0.123	0.916

** From Ref. 1.

* From Figure A7

*** 6 inches of insulation at rear of collector.

**** Useful daylight hours.

A-26

Comparison of Heating and Cooling Loads Required as Input to the Heating System and the Air Conditioner versus the Amount of Energy Supplied by the Solar Concentrator

Figure A13

Corporation

The Effect of Orienting the Concentrator at A Bearing Angle of 19.3° West of South

The preceding analysis assumed that the bearing angle of the concentrator is 19.3 degrees west of south to coincide with the facing direction of the Padonia Elementary School. The question naturally arises as to the effect which this has on the performance of the concentrator. To predict this effect AAI has performed an analysis to compare the incident radiation on the reflector for three months of the year, March, June and December, for both 0 degrees and 19.3 degrees bearing angle. The results as displayed graphically in Figure A-14 indicate that the 19.3 degree bearing angle causes no degradation in total daily radiation during the Summer, 1.3% degradation in the Spring and Fall, and 2.5% degradation in the Winter. Figure A-15 shows the effect of other bearing angles on Winter performance for bearing angles from 0 to 90 degrees.

A desirable effect of the bearing angle, 19.3 degrees west of south, is a shift in the time at which the radiation is available toward the afternoon. Since our peak cooling loads occur in the afternoon, this can be an advantage in the Summer. There is more energy available at the time it is most needed.

Comparison of Incident Radiation on the Padonia
Concentrator for Bearing Angles of 0° (Due South)
And 19.3° West of South

Winter

Spring
&
Fall

Summer

Figure A14

Winter Performance Degradation Factors
Versus Bearing Angle for the Padonia
Elementary Concentrator

Figure A15

V. REFERENCES

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3. Carrier, W. H., et al., Modern Air Conditioning, Heating and Ventilating, second edition, Pitman Publishing Corporation, New York, 1950.
4. Brown, A. I., and Marco, S. M., Introduction to Heat Transfer, third edition, McGraw-Hill Book Co., New York, 1958.

APPENDIX B

PADONIA SCHOOL OPERATIONAL LOGIC

COLLECTOR POSITION CONTROL

The collector positioning control has 5 modes of operation consisting of overheat, tracking, search, freeze, and drain.

OVERHEAT MODE

The system will go into overheat if the hotwater tank top temperature goes over 225°F, and all collectors will run to the north stop.

The collectors will also go into overheat on an individual basis if the temperature in a given collector exceeds 250°F. In this case only the hot collector will run to the north stop.

The overheat mode is locked in until it is either manually reset or the freeze mode is activated.

The overheat mode over-rides all other modes except freeze.

TRACKING MODE

The system will be in the tracking mode whenever there is a focused beam of sufficient strength on the tracker sensor.

The collectors track on an individual basis.

The tracking mode over-rides all other modes except overheat.

SEARCH MODE

The system will be in the search mode when the direct insulation exceeds 100 BTU/ft²/hr and the tracking or overheat modes are not active.

The collectors will all sweep from one stop to the other until the focused beam falls on the tracker sensor.

The collectors can sweep in different directions at the same time.

FREEZE MODE

The system will go into the freeze mode when the direct insulation drops below 100 BTU/ft²/hr and the temperature in the center collector drops below 40°F and the tracking mode is not active.

The collectors will all run to the vertical position and drain in this mode. All collectors must be vertical to open the drain valves.

DRAIN MODE

The drain mode is active when the collector pump has not run for 1/2 hour and no other mode is active.

The collectors will run to the vertical position and drain in this mode.

All collectors must be vertical before the drain valves will open.

PUMP CONTROL

There are 5 pumps in the system consisting of the collector pump, load pump, hot water pump, chilled water pump, and the condenser water pump.

COLLECTOR PUMP

The collector pump is turned on whenever any one of the collectors is 10°F over the hotwater tank bottom temperature. The pump is locked on for 3 minutes to stabilize system temperatures and the 3 minute timer will recycle as long as the collector is 10°F over the hotwater tank bottom temperature.

After the 3 minute timer runs out, the pump will shut down when the collector Δ T falls below 1°F.

The following pumps are controlled by 2 sets of logic that are selected by setting the system in either the summer or winter mode.

LOAD PUMP SUMMER MODE

The pump logic receives the command to turn on when the cold water storage tank top temperature is below 57°F and the outside ambient temperature is over 72°F. The pump turn on is delayed 24 sec. to allow the valves in the school to switch from the school system to the solar system.

When the cold water tank top temperature exceeds 57°F or the outside ambient temperature falls below 72°F, the pump shuts off and 10 seconds later the school valves return to the school system.

LOAD PUMP WINTER MODE

The pump logic receives the command to turn on when the hot water tank top temperature exceeds 110°F and the outside ambient temperature is below 72°F . The pump turn on is delayed 24 seconds to allow the valves in the school to switch from the school system to the solar system.

When the hotwater tank top temperature falls below 110°F or the outside ambient temperature goes over 72°F , the pump will shut off and 10 seconds later the school valves will return to the school system.

The load pump will also be shut down for 5 minutes when the collector pump comes on after the collectors have drained to allow air in the collectors to clear. The school valves will not switch in this condition. In addition, the load pump will be shut down for 1/2 hour, during the drain mode. The school valves will be switched in this condition.

HOT WATER PUMP, CHILLED WATER PUMP, CHILLER, AND CONDENSER WATER PUMP

The hot water pump, chilled water pump, chiller, and the condenser water pump are all turned on at the same time.

These pumps are turned on when the hotwater tank top temperature is over 185°F and the cold water tank top temperature is over 50° and the system is in the summer mode. They will shut down if no flow is present with 5 seconds in the condenser water pump circuit. If this occurs, they must be manually restarted by switching any one of the front panel controls for these pumps to "OFF" and then back to "AUTO".

These pumps shut down when the hotwater tank top temperature drops below 160°F or the cold water tank bottom temperature drops below 45°F .

These pumps will also be turned off for 5 minutes when the collector pump comes on after the collectors have drained to allow air in the collectors to clear.

These pumps do not operate when the system is in the winter mode.

APPENDIX C

E CUBE Computer Run to Determine the Heating and Cooling
Requirements for the Padonia Elementary Cafetorium
Library and Administrative Suite

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETERIUM, LIBRARY AND ADMINISTRATIVE

NUMBER OF DAY TYPES PER MONTH

DAY TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	22	19	15	21	22	14	22	21	15	22	20	16
2	9	9	16	9	9	16	9	10	15	9	10	15

SETBACK TEMPERATURE CHANGE (DEGREES)

DAY TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SETBACK HRS	
													AM	PM
1	-8	-8	-8	-8	4	4	4	4	4	-8	-8	-8	7	7
2	-8	-8	-8	-8	4	4	4	4	4	-8	-8	-8	12	12

HOURS/DAY OF HEATING SYSTEM SHUTOFF

DAY TYPE	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		HRS O/A SHUTOFF	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
1	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	12	12	12	12	12	12	-0	-0	-0	-0	-0	-0	-0	-0	7	7
2	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	12	12	12	12	12	12	-0	-0	-0	-0	-0	-0	-0	-0	12	12

HOURS/DAY OF COOLING SYSTEM SHUTOFF

DAY TYPE	JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC		CFM DURING O/A SHUT OFF	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM		
1	12	12	12	12	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	12	12		54
2	12	12	12	12	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	12	12		54

NOTE - AM HOURS = NUMBER OF HOURS AFTER MIDNIGHT
PM HOURS = NUMBER OF HOURS BEFORE MIDNIGHT

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETERIUM, LIBRARY AND ADMINISTRATIVE

SPECIAL OPTIONS

FUEL INTERRUPTION

NUMBER OF DAYS												HEATING SHUTOFF TEMP	COOLING SHUTOFF TEMP	INSTALLED HEATING CAPACITY	INSTALLED COOLING CAPACITY
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TEMP	TEMP		
-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	417.	464.

HEAT STORAGE FACTOR = 8.00 BTU/SQ.FT./DEGREE FAHRENHEIT

HEATING POINTS

DRY BULB TEMP	O/A SENSIBLE MBTU/HR	TRANSMISSION MBTU/HR	DEW PT TEMP	O/A LATENT MBTU/HR
68	0.	-4.	41	0.
36	-103.	-56.	25	0.

COOLING POINTS

DRY BULB TEMP	O/A SENSIBLE MBTU/HR	TRANSMISSION MBTU/HR	BAL HT AT DB TEMP, MBTU/HR	DEW PT TEMP	O/A LATENT MBTU/HR	COOLING LOAD FOR BAL HT, MBTU/HR	BAL HT AT COOLING LOAD, MBTU/HR
84	24.	12.	-0.	67	87.	-0.	-0.
77	2.	1.	-0.	67	87.	-0.	-0.

ANNUAL SOLAR PEAK LOAD DISTRIBUTION WITH 100 PCT. SOLAR = 56. MBTU/HR

	JAN, NOV	FEB, OCT	MAR, SEP	APR, AUG	MAY, JUL	JUN	DEC
6AM	0.000	0.000	0.000	.443	.808	.916	0.000
7AM	.000	.226	.798	1.165	1.343	1.400	0.000
8AM	.573	1.005	1.314	1.528	1.623	1.651	.347
9AM	.954	1.260	1.499	1.653	1.719	1.737	.815
10AM	.992	1.249	1.451	1.588	1.644	1.662	.873
11AM	.917	1.035	1.225	1.370	1.437	1.450	.712
12 N	.655	.870	1.051	1.206	1.279	1.297	.574
1PM	.632	.828	1.013	1.163	1.243	1.261	.535
2PM	.524	.729	.913	1.072	1.155	1.177	.436
3PM	.341	.542	.736	.907	1.000	1.027	.260
4PM	.123	.286	.481	.673	.785	.817	.060
5PM	.000	.032	.189	.389	.527	.575	0.000
6PM	0.000	0.000	0.000	.104	.248	.303	0.000

SOLAR DISTRIBUTION TABLE PERCENTAGES									REFERENCE TIME		SOLAR
N	NE	E	SE	S	SW	W	NW	H	MONTH	HOUR	LATITUDE
10.	-0.	47.	-0.	1.	-0.	3.	-0.	39.	JUL	3PM	40.

LOCATION OF WEATHER DATA IS PHILADELPHIA, PENNSYLVANIA

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETERIUM, LIBRARY AND ADMINISTRATIVE

12 HOURS BEFORE AND AFTER ANNUAL PEAK HEATING HOUR

YR	HR	MO	DAY	TIME	D/T	DBT	DPT	CC	HEATING LOAD*	COOLING LOAD*	HEAT STORAGE	TEMP DRIFT	ELEC LOAD	PROC LOAD
5	1	1	4AM	1	32	20	1		0.	0.	-293907.	-3.67	0.	-0.
6	1	1	5AM	1	23	16	3		0.	0.	-358726.	-4.48	0.	-0.
7	1	1	6AM	1	25	8	0		0.	0.	-427216.	-5.34	0.	-0.
8	1	1	7AM	1	22	10	10		200968.	0.	-211183.	-2.64	0.	-0.
9	1	1	8AM	1	16	-1	0		95296.	0.	0.	0.00	30.	-0.
10	1	1	9AM	1	14	-5	0		81480.	0.	0.	0.00	30.	-0.
11	1	1	10AM	1	15	-5	0		74497.	0.	0.	0.00	30.	-0.
12	1	1	11AM	1	15	-5	8		65629.	0.	0.	0.00	30.	-0.
13	1	1	12 N	1	15	-4	9		37977.	0.	0.	0.00	30.	-0.
14	1	1	1PM	1	17	-5	6		92445.	0.	0.	0.00	30.	-0.
15	1	1	2PM	1	17	-3	6		97207.	0.	0.	0.00	30.	-0.
16	1	1	3PM	1	16	-2	6		125109.	0.	0.	0.00	30.	-0.
17	1	1	4PM	1	15	-4	1		228854.	0.	0.	0.00	7.	-0.
18	1	1	5PM	1	12	-7	1		0.	0.	-97801.	-1.22	0.	-0.
19	1	1	6PM	1	11	-8	0		0.	0.	-195229.	-2.44	0.	-0.
20	1	1	7PM	1	11	-8	0		0.	0.	-290615.	-3.63	0.	-0.
21	1	1	8PM	1	11	-6	0		0.	0.	-384002.	-4.80	0.	-0.
22	1	1	9PM	1	11	-5	0		0.	0.	-475433.	-5.94	0.	-0.
23	1	1	10PM	1	11	-4	0		0.	0.	-564947.	-7.06	0.	-0.
24	1	1	11PM	1	12	-3	0		85962.	0.	-640000.	-8.00	0.	-0.
25	1	2	12 M	1	13	-1	0		82713.	0.	-640000.	-8.00	0.	-0.
26	1	2	1AM	1	14	1	0		81036.	0.	-640000.	-8.00	0.	-0.
27	1	2	2AM	1	16	1	0		77694.	0.	-640000.	-8.00	0.	-0.
28	1	2	3AM	1	16	2	0		77684.	0.	-640000.	-8.00	0.	-0.
29	1	2	4AM	1	17	2	0		76007.	0.	-640000.	-8.00	0.	-0.

* EXCLUDING STORAGE. ACTUAL SYSTEM LOAD IS HEATING LOAD PLUS NEGATIVE STORAGE FROM PREVIOUS HOUR.

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETORIUM, LIBRARY AND ADMINISTRATIVE

12 HOURS BEFORE AND AFTER ANNUAL PEAK COOLING HOUR

YRHR	MO	DAY	TIME	D/T	DBT	DPT	CC	HEATING LOAD*	COOLING LOAD*	HEAT STORAGE	TEMP DRIFT	ELEC LOAD	PROC LOAD
4753	7	18	12 M	1	79	70	9	0.	0.	129187.	1.61	0.	-0.
4754	7	18	1AM	1	79	70	2	0.	0.	130669.	1.63	0.	-0.
4755	7	18	2AM	1	76	70	10	0.	0.	127107.	1.59	0.	-0.
4756	7	18	3AM	1	75	70	8	0.	0.	121948.	1.52	0.	-0.
4757	7	18	4AM	1	74	70	7	0.	0.	115226.	1.44	0.	-0.
4758	7	18	5AM	1	74	70	2	0.	0.	108645.	1.36	0.	-0.
4759	7	18	6AM	1	74	71	1	0.	0.	146423.	1.83	0.	-0.
4760	7	18	7AM	1	73	71	3	0.	73138.	0.	0.00	0.	-0.
4761	7	18	8AM	1	81	72	2	0.	224180.	0.	0.00	30.	-0.
4762	7	18	9AM	1	83	74	2	0.	253893.	0.	0.00	30.	-0.
4763	7	18	10AM	1	86	75	1	0.	266654.	0.	0.00	30.	-0.
4764	7	18	11AM	1	88	74	1	0.	299778.	0.	0.00	30.	-0.
4765	7	18	12 N	1	90	74	1	0.	335609.	0.	0.00	30.	-0.
4766	7	18	1PM	1	91	75	1	0.	268870.	0.	0.00	30.	-0.
4767	7	18	2PM	1	93	78	1	0.	273740.	0.	0.00	30.	-0.
4768	7	18	3PM	1	92	75	2	0.	244156.	0.	0.00	30.	-0.
4769	7	18	4PM	1	92	75	4	0.	140053.	0.	0.00	7.	-0.
4770	7	18	5PM	1	90	76	3	0.	0.	49996.	.62	0.	-0.
4771	7	18	6PM	1	76	71	10	0.	0.	52702.	.66	0.	-0.
4772	7	18	7PM	1	75	73	10	0.	0.	49098.	.61	0.	-0.
4773	7	18	8PM	1	76	73	10	0.	0.	47240.	.59	0.	-0.
4774	7	18	9PM	1	77	73	10	0.	0.	47092.	.59	0.	-0.
4775	7	18	10PM	1	76	73	10	0.	0.	45276.	.57	0.	-0.
4776	7	18	11PM	1	76	74	10	0.	0.	43498.	.54	0.	-0.
4777	7	19	12 M	1	75	73	10	0.	0.	41757.	.52	0.	-0.

* EXCLUDING STORAGE. ACTUAL SYSTEM LOAD IS COOLING LOAD PLUS POSITIVE STORAGE FROM PREVIOUS HOUR.

MAXIMUM SYSTEM COOLING LOAD IS 28. TONS.

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETORIUM, LIBRARY AND ADMINISTRATIVE

MONTHLY PEAK LOADS

MONTHS	HEATING PEAK (MBTU/HR)		COOLING PEAK (MBTU/HR) (TONS)			ELECTRICAL PEAK (KW)		PROCESS PEAK (MBTU/HR)	
	DAY-HR		DAY-HR			DAY-HR		DAY-HR	
JAN	417.	1- 7AM	0.	0.	0-	30.	1- 8AM	0.	0-
FEB	417.	1- 7AM	0.	0.	0-	30.	1- 8AM	0.	0-
MAR	417.	1- 7AM	155.	13.	17-12 N	30.	1- 8AM	0.	0-
APR	417.	1- 7AM	266.	24.	29- 7AM	30.	1- 8AM	0.	0-
MAY	417.	1- 7AM	334.	28.	29-12 N	30.	1- 8AM	0.	0-
JUN	0.	0-	342.	29.	29- 7AM	30.	1- 8AM	0.	0-
JUL	0.	0-	336.	28.	18-12 N	30.	1- 8AM	0.	0-
AUG	0.	0-	328.	27.	25-12 N	30.	1- 8AM	0.	0-
SEP	265.	27- 7AM	310.	26.	1-12 N	30.	1- 8AM	0.	0-
OCT	417.	10- 7AM	260.	22.	3-12 N	30.	1- 8AM	0.	0-
NOV	417.	1- 7AM	179.	15.	3-12 N	30.	1- 8AM	0.	0-
DEC	417.	1- 7AM	0.	0.	0-	30.	1- 8AM	0.	0-

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETORIUM, LIBRARY AND ADMINISTRATIVE

MONTHLY AND YEARLY SUMS OF BUILDING LOADS.

	HEATING LOAD MBTU	COOLING LOAD MBTU	ELECTRICAL LOAD KWH	PROCESS LOAD MBTU	AUX FUEL HRS
JAN	39028.	0.	5427.	0.	0
FEB	30327.	0.	4687.	0.	0
MAR	20989.	3811.	3700.	0.	0
APR	7801.	17996.	5180.	0.	0
MAY	3084.	31751.	5427.	0.	0
JUN	0.	29755.	3453.	0.	0
JUL	0.	39592.	5427.	0.	0
AUG	0.	41951.	5180.	0.	0
SEP	1466.	21591.	3700.	0.	0
OCT	10495.	17514.	5427.	0.	0
NOV	20366.	7075.	4933.	0.	0
DEC	34076.	0.	3947.	0.	0
TOTAL	167632.	211035.	56489.	0.	0

CONSUMPTION PER UNIT BASIS

HEATING LOAD MBTU/SQFT	COOLING LOAD MBTU/SQFT	ELECTRICAL LOAD KWH/SQFT	PROCESS LOAD MBTU/SQFT
16.76	21.10	5.65	0.00

ENERGY REQUIREMENTS

PADONIA ELEMENTARY CAFETERIUM, LIBRARY AND ADMINISTRATIVE

UNITIZED DATA

SOLAR LOAD	5.61	BTUH/SQFT
INTERNAL LOAD	20.02	BTUH/SQFT
MAX ELECTRIC LOAD (LIGHTS)	2.99	WATTS/SQFT
MAX ELECTRIC LOAD (MISC.)	0.00	WATTS/SQFT
MAX PROCESS LOAD	0.00	BTUH/SQFT

HEATING

COOLING

MAX TRANSMISSION LOAD	5.57	BTUH/SQFT	MAX TRANSMISSION LOAD	1.21	BTUH/SQFT
MAX O/A SENSIBLE LOAD	10.33	BTUH/SQFT	MAX O/A SENSIBLE LOAD	2.42	BTUH/SQFT
MAX O/A LATENT LOAD	0.00	BTUH/SQFT	MAX O/A LATENT LOAD	8.73	BTUH/SQFT
MAX BALANCE HEAT	0.00	BTUH/SQFT	ANNUAL COOLING PEAK	357.55	SQFT/TON
INSTALLED HEATING CAPACITY	41.70	BTUH/SQFT	INSTALLED COOLING CAPACITY	46.45	BTUH/SQFT
DESIGN HEATING LOAD	15.90	BTUH/SQFT	DESIGN COOLING LOAD	37.99	BTUH/SQFT
ANNUAL HEATING PEAK	22.89	BTUH/SQFT	ANNUAL COOLING PEAK	33.55	BTUH/SQFT
HOURS AT INSTALLED PEAK	137		HOURS AT INSTALLED PEAK	0

APPENDIX D
(SYSTEM DRAWINGS)

General Arrangement

Pedestal-Interior Wall Installation

2		1	
REVISIONS			
ZONE	LTR	DESCRIPTION	DATE APPROVED
	A	ADDED NOTES, CHG PICTURE	1-17-77 C.H.H.

57607-40042	
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED	
DIMENSIONS ARE IN INCHES	
AFTER PLATING	
TOLERANCE	
ANGLES	° ' "
DECIMAL	
2 PLACE	3 PLACE
MATERIAL:	
NOTED	

ITEM NO.	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
PARTS LIST					
<div style="display: flex; justify-content: space-between;"> 1 2 3 4 5 6 7 </div>
<div style="margin-left: 20px;"> <p>3626.01</p> <p>CONTRACT NO.</p> <p>BALTIMORE, MD.</p> <p>DRAWN BY <i>W. H. H. 1-25-36</i></p> <p>CHECKED BY <i>W. H. H. 1-25-36</i></p> <p>DESIGNED BY <i>W. H. H. 1-25-36</i></p> <p>ENGINEERING PROJECT <i>for the building 317C</i></p> </div>			<p>PEDESTAL</p> <p>TY. EXTERIOR WALL</p> <p>INSTALLATION</p>		
DESIGN ACT APP			SIZE D CODE IDENT NO. 917384 57607-40036		
APPROVAL		DATE		SHEET 1 OF 1

REVISIONS			
ZONE	LTR	DESCRIPTION	DATE

THE DESIGN AND CONSTRUCTION OF THE PADONIA ELEMENTARY SCHOOL SOLAR HEAT AND AIR CONDITIONING INSTALLATION MEETS ALL APPLICABLE REQUIREMENTS OF THE BALTIMORE COUNTY BUILDING CODE AND THE FOLLOWING CODES AND SPECIFICATIONS:

- BOCA BASIC BUILDING CODE - 5TH EDITION 1970 AND ACCUMULATIVE SUPPLEMENT 1971
- AISC SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS, 6TH EDITION, 1963
- ACI BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (A.C.I. 318-63), 1963
- ASME BOILER AND PRESSURE VESSEL CODE SECTION VIII, 1965

- LEGEND
- GRADES — 396 — OR — 396 —
 - = CATCH BASIN
 - = MAN HOLE
 - 10,000 STORAGE TANK AND CAPACITY IN GALLONS
 - //// AAI CHILLER AND INSTRUMENTATION ROOM
 - \\\\ AAI SOLAR CONCENTRATOR

APPROXIMATE DISTANCE FROM EQUIPMENT ROOM TO WATER METER HOOK-UP 550'

ITEM NO.	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
PARTS LIST					
1	1	2	3	4	5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING					
TOLERANCE					
ANGLES					
DECIMAL					
2 PLACE 3 PLACE					
MATERIAL:					
NEXT ASSY USED ON					
APPLICATION					
3626 CONTRACT NO. BALTIMORE, MD. DRAWN HORNER 2/23/76 CHECKED [Signature] 2/26 STRESS [Signature] DESIGN [Signature] ENGINEERING [Signature] PROJECT [Signature]			SITE PLAN SOLAR EXPERIMENT PADONIA ELEMENTARY SCHOOL SIZE D CODE IDENT NO. 97384 57607-40037 SCALE 1"=50' SHEET 1 OF 1		
DESIGN ACT APP			APPROVAL		
DATE			DATE		

Site Plan

Chiller and Equipment Room

REVISIONS			
NO.	DESCRIPTION	DATE	APP.
1	REVISION		
2	REVISION

- NOTES:
- 1- LIQUID ABRASIVE NON-SLIP FLOOR COVERING AVAILABLE FROM MCMASTER-CARR, CHICAGO, ILL.
 - 2- ALL WOOD SHALL BE PRESURE TREATED WITH APPROPRIATE CHEMICALS TO 1) PRECLUDE MOISTURE INDUCED DECAY 3) EXHIBIT FIRE RETARDANT PROPERTIES IN ACCORDANCE WITH SPECIFICATION ALUMNA C 208-63. AFTER TREATMENT, THE WOOD SHALL BE KILN DRIED TO A MOISTURE CONTENT OF 17 TO 19%.
 - 3- FOR DETAIL SEE DWS. NO. 57607-40137.

ITEM	QTY	CODE	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	1	5	5	5	5
6	1	6	6	6	6
7	1	7	7	7	7
8	1	8	8	8	8
9	1	9	9	9	9
10	1	10	10	10	10
11	1	11	11	11	11
12	1	12	12	12	12
13	1	13	13	13	13
14	1	14	14	14	14
15	1	15	15	15	15
16	1	16	16	16	16
17	1	17	17	17	17
18	1	18	18	18	18
19	1	19	19	19	19
20	1	20	20	20	20
21	1	21	21	21	21
22	1	22	22	22	22
23	1	23	23	23	23
24	1	24	24	24	24
25	1	25	25	25	25
26	1	26	26	26	26
27	1	27	27	27	27
28	1	28	28	28	28
29	1	29	29	29	29
30	1	30	30	30	30
31	1	31	31	31	31
32	1	32	32	32	32
33	1	33	33	33	33
34	1	34	34	34	34
35	1	35	35	35	35
36	1	36	36	36	36
37	1	37	37	37	37
38	1	38	38	38	38
39	1	39	39	39	39
40	1	40	40	40	40
41	1	41	41	41	41
42	1	42	42	42	42
43	1	43	43	43	43
44	1	44	44	44	44
45	1	45	45	45	45
46	1	46	46	46	46
47	1	47	47	47	47
48	1	48	48	48	48
49	1	49	49	49	49
50	1	50	50	50	50
51	1	51	51	51	51
52	1	52	52	52	52
53	1	53	53	53	53
54	1	54	54	54	54
55	1	55	55	55	55
56	1	56	56	56	56
57	1	57	57	57	57
58	1	58	58	58	58
59	1	59	59	59	59
60	1	60	60	60	60
61	1	61	61	61	61
62	1	62	62	62	62
63	1	63	63	63	63
64	1	64	64	64	64
65	1	65	65	65	65
66	1	66	66	66	66
67	1	67	67	67	67
68	1	68	68	68	68
69	1	69	69	69	69
70	1	70	70	70	70
71	1	71	71	71	71
72	1	72	72	72	72
73	1	73	73	73	73
74	1	74	74	74	74
75	1	75	75	75	75
76	1	76	76	76	76
77	1	77	77	77	77
78	1	78	78	78	78
79	1	79	79	79	79
80	1	80	80	80	80
81	1	81	81	81	81
82	1	82	82	82	82
83	1	83	83	83	83
84	1	84	84	84	84
85	1	85	85	85	85
86	1	86	86	86	86
87	1	87	87	87	87
88	1	88	88	88	88
89	1	89	89	89	89
90	1	90	90	90	90
91	1	91	91	91	91
92	1	92	92	92	92
93	1	93	93	93	93
94	1	94	94	94	94
95	1	95	95	95	95
96	1	96	96	96	96
97	1	97	97	97	97
98	1	98	98	98	98
99	1	99	99	99	99
100	1	100	100	100	100

- NOTES:
- 1-HARDWARE NOTED TO BE CARBON STEEL, CADMIUM PLATED.
 - 2-HARDWARE NOTED TO BE CARBON STEEL #5 GRADE (MIN. TENSILE 120,000 P.S.I.) CADMIUM PLATED.
 - 3-LIMIT SWITCH TO BE MOUNTED IN #1 POSITION PER DUFF NORTON.
 - 4-BALL SCREW ACTUATOR TO HAVE RUBBER BELLOW COVER WITH ONE GUIDE PLATE PER DUFF NORTON.
 - 5-HARDWARE NOTED TO BE ALLOY STEEL #8 GRADE (MIN. TENSILE 145,000 P.S.I.) CADMIUM PLATED.
 - 6-PIPE AND FITTINGS TO BE BLACK STEEL.
 - 7-WRAP PIPE THREADS WITH TEFLON TAPE OR PIPE DOP BEFORE SCREWING TOGETHER.

ITEM	QTY	CODE	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
54	1	1	ENL20SS		DELTA FLUID P. NEEDLE VALVE
55	2	2	8-4 FT X .55		PARKER HANFMAN CONNECTOR
51	2	2	1/2" STAINLESS STEEL SEAMLESS TUBING		1/2" STAINLESS STEEL SEAMLESS TUBING
50	2	2	8-12 CBTX-SS		PARKER HANFMAN ELBOW 90°
49	2	2	1/2" NPT X 1/2" NPT	NOTE 6	RED BUSH.
48	2	2	1/2" NPT	NOTE 6	PIPE UNION
47	4	4	1/2" NPT	NOTE 6	PIPE TEE
46	1	1	1/2" NPT X 45°	NOTE 6	CLOSE NIPPLE
45	2	2	1/2" NPT X 45°	NOTE 6	PIPE ELBOW
44	1	1	1/2" NPT X 1/2" NPT	NOTE 6	PIPE NIPPLE
43	2	2	1/2" NPT X 1/2" NPT	NOTE 6	PIPE NIPPLE
42	1	1	1/2" NPT X 1/2" NPT	NOTE 6	PIPE NIPPLE
41	1	1	1/2" NPT X 90°	NOTE 6	ELBOW
40	2	2	1/2" NPT X 1/2" NPT	NOTE 6	PIPE NIPPLE
39	1	1	57607-40164-1		THD. PROTECTOR
38	1	1	57607-40085-1		TOE SHAFT
37	12	12	3/4" DIA.	NOTE 1	LOCK WASHER
36	12	12	3/4" DIA. X 1/2" L.	NOTE 5	BOLT, HEX.
35	2	2	57607-40161-1		SADDLE
34	2	2	57607-40160-1		SPACER
33	1	1	57607-40165-1		SPACER
32	1	1	57607-40163-1		U-BOLT
31	2	2	1/4" - 20 UNC	NOTE 1	NUT
30	32	32	1/2" DIA.	NOTE 1	FLAT WASHER
29	2	2	57607-40088-1		BEARING, USS.
28	14	14	10 X 1.250 L.		SCREWS
27	1	1	57607-40155-1		PLATE, COVER
26	1	1	57607-40156-2		PLATE, COVER
25	12	12	3/4" - 10 UNC	NOTE 1	NUT
24	1	1	57607-40083-10		STRET
23	2	2	57607-40126-10		TOE SHAFT RED.
22	36	36	1/2" - 13 UNC	NOTE 1	NUT
21	2	2	57607-40162-1		U-BOLT
20	4	4	1/2" - 13 UNC X 2 1/2"	NOTE 2	BOLT, HEX.
19	32	32	1/2" DIA.	NOTE 1	LOCK WASHER
18	28	28	1/2" - 13 UNC X 2"	NOTE 2	BOLT, HEX.
17	6	6	1/2" DIA. X 2"	NOTE 1	COTTER PIN
16	2	2	2 1/2" X 3/8" TH X 1/2"	NOTE 1	ARMATLEX
15	2	2	57607-40092-1		SPT. PLATE
14	2	2	53 X 2519		SEAL
13	6	6	58 22206		McGILL BEARING
12	2	2	9120 NPP		BEARING
11	2	2	1 1/2" DIA. UNISPHERE		DODGE PILLION BLOCK
10	1	1	SK 6200-T		SK 6200-T
9	1	1	SK 6000-B		SK 6000-B
8	1	1	SK 3820-R-4		SK 3820-R-4
7	1	1	57607-90001-1		57607-90001-1
6	1	1	57607-40121-1		57607-40121-1
5	2	2	57607-40100-1		57607-40100-1</

NOTES:

1. DIMENSION NOTED TO Q OF HOLD DOWN BRACKET
2. MIRROR MASTIC: PALMER MIRROR MASTIC, PALMER PRODUCTS CORP, LOUISVILLE, KY. 40207, 1-502-893-3668
3. MIRRORS: BINSWANGER MIRROR CO, MEMPHIS, TENN., 901-323-1156
4. DAP BLACK-TITE CAULK, ASPHALT BASE, C.R. LAURENCE CO, INC.

WOOD DECKING, SEE DWG. 57607-4007B

MIRRORS SEE NOTE 3

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

ALUMINUM SIDING

DECKING

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

SECTION D-D
SCALE: 1/1"

SECTION C-C
SCALE: 1/1"

SECTION B-B
SCALE: 1/1"

SECTION E-E (2 PLCS)
SCALE: 1/1"

SECTION E-E (1 PL)
SCALE: 1/1"

ITEM	QTY	CODE	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
19	180		57607-40168		CAP
18	18		33.56" x 60"	NOTE 3	MIRROR
17	6		33.56" x 54"		
16	2		22.50" x 60"		
15	3		30.38" x 60"		
14	2		22.50" x 18"		
13	2		22.50" x 30"		
12	3		30.38" x 25"		
11	3		30.38" x 6"		
10	2		22.50" x 84"		
9	3		30.38" x 54"		
8	48		36.00" x 54"		
7	144		36.00" x 60"	NOTE 3	MIRROR
6	180		#8 x 2" L.G. WOOD		WOOD SCREW
5	1800		2-007	PARKER	O-RING
4	1800		57607-4007B	NOTE 4	BLACK CAULK
3	60		57607-4007B		HOLD DOWN STRIP
2	180		57607-4007B		HOLD DOWN STRIP
1	2350			NOTE 2	MIRROR MASTIC
				-10	ASSEMBLY
ITEM	QTY	CODE	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
1	1		36.26.01		CONTRACT NO.
2	1		BALTIMORE, MD.		DESIGNED BY
3	1		1979		CHECKED BY
4	1		1979		DESIGNED BY
5	1		1979		CHECKED BY
6	1		1979		DESIGNED BY
7	1		1979		CHECKED BY
8	1		1979		DESIGNED BY
9	1		1979		CHECKED BY
10	1		1979		DESIGNED BY
11	1		1979		CHECKED BY
12	1		1979		DESIGNED BY
13	1		1979		CHECKED BY
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95	1		1979		CHECKED BY
96	1		1979		DESIGNED BY
97	1		1979		CHECKED BY
98	1		1979		DESIGNED BY
99	1		1979		CHECKED BY
100	1		1979		DESIGNED BY

Mirror Installation

Installation-General Arrangement

4	1	57607-40044-10	SUPPORT BEAM		
3	3	57607-40081-10	COLLECTOR ASSY		
2	1	57607-40080-10	POSSIBLE PUMP		
1	1	57607-40078-10	REFLECTOR ASSEMBLY		
ITEM NO.	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
PARTS LIST					
1 1 2 3 4 5 6 7 8					
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING TOLERANCE			PADONIA		
ANGLES			INSTALLATION		
DECIMAL			GENERAL ARRANGEMENT		
2 PLACE 3 PLACE			SIZE		
MATERIAL:			CODE IDENT NO.		
NEXT ASSY USED ON			97384		
APPLICATION			57607-40200		
APPROVAL			SCALE: AS SHOWN		
DATE			SHEET 1 OF 1

TABLE A

MEMBER NO.	TENSION (+) / COMPRESSION (-)	MAX. AXIAL FORCE (KIPS)	NOMINAL SIZE	LUMBER GRADE
1	+	8.7	2x10	NO. 1
2	+	8.7	2x10	NO. 1
3	+	10.4	2x10	NO. 2 M.G.
4	+	6.3	2x10	NO. 2 M.G.
5	+	3.0	2x10	NO. 2 M.G.
6	+	4.5	2x8	NO. 2 M.G.
7	-	3.0	2x10	NO. 1 DENSE
8	-	15.0	2x10	NO. 1 DENSE
9	-	9.4	2x10	NO. 1 DENSE
10	+	1.6	2x4	NO. 2 M.G.
11	-	0	2x4	NO. 2 M.G.
12	+	6.0	2x4	NO. 2 M.G.
13	-	2.7	2x4	NO. 2 M.G.
14	+	4.9	2x4	NO. 2 M.G.
15	-	2.9	2x4	NO. 2 M.G.
16	+	5.0	2x4	NO. 2 M.G.
17	-	3.4	2x4	NO. 2 M.G.
18	+	C.G.	2x4	NO. 2 M.G.