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# DOE / NASA CONTRACTOR REPORT

DOE/NASA CR-150524

## INSTALLATION PACKAGE - SIMS PROTOTYPE SYSTEM 1A

Prepared by

IBM Corporation  
Federal Systems Division  
Huntsville, Alabama 35805

Under Contract NAS8-32036 with

National Aeronautics and Space Administration  
George C. Marshall Space Flight Center, Alabama 35812

for the Department of Energy



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# U.S. Department of Energy



## Solar Energy

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# **INSTALLATION PACKAGE - SIMS PROTOTYPE SYSTEM 1A**

## **INDEX**

	<b>Page</b>
<b>PART I - Installation Manual</b>	<b>A1</b>
<b>PART II - Operation &amp; Maintenance Manual</b>	<b>B1</b>
<b>PART III - Installation Drawing</b>	<b>C1</b>

# Installation Manual

## SIMS Prototype System 1

Prepared for the  
GEORGE C. MARSHALL  
SPACE FLIGHT CENTER  
Huntsville, Alabama

December 10, 1976

Contract No. NAS8-32036  
MSFC No. DR501-19  
IBM No. 7933626

**IBM**

**WYLE LABORATORIES**

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# INSTALLATION MANUAL FOR SIMS PROTOTYPE SYSTEM 1

## CONTENTS

	<u>Pages</u>
1. General	1
2. System Description	2
3. Installation Considerations	3
4. Subsystem Description and Installation Procedures	8
A. Collector Subsystem	9
B. Energy Storage Subsystem	21
C. Energy Transport Subsystem	22
D. Domestic Hot Water Subsystem	26
E. Control Subsystem	29
F. Auxiliary Energy Subsystem	33
G. Integration Subsystem	36
H. Testing and Balancing	41
I. SDAS - Reference	42
5. System Operation	43

# INSTALLATION MANUAL FOR SIMS PROTOTYPE SYSTEM 1

## 1. General

This manual pertains to the installation of an integrated solar heating and hot water system, designed for residential or small commercial applications. Figure 1 is a pictorial illustration of a typical installation.

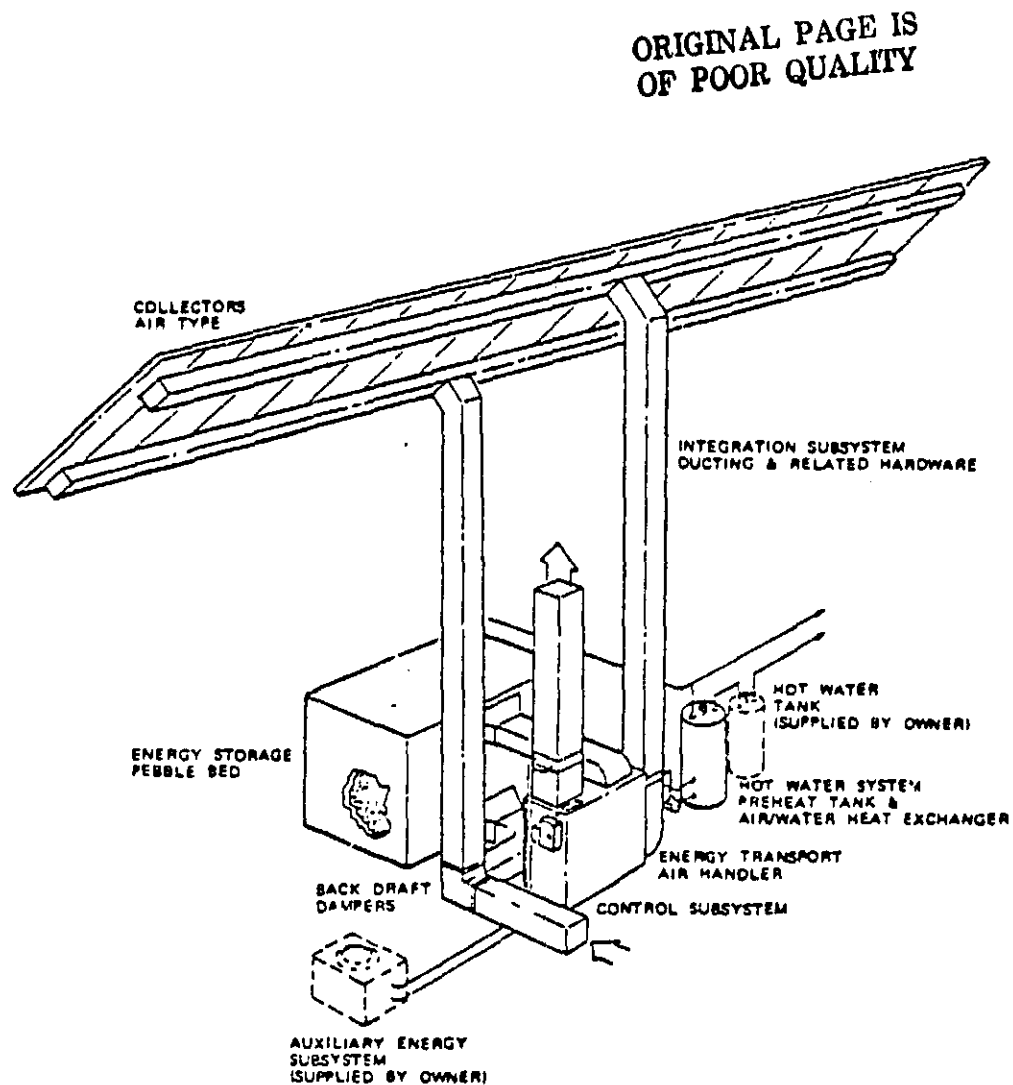


Figure 1 - Typical Solar Heating and Hot Water System using Air type collectors.



## 2. System Description

Principal elements of the system are: 1) flat plate air type solar collectors, 2) a pebble bed for thermal storage of collected solar energy, 3) an air handling unit to move and direct the air through the energy transport system 4) an air-to-water heat exchanger and circulating pump to allow for transfer of heat from the collector/storage circuit to the domestic hot water circuit, 5) a domestic hot water pre-heat tank for storage and transfer of collected energy into the conventional domestic water heater, 6) an air-to-air heat pump and electric strip heaters to supply auxiliary energy during periods of insufficient solar insolation, and 7) a ducting system to convey the solar heated air between system components and into the heated space.

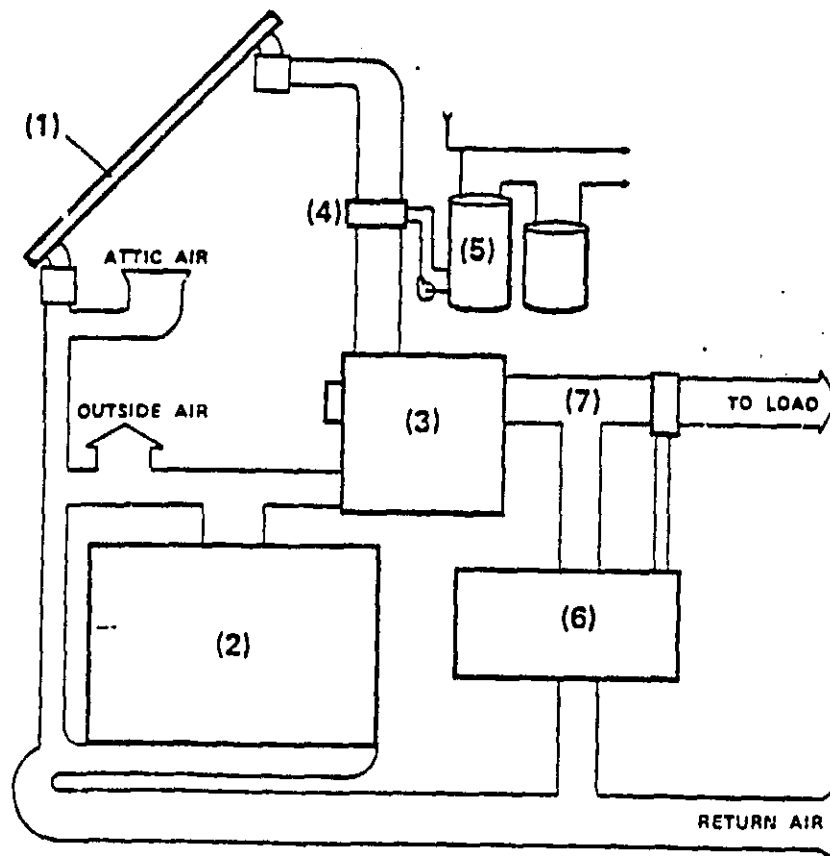
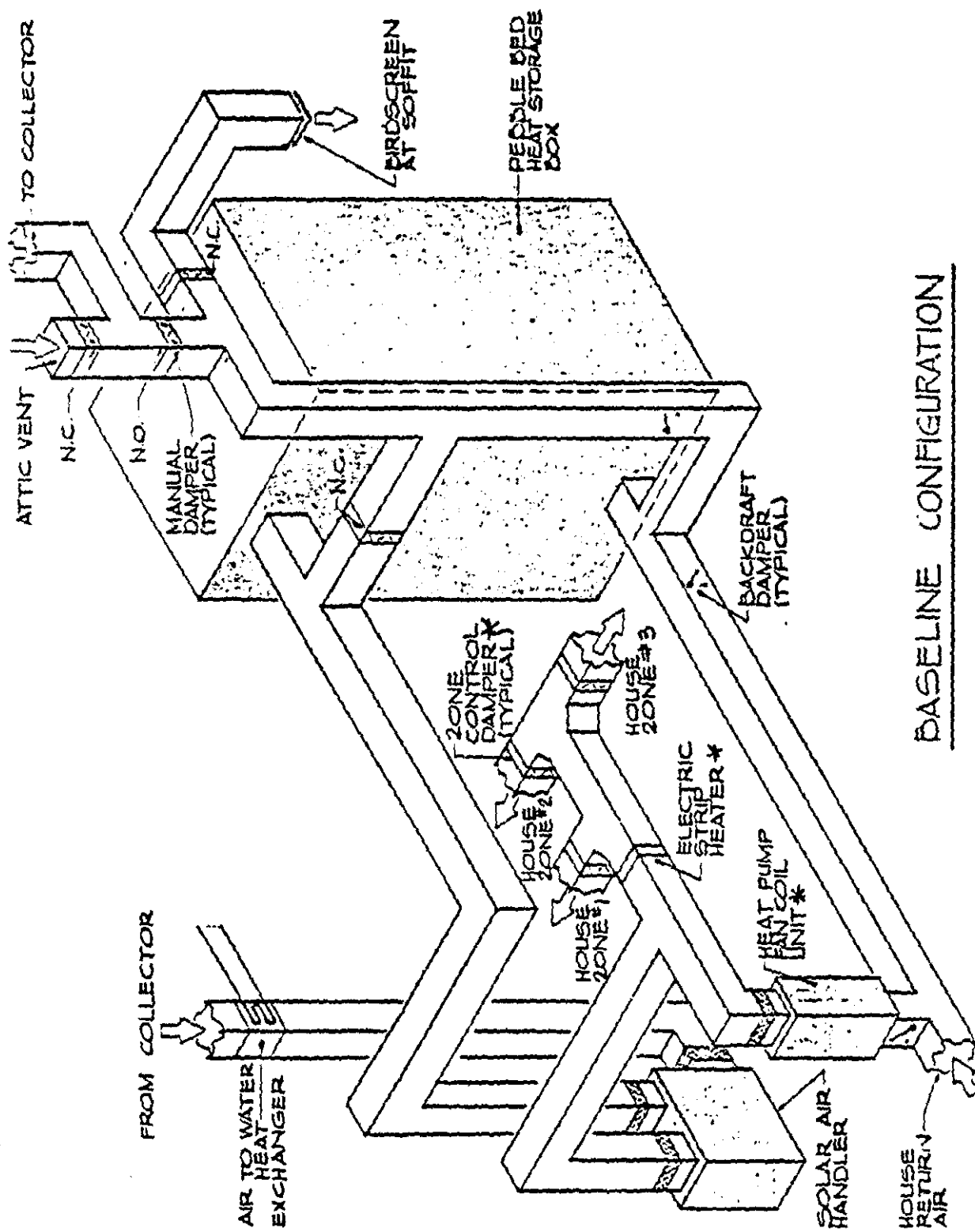


Figure 2 - Principal Elements of system

The principal elements of the system are shown schematically in Figures 3 and 4. The baseline configuration of the solar heating system in Figure 3 shows the interconnecting ductwork, control dampers, back draft dampers and the principal system elements which connect to the solar collector panels. Also illustrated is the fact that more than one house side zone can be accommodated when air flow variations are properly matched to the fan capabilities of the solar air handler.

Figure 4 illustrates hot water heating system, depicting the system principal elements and the interconnecting piping systems.

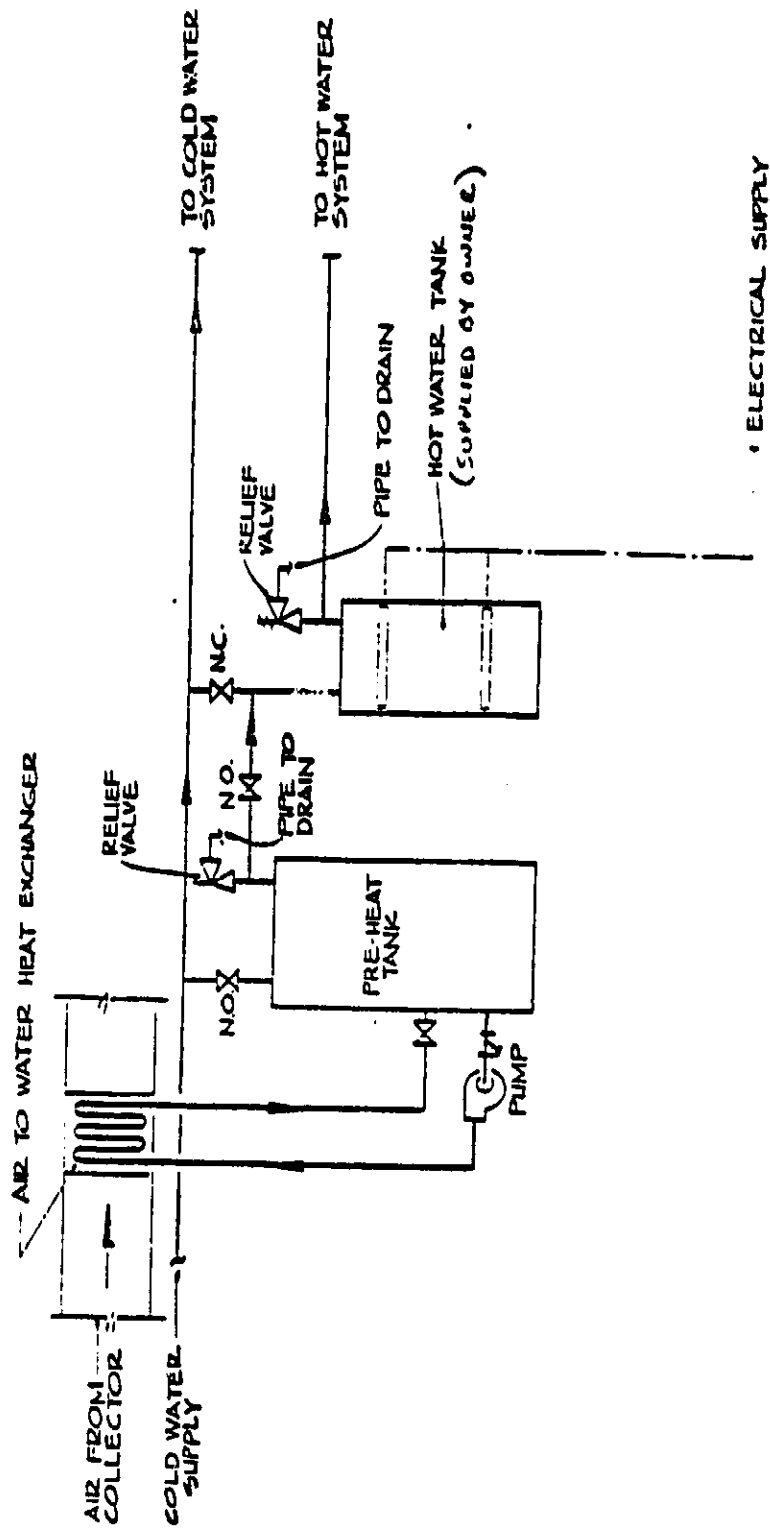
(Please refer to Figures 3 and 4 on the following pages).



BASELINE CONFIGURATION

FIGURE 3

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DOMESTIC WATER HEATING SCHEMATIC

FIGURE 4

### 3. Installation Considerations

The performance of any heating system is influenced to a large degree by the integration of the system with the total building design and the construction of the building. This is particularly true of solar heating systems. Early consideration of the solar system during building design or retrofit analysis will be an important factor in obtaining optimum performance from the system.

#### Architectural Consideration

The collector subsystem is designed to form an integral part of building structure and replace a portion of the normal roof structure. Therefore, it is important that careful consideration be given to the aesthetics of the building - collector interface and the orientation and placement of the building on the building site. For the maximum solar collection, the collectors should face due south. Variation of  $\pm 20^\circ$  of the surface azimuth angle will not have significant effect on the total relative annual insolation on the collector surface. The collectors should be tilted from the horizontal at an angle of the local latitude + 10 to  $15^\circ$  for optimum collector efficiency during winter. This angle may vary  $\pm 10^\circ$  without significant degradation of collector performance.

Other architectural considerations should include the effects of shading by the building itself, adjacent buildings, trees, etc. as these effects can seriously affect collector performance with significant decreases of available radiation.

#### Building Construction

The building construction should meet the HUD Minimum Property Standards (NBSIR 76-1059 "Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems") and all applicable local codes. Placement of the subsystems should be optimized to reduce duct runs and piping requirements.

Walls and ceilings should be insulated to R19 and R30 values respectively. Windows should be of the insulating glass type or equipped with storm windows.

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### Auxiliary Energy

The solar energy system is generally designed to supply only a percentage of the thermal energy requirements for a typical 24-hour period, at the winter design temperature.

The uncertainty of the availability of solar energy during inclement weather requires that 100% auxiliary energy be available to meet the building heating and hot water demands.

Auxiliary energy for this system can be supplied from fuel oil, gas, electric strip heaters, heat pump or a combination of the above, depending on local considerations. The size of the auxiliary energy subsystems should be calculated for 97-1/2% design temperature in accordance with ASHRAE design data.

#### 4. Subsystem Description and Installation Procedures

The subsystems that are integrated into the solar heating and hot water system are:

1. Collector subsystem
2. Energy storage subsystem
3. Energy transport subsystem
4. Hot water subsystem
5. Control subsystem
6. Auxiliary energy subsystem
7. Integration subsystem

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A summary of the characteristics of the subsystems is presented in Table 1.

*Table 1. Subsystem Summary.*

SUBSYSTEM	DESCRIPTION	MANUFACTURER/SUPPLIER
1. Collector	2' X 12' flat panel single glazing, air type manifold & feeder ducts	Solar Energy Products/EF-212 Constructed on site
2. Energy Storage	11'L x 10'H x 7'W high pebble bed with 3/4" x 1 1/4" washed river stone (Dimensions include air plenums top and bottom)	Constructed on site
3. Energy Transport	1) Centrifugal belt driven blower with built-in motor-controlled dampers. 2) 4 ea. back-draft dampers	Solar Control Corp./Series 30  American Warming & Ventilating Co./Mod SHB-P-1217 Coriastic
4. Hot Water	1) Air-co-water heat exchanger 2) 80 gal. pre-heat tank 3) Circulating pump 4) Conventional hot water heater	Halstead Mitchell/SW2-12-18-8 W. L. Jackson Mfg. Co./SOS01 Grundfos/UP 25-42 SF Supplied by owner
5. Control	1) Energy transport control 2) Hot water differential thermostat 3) Interface Control Unit 4) Auxiliary Energy control	Solar Control Corp./75-176 Rho-Sigma/106  Supplied with Auxiliary Energy Subsystem
6. Auxiliary Energy*	1) Heat pump air-co-air 2) Resistance heaters	Supplied by owner (4-ton unit selected based on cooling load) Supplied by owner
7. Integration	Duct work, piping, insulation, valves and dampers	Constructed on site

\*Although a heat pump with separate resistance heaters is shown, the Solar System is adaptable to any of the conventional energy systems such as gas, electric or fuel oil.

In addition to this installation manual, other applicable documents are:

<u>Title</u>	<u>IBM Number</u>
System Performance for SIMS Prototype SHAC System - Design No. 1	7933444
System 1 Design - Heating and Hot Water	7933608
Collector Subsystem Specification	7933609
Energy Storage Subsystem	7933610
Energy Transport Subsystem	7933611
Hot Water Subsystem	7933612
Control Subsystem	7933613
Auxiliary Energy Subsystem	7933614
Integration Subsystem	7933615
Installation Drawings	
Operation & Maintenance Manuals (General)	

A. Collector Subsystem (7933609)

The Solar Energy Products, Model EF-212, air heating solar collector is shown pictorially in Figure 5. The basic collector module is a 2 ft. by 12 ft. rectangular unit housed in an extended aluminum frame. The solar energy absorber is a corrugated, embossed aluminum sheet 0.016 inches in thickness. A one inch thick polyisocyanurate board forms the bottom of the module structure and serves as the back side thermal insulation of the collector. The module has a single glazing of 1/8" thick tempered safety glass (PPG HERCULITE RK) installed as two separate panes. The inlet air is introduced into the collector through a six inch port at the lower end of the module, passes between the corrugated absorber plate and the insulation, thence, through a six inch outlet port at the upper end of the collector. Collector modules are ganged to form a collector array as shown in Figure 6.



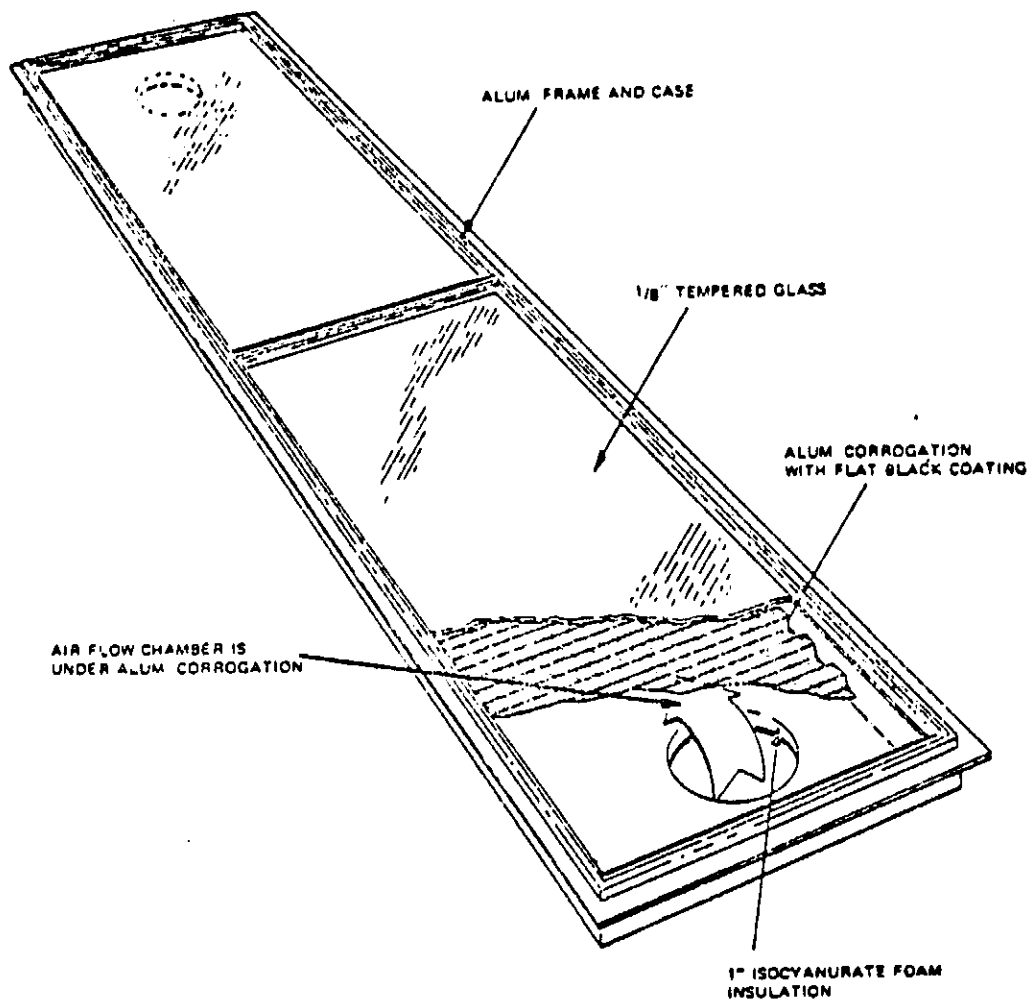


Figure 5 - Solar Energy Products, Model EF-212 Collector (Air type)

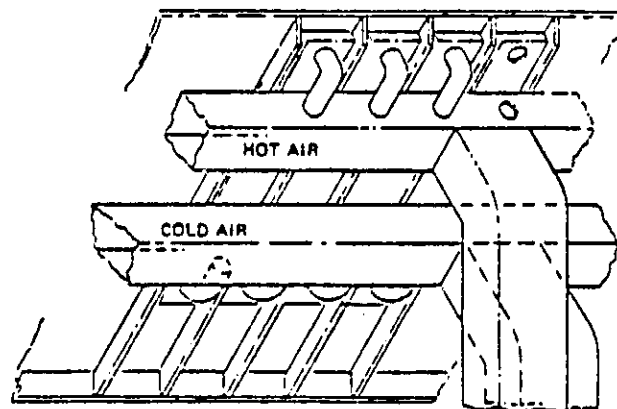


Figure 6 - EF-212 Air Collector Interconnections

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The EF-212 collectors are suitable for integral roof (flush) mounting in new construction projects, retrofit roof mounting on properly designed support structures, or adjacent-to-structure mounting on suitable ground level support frames, where roof mounting is impractical. Tilt angle for the collectors for optimum year round performance should be the local latitude plus  $10 - 15^\circ$  but a variation of  $\pm 10^\circ$  from the value results in only a nominal loss in performance. Due south orientation of the collectors is ideal but, again, a variation of  $20^\circ$  east or west causes only a small loss in collector performance.

Figure 7 shows a typical method of installing the collectors on the roof rafters.

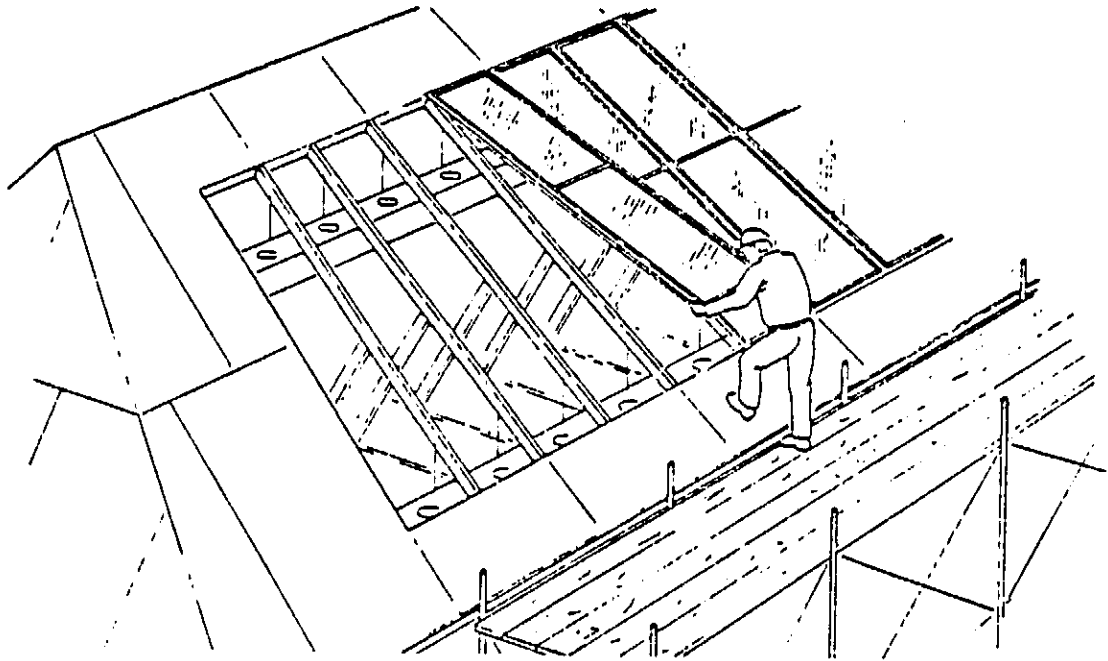


Figure 7 - "Drop-in" Mounting

Rain and moisture sealing of the collector are accomplished by rubber spline seals above and bedding compound below the glass panes. Illustration of these seals and detailed dimensional data on the collector module are presented in Figure 8.

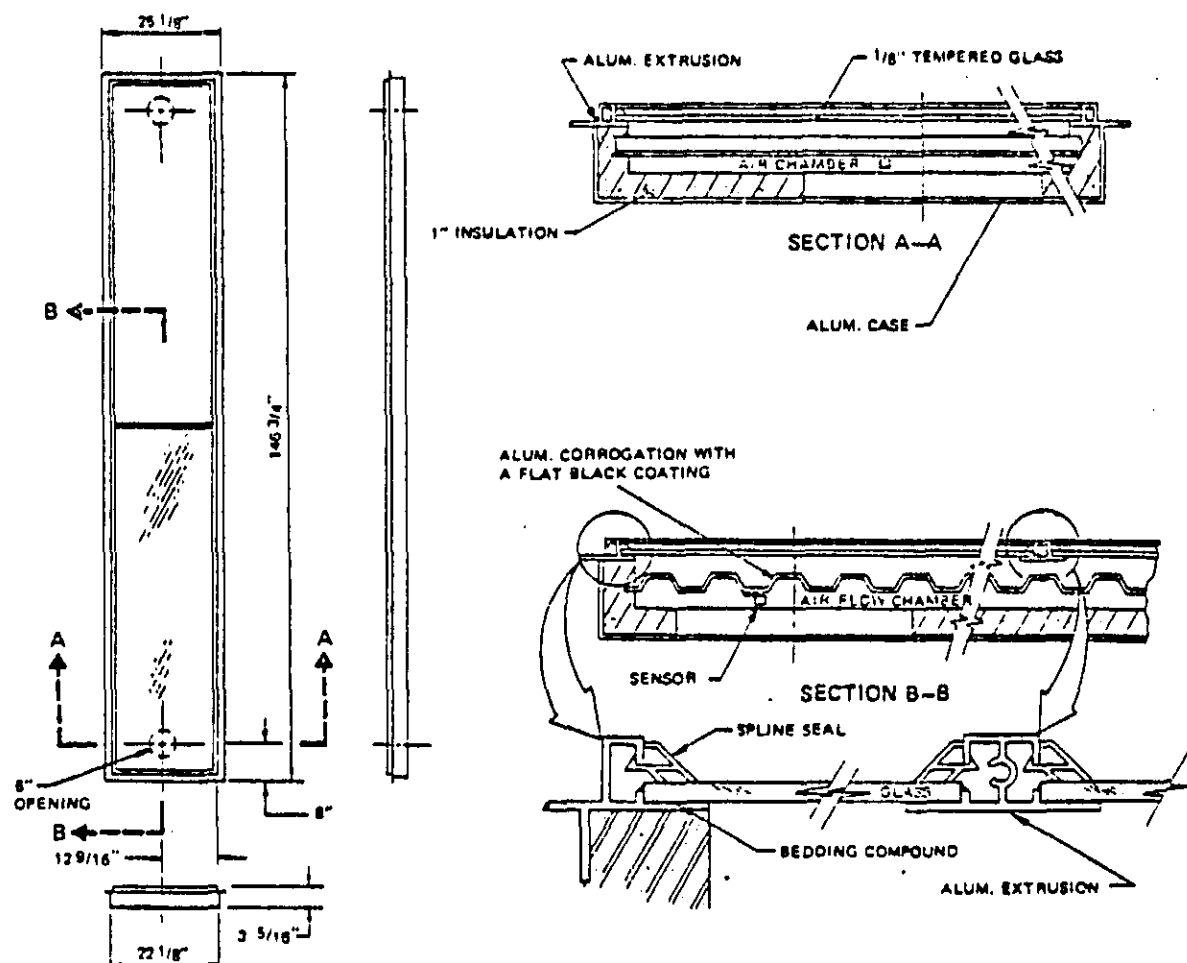


Figure 8 - Details of EF-212 Collectors

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## Installation Procedures for the Solar Collector Panels

The EF-212 Soloron solar air heater is a "Drop-In" collector, that is, it drops in between roof rafters or trusses that are located on 24 inch centers. The result is a solar collector system that is an integral part of the roof. Sheathing and roofing material for the portion of the roof area taken up by the collectors is not needed. The installation involves the following three steps:

- Preparation of the roof;
- Setting and sealing the panels; and
- Collector duct work.

### a. Preparation of the roof

- (1) Trusses or rafters must be located on 24 inch centers. The length of rafters or trusses must be greater than 12 feet.
- (2) The length of the rough opening required for each solar panel is 144 inches.
- (3) Material of the same size as the rafters is nailed in place between the rafters at each end to form a rough opening box.
- (4) Sheathing is applied to the roof. Strips of sheathing must be nailed along the top of the rafters where the panels are to be located. This forms a flush mounting surface all around the area that receives the Soloron panels. Apply 15 lb. felt as detailed.
- (5) Apply roof shingles to the lower portion of the roof up to within 9 inches of the lower edge of the rough opening.
- (6) Nail in place formed stainless steel flashing along the entire perimeter of the rough opening, including corner transitions. Do not nail thru lap. Apply sealant at joints in flashing as detailed.

b. Setting and sealing the panels (refer to Figures 9 thru 13).

- (1) Set the first solar panel in place (either the extreme left or right hand opening) making sure that there are no gaps in the neoprene gaskets and that the panel is properly seated. (Figure 11)
- (2) Drill clearance holes for 2-1/4 inch No. 10 round or pan-head wood screws and neoprene washers through aluminum flanges on one side of the panel (the left side if the first panel is on the left, the right side if the first panel is on the right). The holes should be located approximately 12 inches apart.
- (3) Screw down the left side if the first panel is on the left (right side if first panel is on the right) with 2-1/4 inch No. 10 chrome-plated or stainless steel wood screws and neoprene washers.
- (4) Skip the first rafter or truss opening to the right side if the panel is on the left or the first opening to the left if the panel is on the right and set the next solar panel adjacent to the rafter opening.
- (5) Line up bottom edge of the solar panel flanges and drill clearance holes for 2-1/4 inch No. 10 screws approximately 12 inches apart along the bottom flange of the last solar panel set and screw down the bottom edge of the last solar panel set using 2-1/4 inch No. 10 chrome-plated or stainless steel wood screws and neoprene washers.
- (6) Repeat steps 4 and 5 until all alternate solar panels are in place and secured along the bottom flange.
- (7) Set remaining solar panels, one at a time, between the rafters left open, overlapping the side flanges of both solar panels previously set. Drill clearance holes through both overlapping flanges down the sides of the collectors. Screw down the side flanges of the collectors with 2-1/4 inch No. 10 wood screws and neoprene washers.

- (8) Drill clearance holes along the remaining bottom side of the collectors and flashing not fastened; insert neoprene gaskets and screw down with 2-1/4 inch No. 10 wood screws and neoprene washers.
- (9) Drill clearance holes through the flange gasket and flashing along the top edge of the panels, insert neoprene washers and screw down with 2-1/4 inch No. 10 wood screws.
- (10) Apply Tremco "Mono" sealant all around the openings and screw heads. Make sure there are no gaps in the sealant.
- (11) Complete flashing work by installing 6 mil polyethylene sheets as detailed. Use caution to not over cut polyethylene sheets at corners to avoid risk of tearing.
- (12) Apply roofing shingles along the bottom and both extreme sides of the panel array. Insert and nail stainless steel flashing along the bottom of panel array as detailed.
- (13) Complete by applying starter strip along top edge of the collector and shingles up to the ridge of the roof.
- (14) Apply fibrated asphaltic mastic along edge of roofing shingles as detailed.
- (15) Check out the leak-tightness of the installation by hosing water over all the collectors and joints.







**DETAIL SEE DETAIL 2**



Figure 11

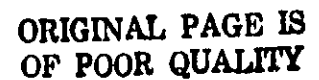


Figure 12

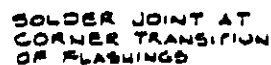
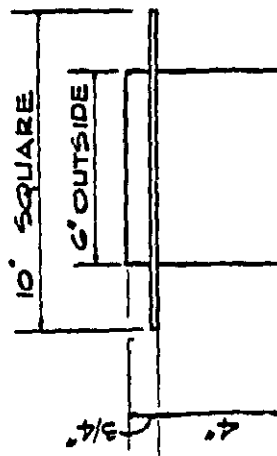


Figure 13

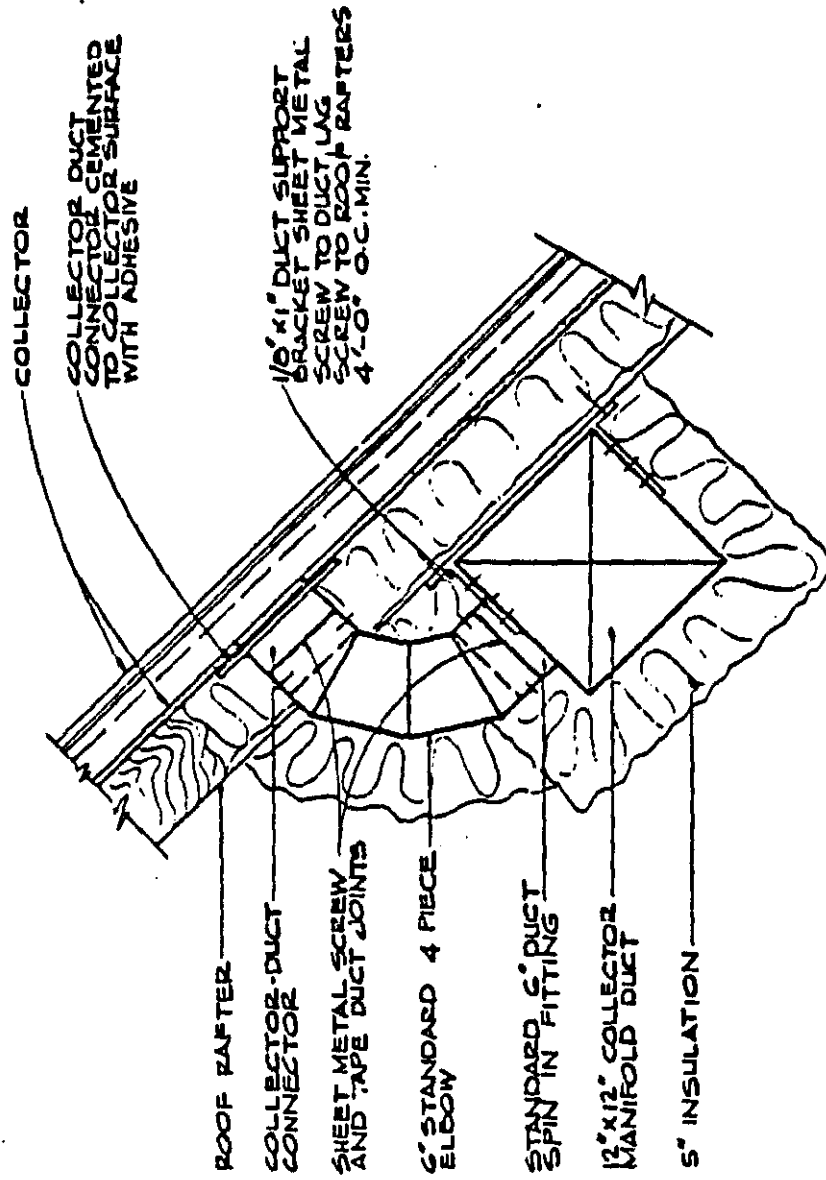
c. Collector Ductwork

After the thermal insulation has been installed behind the collector panels, the hot air manifold and cold air manifold ductwork should be installed. These manifold ducts should be hung from the roof rafters with 1/8" thick x 1" long sheet metal bands screwed to the rafters and ductwork as shown on Figure 13.1. After shop fabricating the collector duct adapters as detailed on Figure 10, they should be adhered to each inlet and outlet port of each collector panel. Prefabricated 90° els are then installed using "spin-in" connections at the manifold ducts and sheet metal screws at the collector duct adaptors. Thermal insulation is then applied to the manifold ducts and collector connections.

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COLLECTOR-DUCT CONNECTOR  
NO SCALE



DUCT CONNECTION DETAIL TO COLLECTOR  
NO SCALE

FIGURE 13.1

## B. Energy Storage Subsystem (7933610)

The energy storage unit provides a means of storing heat from the collector when available but not required to heat the building space. The stored heat can later be drawn from the storage unit and used to condition the building space when heat is not available from the collectors.

The bed consists of pebbles (river rock) of 3/4" to 1-1/2" in size in a suitable container. The rock should be washed to remove dirt that might be picked up by the air circulating through the pebble bed.

This heat storage unit can be of any shape to fit architectural considerations; however, it has been found that an approximate cubic shape offers the optimum configuration for construction, heat loss, and air flow pressure drop. Details of the pebble bed are shown in Figure 13.2.

The heat storage unit should be of masonry construction to withstand the pebble loading and also be capable of withstanding 250° F. temperatures.

The heat storage unit should be insulated to a value of R-11. This could be with roll, batts, boards, foam, or other suitable type insulating materials. Insulations, binders, jackets, adhesives, coatings, tapes and sealers must be listed and labeled by Underwriters Laboratory and have a flame spread rating of 25 or less and smoke development rating and fuel contribution rating of 50 or less when tested in accordance with ASTM E84. The roll or batt type should be applied to the outside of the structural members of the storage unit. If the insulation material is firm enough, it could be applied to the interior of the storage unit. The top and bottom of the unit must be insulated as well as the sides.

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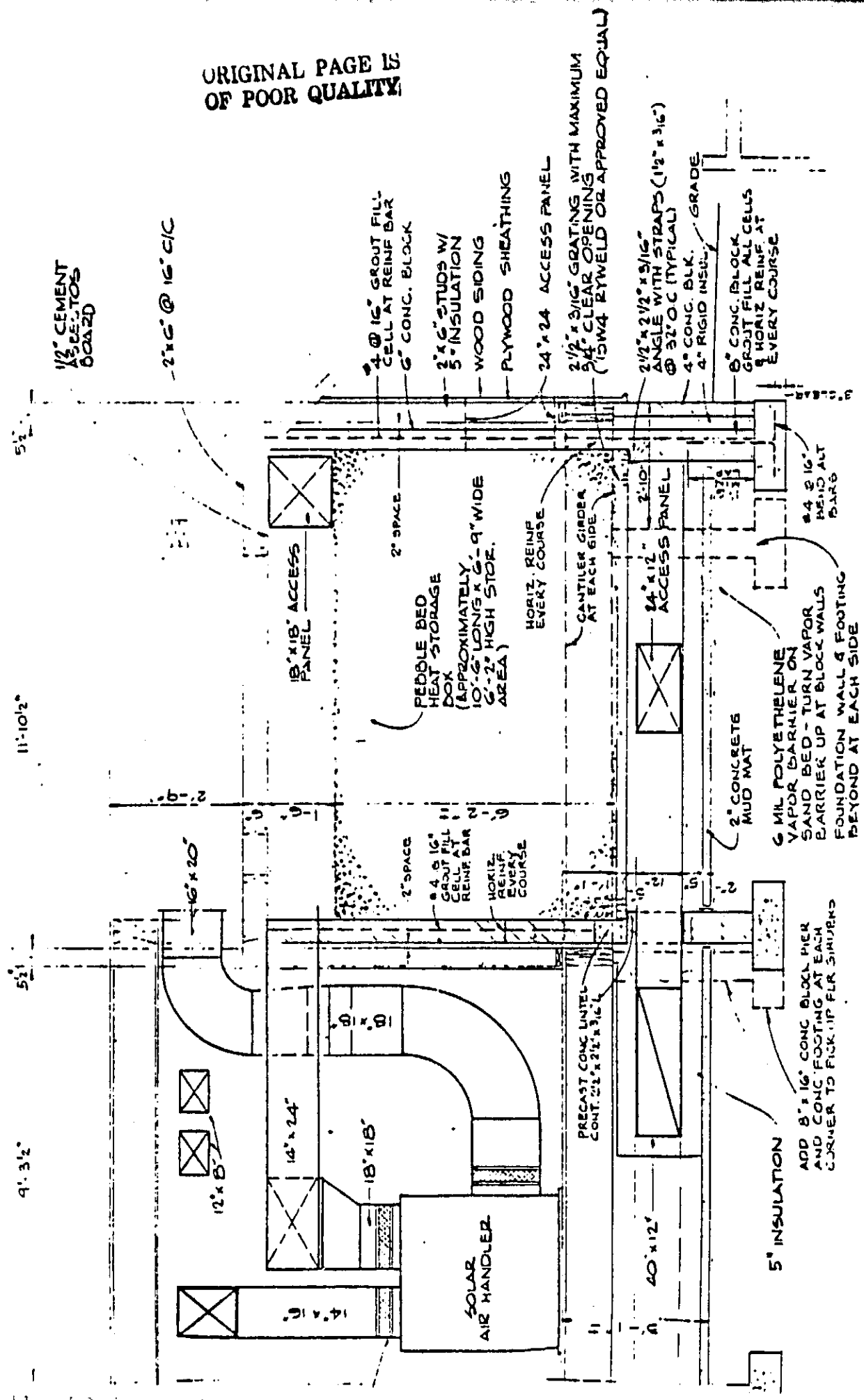


FIGURE 13.2  
-22-

A typical heat storage unit of masonry construction would consist of 8" block bearing walls with iron angles to support the metal grating. Thermal insulation is applied to the interior and bottom of this structure below the grating. A 6" block wall forms the heat storage unit above the grating. Insulation between a 2 x 6 stud framing is applied to the outside of the wall and appropriate architectural paneling is applied to the exterior of the wall system. The ceiling is constructed of 1/2" thick cement asbestos board with 2 x 6 stud framing on top and 5" insulation applied throughout.

Plenum chambers shall be located at the top and bottom of the pebble bed and shall interface directly with the solar system main ductwork.

The heat storage unit, in combination with the plenum chambers, shall completely enclose the pebble bed and form an integral structure.

Access shall be provided at the top and bottom of the pebble bed so that the pebbles can be inspected or replaced at any time. Access shall also be provided to the bottom plenum chamber for removal of any pebbles which pass through the grating.

The energy storage subsystem shall be completely enclosed and interfaced with the solar system duct insulation so that no thermal leakage can occur.

All elements of the energy storage subsystem shall be sealed to prevent air leakage from the air passages to ambient. The subsystem shall also be sealed to prevent ingress of ground water.

Vertical air flow through the bed is most efficient with the hot air being either supplied or removed at the top and the cool air removed from the bottom.

A plenum is provided at the top and bottom of the storage unit to allow connection of the air circulation system and provide a means of distributing the air throughout the pebble bed.

The energy storage unit can be located in a basement, crawl space, or below ground. Due to the weight of the pebble bed, it should not be placed above ground without adequate structural support.

Typical pebble bed density for rocks  $3/4'' \times 1-1/2''$  in size is approximately 100 pounds per cubic foot ( $\text{lbs/ft}^3$ ). Using a specific heat value of 0.2 for rock gives a heat value of 20 BTU per  $^\circ\text{F}$ . temperature difference between air in and out of the heat storage pebble bed.

A heat storage capacity designed for the range of 10 to 20 BTU/ $^\circ\text{F}$ . for each square foot of collector area will provide the optimum size of the storage unit. Building a larger than optimum storage unit does not provide proportionately more heat storage capability.

The range of 10 to 20 BTU/ $^\circ\text{F}/\text{Ft}^2$  represents approximately 50 to 100 pounds of rock per square foot of collector and  $1/2$  to 1 cubic foot of storage volume.

An additional consideration in sizing the energy storage unit is the depth and area of the unit in order to obtain a sufficient static pressure drop through the pebble bed to ensure that the air, as it circulates through the bed, will distribute evenly across the unit. The minimum recommended pressure drop is 0.15" water gauge. This pressure drop, or resistance to air flow, helps keep the hot air from 'channeling' through the pebble bed. Oversizing the storage unit reduces the resistance to air flow and makes it difficult to obtain the optimum pressure drop. The maximum pressure drop is limited by the capacity of the air circulation system.

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### C. Energy Transport Subsystem (7933611)

The Solar Control Corporation Series 20 Air Handler is shown pictorially in Figure 13.3. The metal cabinet, 42" L X 42" H X 27" W contains a centrifugal belt driven blower, a 1 HP, 115 V, low noise, high temperature motor and motorized dampers. Operation of the blower and dampers to route the air flow for the various modes of system operation is achieved through the control subsystem. A part of the control subsystem is packaged in the Air Handler.

THE MOTOR SIZE AND BLOWER SPEED ARE DETERMINED BY THE MAX. LOAD DEMANDS OF THE SYSTEM. (MOTORS ARE SPECIFIED IN TABLE 2)  
ALL 115 VAC WIRING IS TO BE UL LISTED.

TABLE 2

H. P.	MANUFACTURE	STYLE NO.	FRAME TYPE
1/4	WESTINGHOUSE ELECTRIC CORP.	317P002	FH-SC56
1/3	WESTINGHOUSE ELECTRIC CORP.	317P003	FH-SP56
1/2	WESTINGHOUSE ELECTRIC CORP.	7-7P004	FH-66
3/4	WESTINGHOUSE ELECTRIC CORP.	312P029	FH-856
1	WESTINGHOUSE ELECTRIC CORP.	311P297	FH-P56

DAMPER MOTORS WILL BE:  
DAYTON No. 3M231 WITH MAGNETIC TYPE BRAKE REMOVED.  
7 RPM, 1/100 H. P.  
0.56 FLA, IMPEDANCE PROTECTED  
115 VAC/60 CYCLES, CLOCK-WISE ROTATION (SHAFT END)

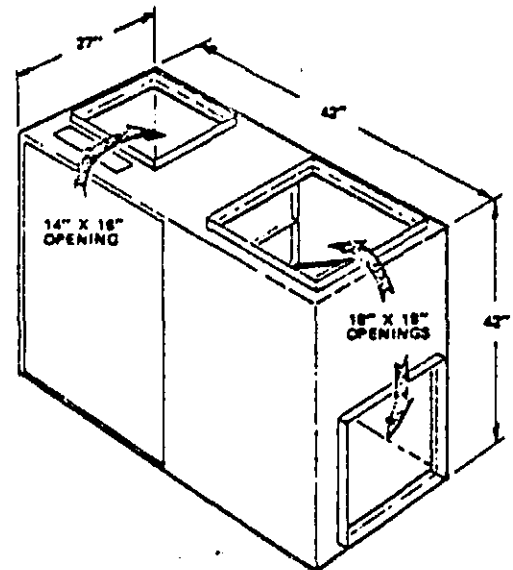


Figure 13.3 Solar Air Handler

The back draft dampers, American Warming & Ventilating Co. SHB-P-1217 are located in the interconnecting duct work. These dampers are constructed of corlastic material and are 18" L X 18" H X 3-1/2" W.

Cabinet, blower, and motor sizes and speed must be selected to ensure adequate air handling capacity to satisfy the collector, energy storage, and building design conditions.

Installation must be done in such a manner that no unplanned restrictions affect the designed static pressure of air volume. The Solar Air Handler should be mounted on 1/4" thick neoprene pad (42" L X 27" W) and anchored to the floor with a minimum of six wood screws. All ductwork connections to the unit must be

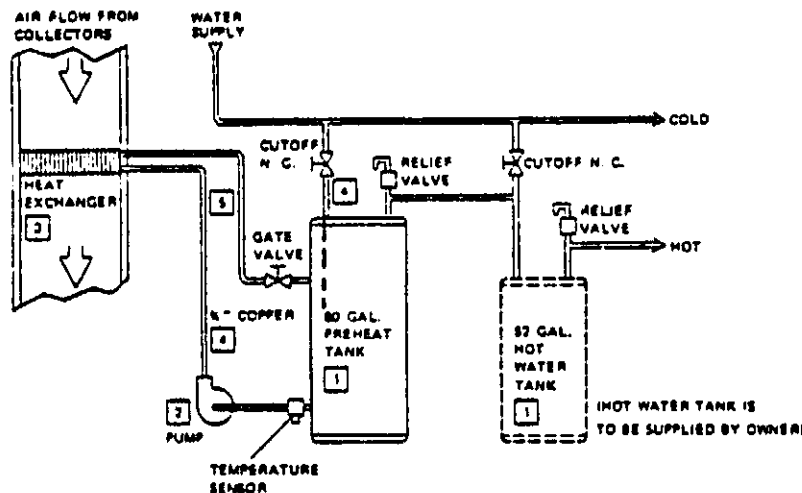
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made with flexible duct connections made of neoprene coated glass fabric.

#### D. Domestic Hot Water Subsystem (7933612)

Hot water for domestic use is provided in the solar system by means of an air-to-water heat exchanger in the air duct from the collector and a water storage tank to preheat the water supplied to the conventional building water heater. A small pump circulates water from the preheat tank through the heat exchanger coil (as illustrated in Figure 13.4). The hot air from the collector heats the water in the coil and it is collected in the preheat tank. Domestic cold water is supplied to the bottom of the preheat tank and the conventional water heater draws its supply from the preheat tank and auxiliary energy is used only if the temperature of the preheat tank drops below the water heater set point. The control subsystem turns the circulating pump on when the collector is delivering air of sufficient temperature to provide heat to the preheat storage tank. Typically, the preheat tank is set for a maximum of 145° F. storage temperature whereas the hot water tank set to maintain 140° F.



#### NOTES:

- 1 ALL TANK CONNECTIONS ARE 1/2" MPT
- 2 PUMP CONNECTIONS ARE 1/2" IPT. ELECTRICAL SERVICE FROM INTERFACE CONTROLLER BOX
- 3 HEAT EXCHANGER CONNECTIONS ARE 1/2" MPT
- 4 ALL PIPING IS 1/2" COPPER TUBING OR EQUIVALENT, INSULATED WITH A MIN. R VALUE OF 8.0 ON HOT WATER LINES
- 5 PIPING IN CIRCULATION LOOP CAN NOT EXCEED 50' OF 1/2" COPPER TUBING OR EQUIVALENT
- 6 FLANGE ISOLATION VALVES ARE USED ON INPUT & OUTPUT FROM PUMP

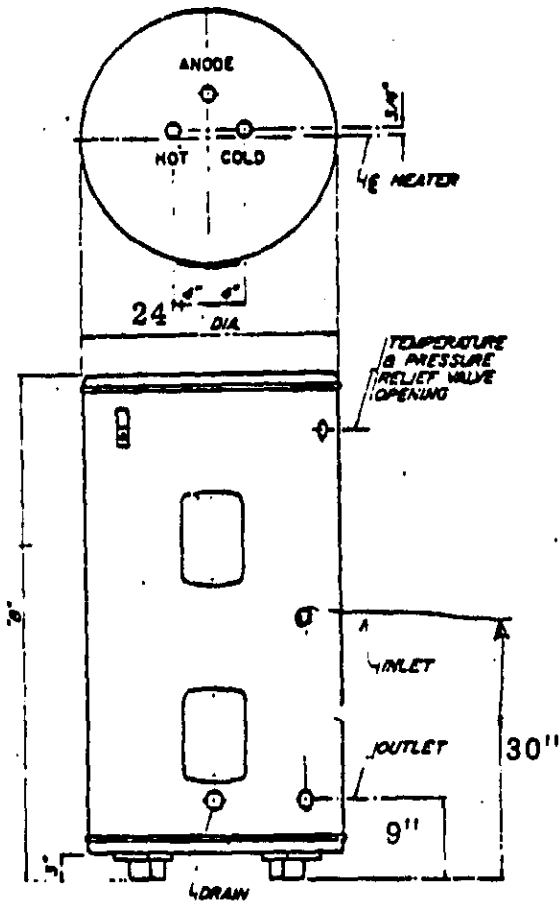
FIGURE 13.4

Components of the hot water subsystem shown in Figure 14 are:

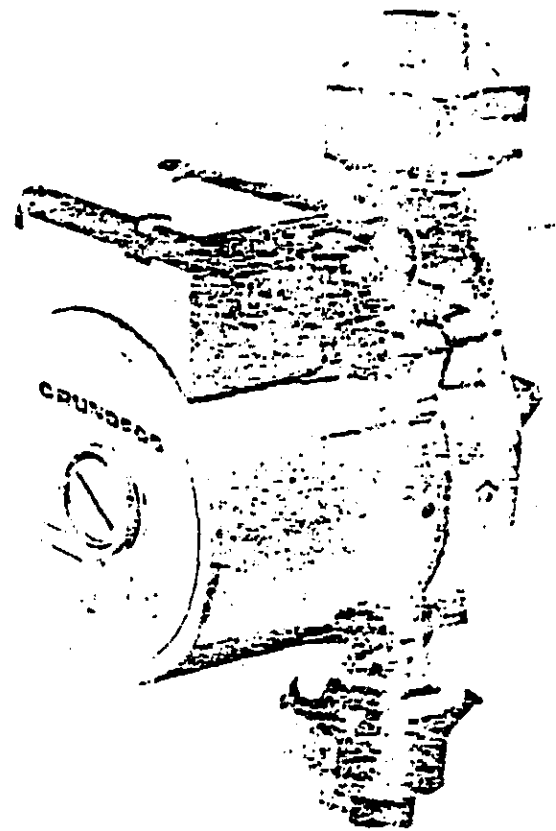
- 1) The Halstead and Mitchell, SW2-18-18-8, air-to-water heat exchanger - has a two row 5/8" O.D. tube constructed to fit into an 18" x 18" duct.
- 2) The W. L. Jackson, S08D1, preheat tank - has an 80-gallon capacity and is 24" in diameter and 73-7/8" in height, including a 2" fiberglass insulation blanket.
- 3) The circulating pump, Grundfos/UP 25-42 SF, is constructed of stainless steel with water lubricated bearings driven by a 1/20 hp, 110V ac motor.

(Please refer to following sheet).

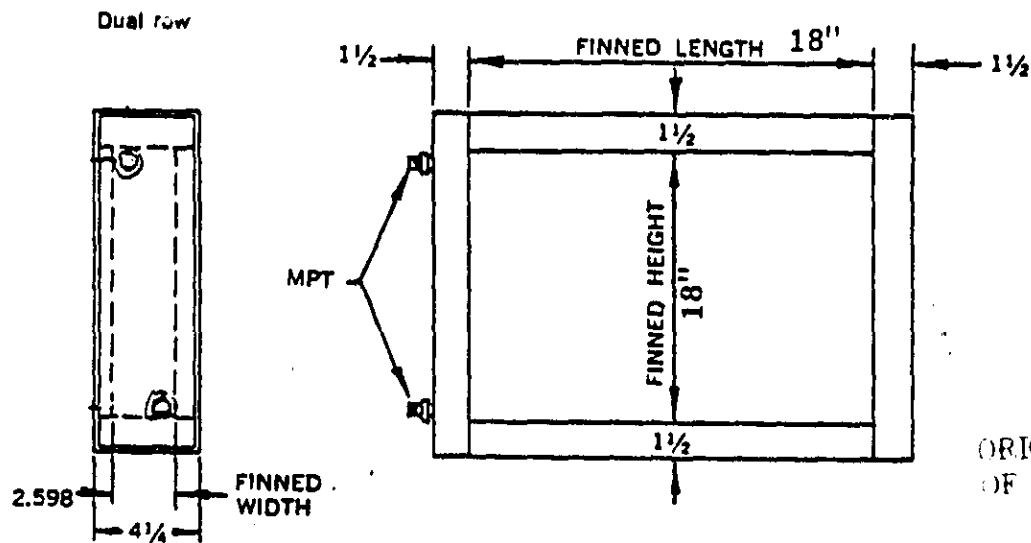
Figure 14



Pre-Heat Tank



Circulating Pump



Air-to-Water Heat Exchanger

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## E. Control Subsystem

The control subsystem provides for sequencing and control of the solar subsystems and heat pump auxiliary to establish operating modes suitable for all conditions of season and solar energy input. The functional units comprising the control system are: (1) Solar Control Corporation Model 75-176 controller (IBM P/N 7933624), (2) Rho-Sigma Model 106 differential thermostat, (3) the conventional control circuit supplied with the heat pump, and (4) an interface control unit, which is a unique design for this system, to interface with the GE Model WA848R1A/WE 948 C heat pump.

The solar controller (7933624) processes three temperature sensor inputs to place the energy transport subsystem in one of six (6) modes of operation. The operational modes, which are discussed in detail in Section 5, System Operation, are:

- Mode 1 - Collector-to-Room Heating
- Mode 2 - Storage-to-Room Heating
- Mode 3 - Heat Pump-to-Room Heating
- Mode 4 - Collector-to-Storage
- Mode 5 - Summer Operation
- Mode 6 - Summer Operation with Attic Vent

The solar controller is used to start and terminate collector operation in the heating season. Turn-on of the collector loop occurs when the differential temperature between the collector outlet and the bottom of the pebble bed is 30° F., nominal. Collector flow is terminated when this value of differential temperature is 15° F., nominal.

The Rho-Sigma differential thermostat provides control of the Domestic Hot Water (DHW) system. Transfer of heat from the collector loop to the DHW loop starts when the differential temperature between the collector outlet and the preheat tank is 20° F., nominal and terminates when this differential falls to 3° F.

The interface control unit provides the electrical isolation, routing and sequencing required to coordinate control of the heat pump with the solar subsystems. The unit is designed for construction by the site electrical contractor using conventional HVAC components and fabrication techniques.

Table 3 is a summary of the system conditions and parameters as a function of control mode.

Table 3 - Summary of System Conditions/Parameters

	BLDG. HEAT REQD.	SOLAR ENERGY AVAIL.	STORAGE TEMP GREATER THAN 90°F	DHW TEMP. LESS THAN DIFFERENCE	DHW PUMP	MODE
Interface	Yes	Yes	-	No	Off	1
Control Box	Yes	Yes	-	Yes	On	1
Select	Yes	No	Yes	-	-	2
Switch in	Yes	No	No	-	-	3
"Solar"	No	Yes	-	No	Off	4
Position	No	Yes	-	Yes	On	4
Select	No	Yes	-	No	Off	System Off
Switch in	No	Yes	-	Yes	On	5 - 6
"Heat Pump"	No	Yes*	-	-	-	5 - 6
Position						

\*Collector temperature is greater than maximum allowable.

-Does not apply.

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The control subsystem components are typically mounted in the mechanical equipment room near the air handling unit. Interconnecting field wiring is shown in Figure 15.

Control subsystem temperature sensor installation requirements are shown in Figure 16. Sensor wires may be 18 gauge twisted pairs for runs up to 200 feet. The two collector sensors must be mounted (with good thermal conductivity) to the absorber plate near the collector outlet. The DHW pre-heat tank sensor mounts in a standard 1/2 NPT port.

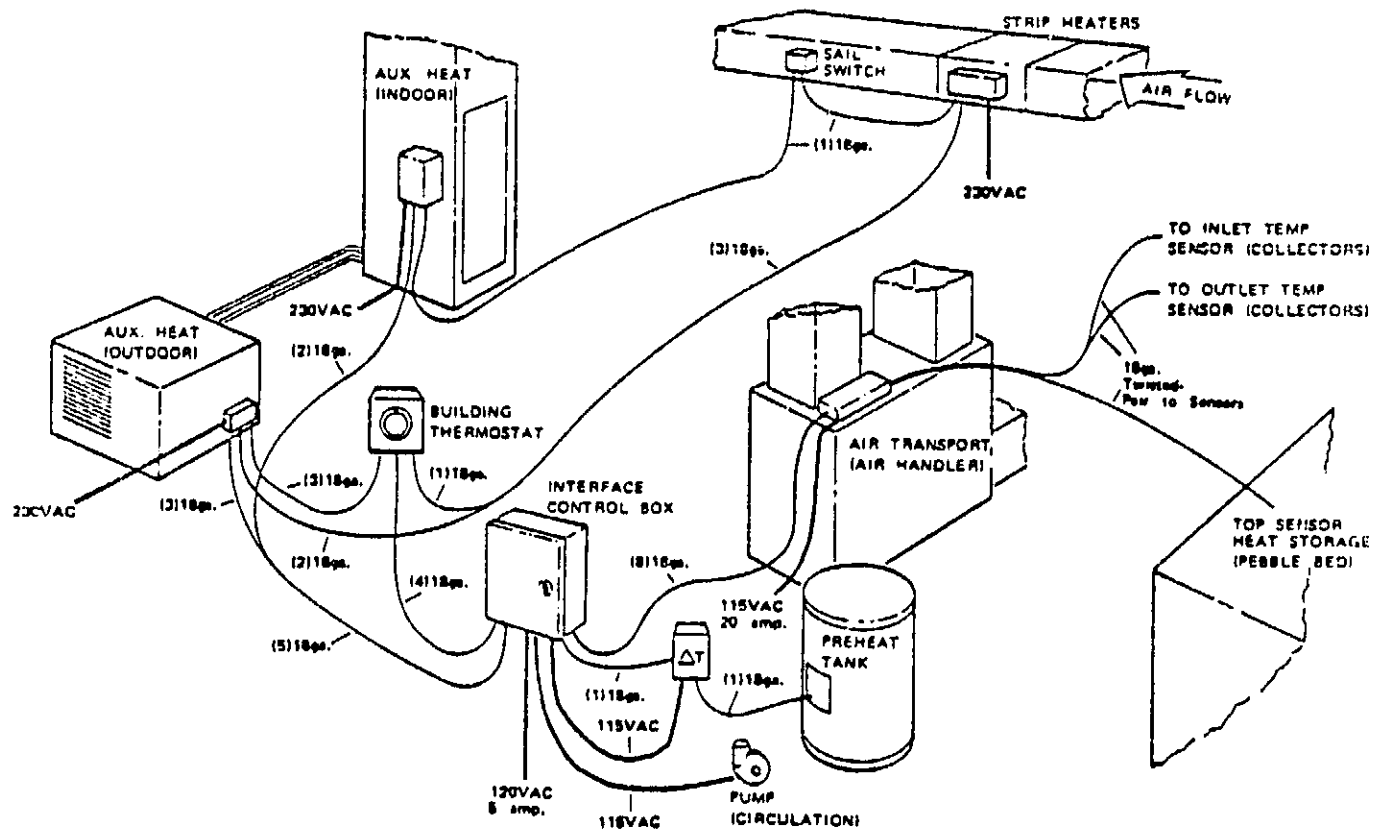
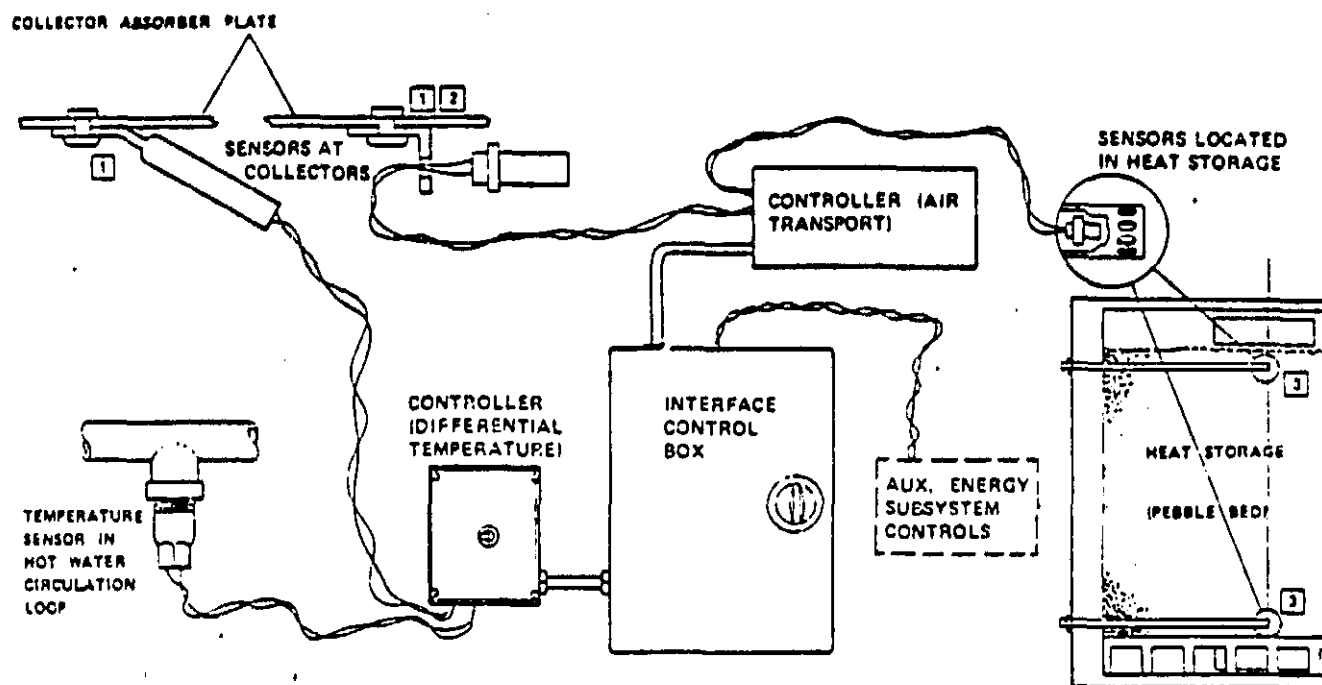


Figure 15 - Interconnecting Field Wiring



NOTES:

- 1 COLLECTOR SENSORS MOUNTED FOR GOOD THERMAL CONTACT AND MAXIMUM EXPOSURE TO AIR FLOW AT EXIT DUCT
- 2 SENSOR MOUNTING BRACKET NOT TO EXCEED  $\frac{1}{16}$ " THICK X 1" LEGS
- 3 TYPICAL ACCESS TO CENTER-LINE OF STORAGE IS AT A LEVEL 8" FROM TOP OF ROCK AND 8" FROM BOTTOM WITH CONDUIT OF  $\frac{1}{2}$ " I.D. MINIMUM

THE FUNCTIONAL UNITS ARE:

CONTROLLER (AIR TRANSPORT)	SOLAR CONTROL CORP. ZIA MODEL 75-176
CONTROLLER (DIFFERENTIAL TEMPERATURE)	RHO SIGMA MODEL 106
INTERFACE CONTROL BOX	IBM 7933S19

Figure 16 - Control Subsystem and Temperature Sensors

#### F. Auxiliary Energy Subsystem (7933613)

Since there are days when the solar energy will not be adequate to heat the building, an auxiliary system is required, designed to provide the entire heating requirements of the building.

The auxiliary heating can be supplied by heat pump, electric strip heaters, and gas or oil fired furnaces. Selection should be based on local requirements and availability of equipment. Sizing of capacity would be according to conventional building heat load calculations and code requirements.

For illustration, an air-to-air heat pump with separate outdoor and indoor units and separate auxiliary electric resistance heaters is discussed. The selection of a heat pump has several advantages:

- Higher coefficient of performance (COP) than electric heaters by themselves.
- A completely independent system in the event the solar system is unable to function.
- Cooling can be provided in the summertime.

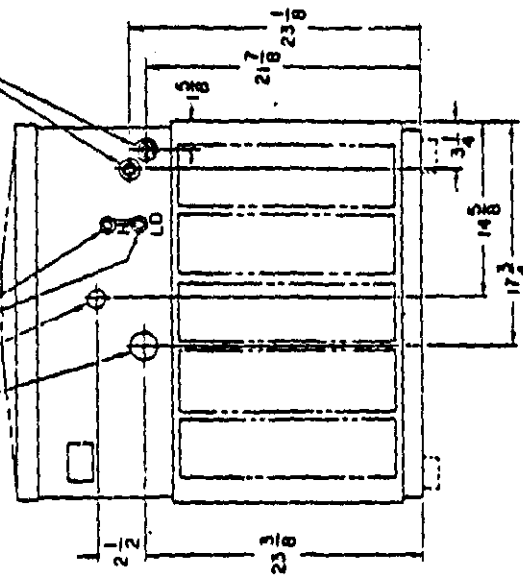
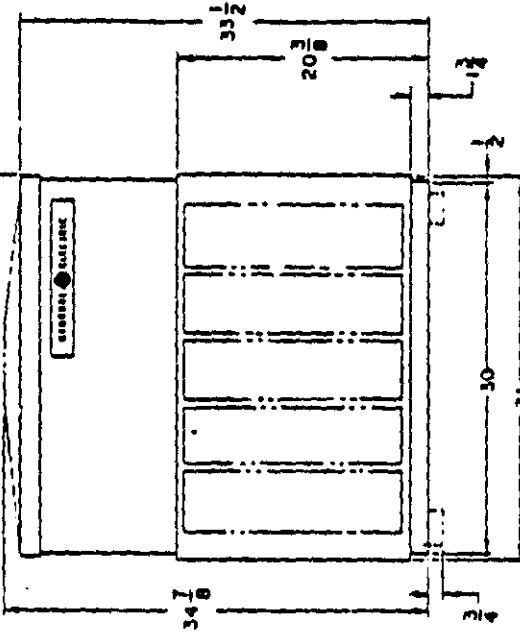
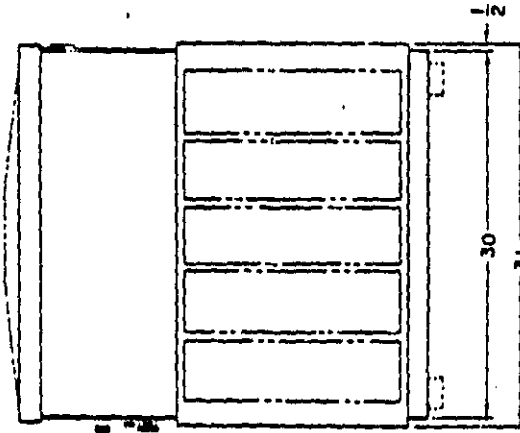
For System 1, the heat pump auxiliary energy system is not supplied by the government but is owner-selected and applied. For System 1, the recommended auxiliary energy components are a split system heat pump with a duct mounted electric strip heater. Typical components are illustrated in Figures 17 and 18.



TOP DISCHARGE AREA SHOULD BE UNRESTRICTED  
UNIT SHOULD BE PLACED SO ROOF RUN-OFF  
WATER DOES NOT POUR DIRECTLY ON UNIT,  
AND SHOULD BE AT LEAST 12" FROM WALL  
AND ALL SURROUNDING SHRUBBERY ON TWO  
SIDES OTHER TWO SIDES COMPLETELY  
UNOBSTRUCTED.

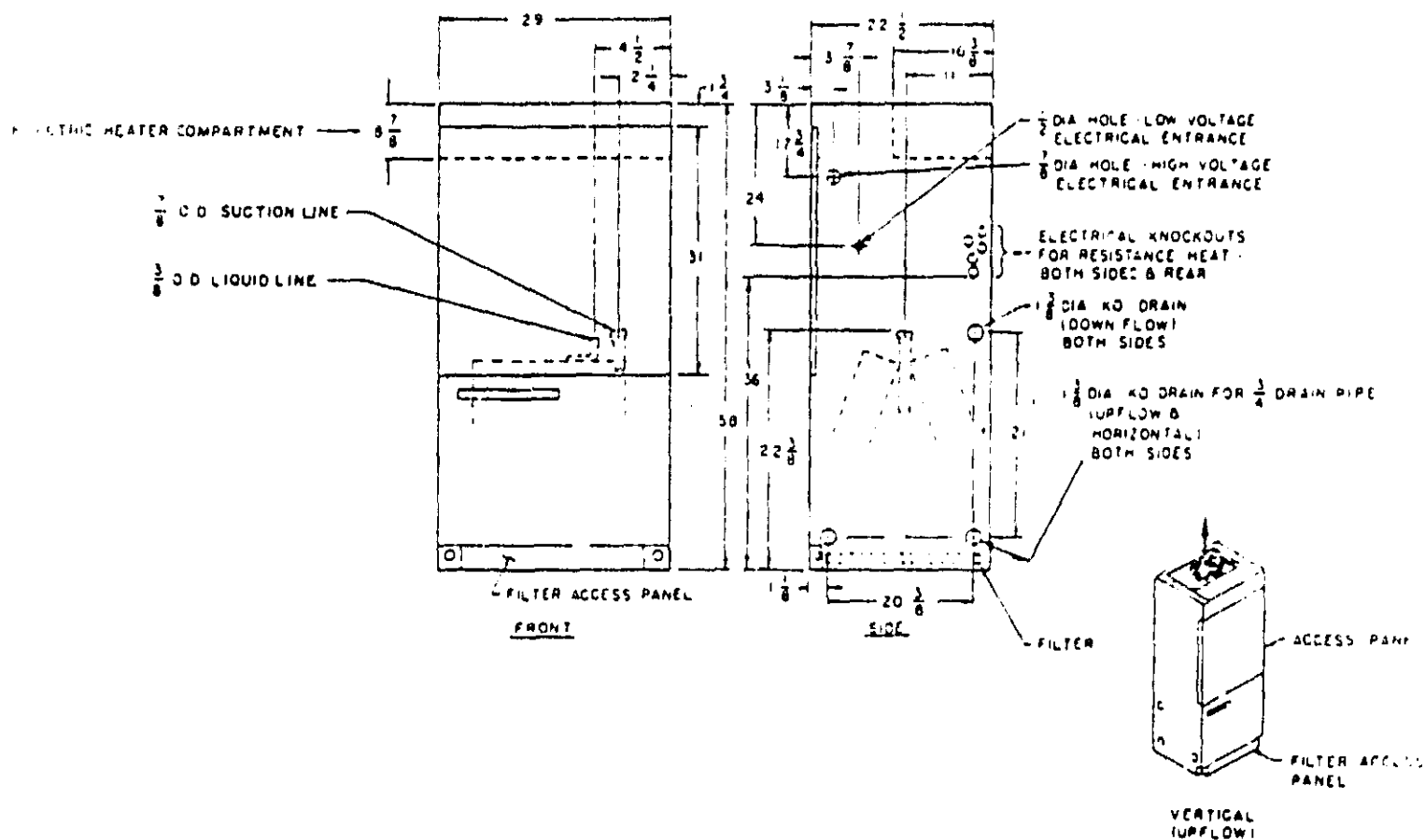
$1\frac{1}{8}$  x  $\frac{3}{8}$  DIA. K.O. FOR  
POWER WIRING  
 $\frac{7}{8}$  DIA WITH RUBBER  
GROMMET FOR  
CONTROL WIRING

GAS LINE COUPLING -  
MALE HALF - 12  
LIQUID LINE COUPLING -  
MALE HALF - 6  
PRESSURE TAPS  
FLARE FITTINGS

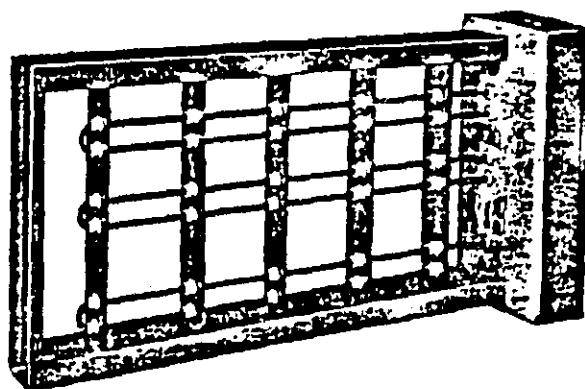


Heat Pump - Outdoor Unit

Figure 17



Heat Pump - Indoor Unit



Electric Strip Heater for Duct Mounting

Figure 18

## G. Integration Subsystem

In addition to the major subsystems discussed previously, close attention must be paid to the design, fabrication and installation of the ductwork and dampers which constitute the solar air distribution system. The best available components, interconnected by a poor duct system, will provide less than optimum performance. Performance of a solar heating system is highly dependent on proper integration of the various subsystems into a functioning system.

It is important to be familiar with the HUD Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems (NBSIR 76-1059) and the NASA Interim Performance Criteria for Commercial Solar Heating and Combined Heating/Cooling Systems and Facilities. It is assumed that the contractor is already familiar with the manuals published by the National Environmental Systems Contractors Association (NESCA) and the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE).

The building space distribution system is of equal importance to the overall success of the solar heating system and should not be overlooked. ASHRAE and NESCA manuals define the requirements for adequate distribution systems.

Sheet metal ductwork shall be made of zinc coated (galvanized) steel sheets conforming to the latest ASIM specification A-525 commercial class G90. Ductwork construction shall be in accordance with the ASHRAE guide and data book 1969. Hangers and supports shall be in accordance with SMACNA recommendations.

Ductwork shall be supported directly from the building structure and not from the supporting systems and equipment if other trades.

It is essential that all sheet metal duct systems be air tight.

All joints shall be sealed with a nonhardening sealant. Sealing compound shall be Benjamin Foster, or as approved.

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Materials used to install and insulate the integration subsystem shall be capable of withstanding temperatures from minus 10 to 250 degrees F. without deterioration.

Dampers shall provide full closure of the duct and the entire assembly shall be free of flutter and vibration. Blade widths shall not exceed 8 inches.

Damper blades shall be at least two gages heavier than the duct and of the same material.

Damper shall be accessible for adjustment in all cases.

Damper rods, quadrants, rod end, rod end bearings, etc. shall be suitable for the size damper installed.

Dampers shall be fastened securely into the ductwork with frames caulked to the ducts in such a manner to eliminate air leakage between the damper frames and the duct sides. Damper frames shall not be utilized to square ducts.

Dampers shall operate freely from full open to full closed and from full closed to full open without binding, sticking, or scraping the sides of the duct.

Manual dampers are provided for change over from summer to winter operation. This allows operation of the domestic hot water pre-heat system while bypassing the pebble bed heat storage unit. An additional benefit of the manual damper is the provision for venting the attic space.

Back draft dampers to control the direction of air flow will be equal to American Warming and Ventilating Inc. Model SHB-D-1217 as illustrated in Figure 19.

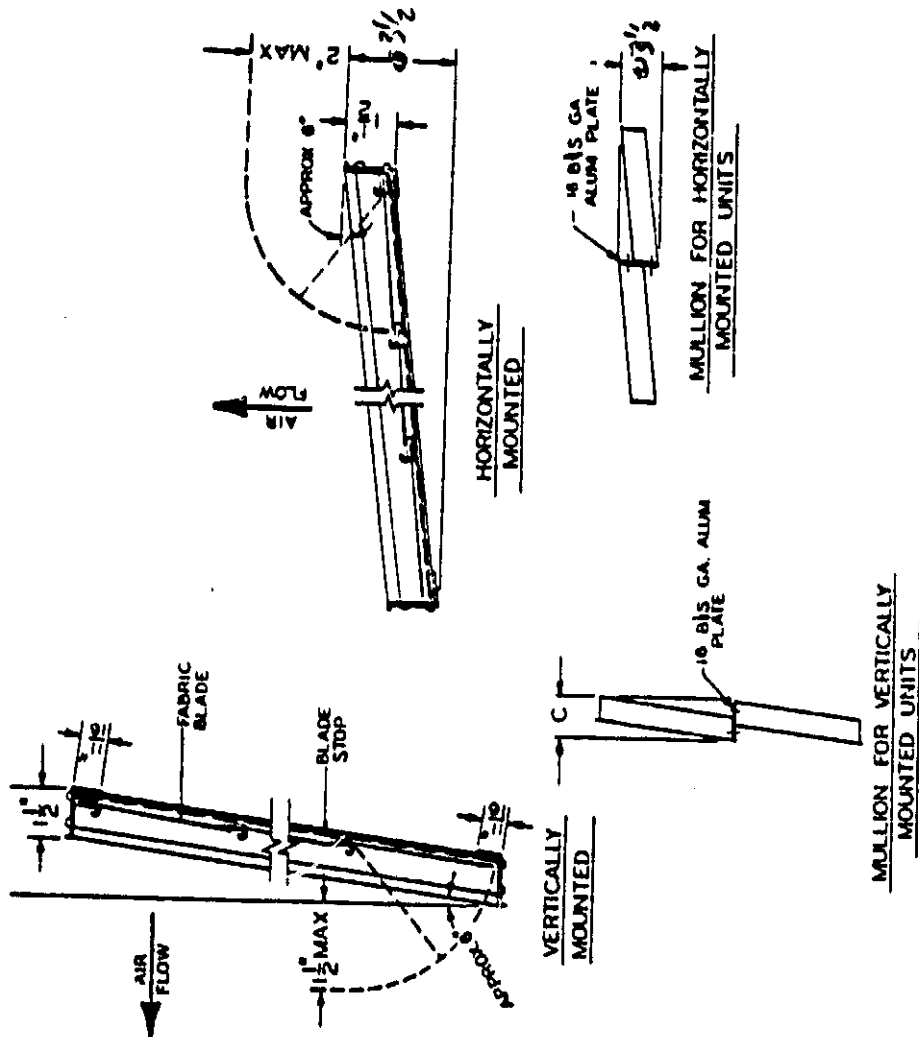
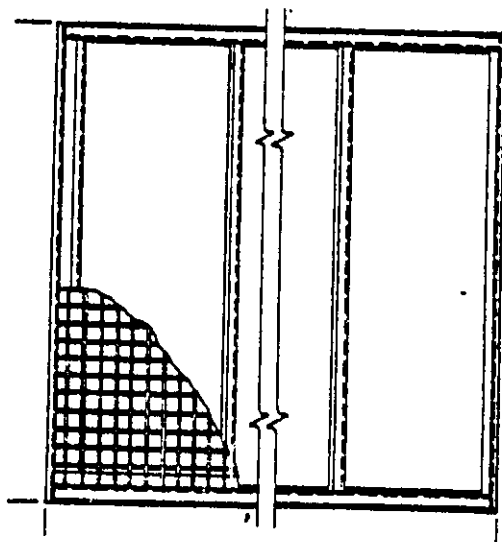


Figure 19

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The interconnecting piping valves and fittings and installation for the domestic water heating system shall be as follows:

1. Domestic hot water piping materials

<u>Item</u>	<u>Type Joint</u>	<u>Size</u>	<u>Class or Press Rating</u>	<u>Material or Spec N</u>	<u>Remarks</u>
Tubing	Solder	Up to 2-1/2 Inch	Type L	ASTM B-88	Hard Drawn
Fittings	Solder	Up to 2-1/2 Inch	Type L	ASTM B-88	Wrought Copper

2. Piping Installation

Unions and companion flanges shall be installed in the pipe lines at such locations as needed to permit the removal of fixtures, apparatus or equipment without dismantling.

All horizontal water lines shall pitch to low points to provide for complete drainage of the system. Pitch, unless otherwise shown, shall be not less than 1 inch in 40 feet. Install drain valves at low points. Air vents shall be installed at all high points and at locations where air may pocket on all water lines.

Soldered Joints for Copper Tubing

Domestic hot water piping copper joints shall be soldered with 50-50 solder composed of 50 percent tin and 50 percent lead of the wire type. Flux used with solder shall be as recommended by the solder manufacturer.

3. Insulating Couplings

In all cases where dissimilar metals such as connecting copper or brass to iron or steel arises, corrosion caused by galvanic action shall be avoided by insulating the connection by means of an insulating coupling or a dielectric flanged union. Walter Vallett Company; Epco Sales Inc.; or as approved.

**4. Valves**

Valves shall be Crane Company, Walworth, Hammond, Jenkins, Milwaukee, Lunkenheimer, Stockham, Fairbanks, Powell, or as approved.

All bronze globe and gate valves shall be equipped with a gland follower.

All valves, except check valves, shall be capable of being packed under pressure when wide open.

**5. Valve Installation**

Gate valves shall be provided at each item of equipment or fixture to permit complete isolation of that equipment or fixture from the piping system.

Gate valves are required where service is fully open or closed.

**6. Water Piping - Flushing and Cleaning**

All water piping shall be flushed at a minimum velocity of 6 feet per second in order to remove foreign matter from the system.

**7. Insulation for piping systems shall be minimum of R5.**

## H. Testing and Balancing

The ductwork and piping systems associated with solar system should be tested and balanced in the following manner:

Pressure tests on domestic water piping:

<u>System</u>	<u>Type of Test</u>	<u>Test Pressure</u>	<u>Permissible Pressure Drop</u>
Domestic Hot Water	Water	<sup>5</sup> 100 lb.	2 PSI - 2 hours

### Water Test

System shall be charged with water to the pressure specified. Exterior surface of pipe and fittings shall not show cracks or other forms of leaks and shall be completely drop dry. Tests shall be made before piping is painted, covered, or concealed.

If inspection or test shows defects, such defective work or material shall be replaced and inspection and tests repeated. Repairs to piping shall be made with new material and to the satisfaction of the authorized inspectors. Where solder joints require repair, the fittings shall be cleaned and resoldered.

### Testing and balancing of the Solar System Ductwork

Balance and adjust each system to provide air flow, pressures and capacities as indicated. Any system that does not meet these requirements shall be corrected at no additional cost to the owner. The tests shall include manufacturer's name, model number, and size of fan or unit tested. Test form shall include fan RPM, capacity, and motor nameplate data listing horsepower, amperes, voltage characteristics and RPM. The test form shall include required and actual data on fans, motors, solar collectors, pebble bed (energy storage subsystem), supply and return outlets. Position of automatic dampers during test, and all other pertinent data to provide the basis for a complete engineering analysis of the systems. Systems shall be completed prior to testing. The contractor shall provide six (6) certified copies of the test data for all systems.



Tests shall be conducted on all solar system operating modes using the instruments and forms in accordance with the National Environmental Balancing Bureau (NEBB) or the Associated Air Balance Council (AABC). All solar systems and modes shall operate without air leakage.

I. Site Data Acquisition Subsystem (SDAS) Reference

For installation which are required to meet the data collection, performance evaluation and data dissemination goals of the National Program for Solar Heating and Cooling, reference should be made to the "Instrumentation Installation Guidelines for the National Solar Heating and Cooling Demonstration Program" Manual SHC-1006. This document provides the definition of the responsibilities of both the Site Contractor and ERDA in accomplishing the required instrumentation installation.

## 5. System Operation

System No. 1 provides modes of operation which supply solar heated air either directly from the collectors or from the pebble bed storage into the house air distribution system. When solar energy is insufficient to supply the space heating needs, a full capacity heat pump will supply the house heating demand. The house heating load will be supplied either entirely from auxiliary energy; hence, there will never be simultaneous operation of the two systems during the heating season.

Domestic hot water preheating is accomplished by an air-to-liquid finned coil heat exchanger in the solar supply duct. Year-round hot water is provided since the house air distribution in the cooling season is independent of the solar system. A full capacity auxiliary hot water tank is provided to supply the hot water demand at the selected output temperature. The pre-heat tank will supply water at a preselected maximum temperature (140° F.). The conventional hot water tank will "top off" the preheated inlet water to the required delivery temperature.

The system flow diagram, Figure 20, shows the air flow control dampers with an accompanying damper schedule. Control damper and fan status is given for each of the five following modes of operation:

- Mode 1 - Collector-to-Load
- Mode 2 - Storage-to-Load
- Mode 3 - Heat Pump-to-Load
- Mode 4 - Collector-to-Storage
- Mode 5 - Summer Operation Without Attic Vent
- Mode 6 - Summer Operation With Attic Vent

Primary control is experienced by two sets of ganged double dampers internal to the Air Handler Unit (dampers D1 and D2, Figure 20). Each double damper is physically two individual blade dampers, mechanically coupled to be operated by one motor and control input. Dampers are ganged such that when damper A of a set is open, damper B will be closed. Conversely, if damper B is open, damper A will be closed.

# DAMPER SCHEDULE

DAMPER/FAN	D1	D2	MD1	MD2	FANS	
MODE	A	B	A	B	F1	F2
COLLECTOR-TO-LOAD	O	C	O	C	C	ON
STORAGE-TO-LOAD	C	O	C	C	C	ON
AUX. HEAT-TO-LOAD	O	C	C	O	C	OFF
COLLECTOR-TO-STORAGE	O	C	C	O	C	ON
SUMMER OPERATION	O	C	C	O	C	ON
SUMMER OPER.(ATTIC)	O	C	C	O	C	ON

O = OPEN C = CLOSED ON\* = HOUSE COOLING

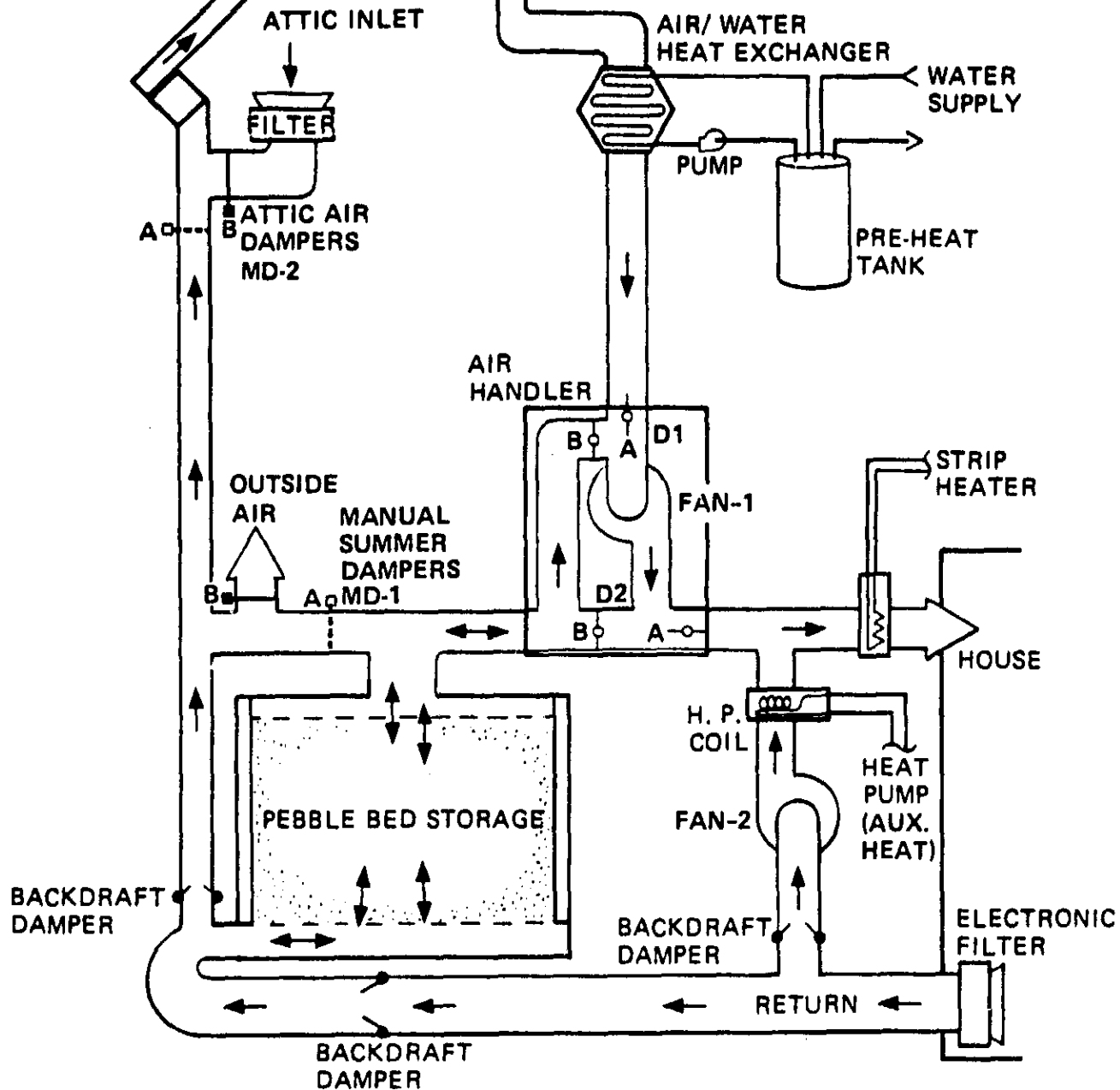


Figure 20 - System Flow Diagram

Operating modes, in order of selection priority, are discussed in the following paragraphs:

#### Mode 1 - Collector-to-Load

Figure 21 depicts the air flow in the system when the collector subsystem provides the heated air to the building. This mode will be selected when the building thermostat calls for heat and the air temperature from the collector is greater than  $T_{(out)}$  minimum and the collector is on. (See Figure 20 for damper and fan status.)

#### Mode 2 - Storage-to-Load

The control logic will select this mode of operation if Mode 1 conditions are not met and the temperature in the top of the pebble bed is greater than  $T_{(out)}$  minimum. (See Figure 20 for damper and fan status.) Figure 22 shows the air flow path in this operating mode.

#### Mode 3 - Heat Pump-to-Load

When the conditions for Mode 1 and Mode 2 cannot be met, space heating is provided by the heat pump as shown in Figure 23. In this mode, Fan F2 is on and the source of heat is the condenser coil of the heat pump. (See Figure 20 for damper and fan status.)

#### Mode 4 - Collector-to-Storage

If the building does not require heat or the solar collector cannot provide heated air above the  $T_{(out)}$  minimum but is, nevertheless, collecting usable energy, the system will operate in a collector-to-storage mode, as indicated in Figure 24. If the differential temperature between the collector outlet and the bottom of the pebble bed is greater than  $\Delta T_{(on)}$  (approximately 30° F.) - the control logic will place the system in Mode 4. (See Figure 20 for damper and fan status.)

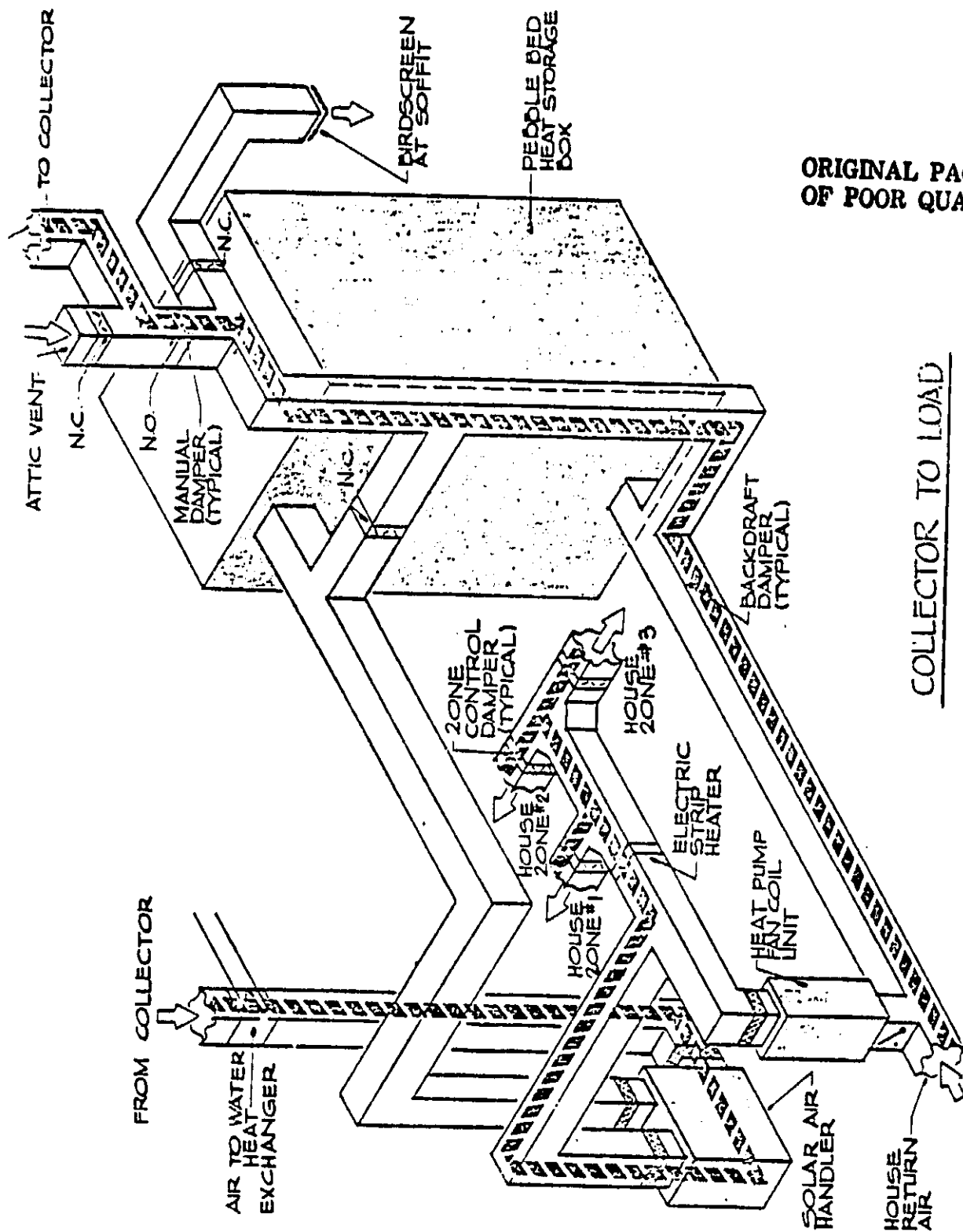
#### Mode 5 - Summer Operation Without Attic Vent

During summer or warm weather operation when space heating is not required, the system will operate in Mode 5, with flow paths as shown in Figure 25. The building air distribution is handled by Fan F2 (heat pump) in either a "Cooling" or "Fan Only" mode. In this mode, the solar collection loop will be used for hot water pre-heating only. This mode calls for operation of manual dampers MD1 and MD2 which are moved to positions shown in the Damper Schedule, Figure 4-1, to provide bypassing of storage.

### Mode 6 - Summer Operation With Attic Vent

An option exists whereby the attic and outside air dampers may be opened to provide ventilation of the attic space, and control temperature rise in the collector. Flow paths are shown in Figure 26. Operation in this mode is identical to Mode 5 except that manual damper MD-2 is opened, thereby ventilating the attic space and exhaust air damper to the outside is opened.

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MODE 1

COLLECTOR TO LOAD

FIGURE 21

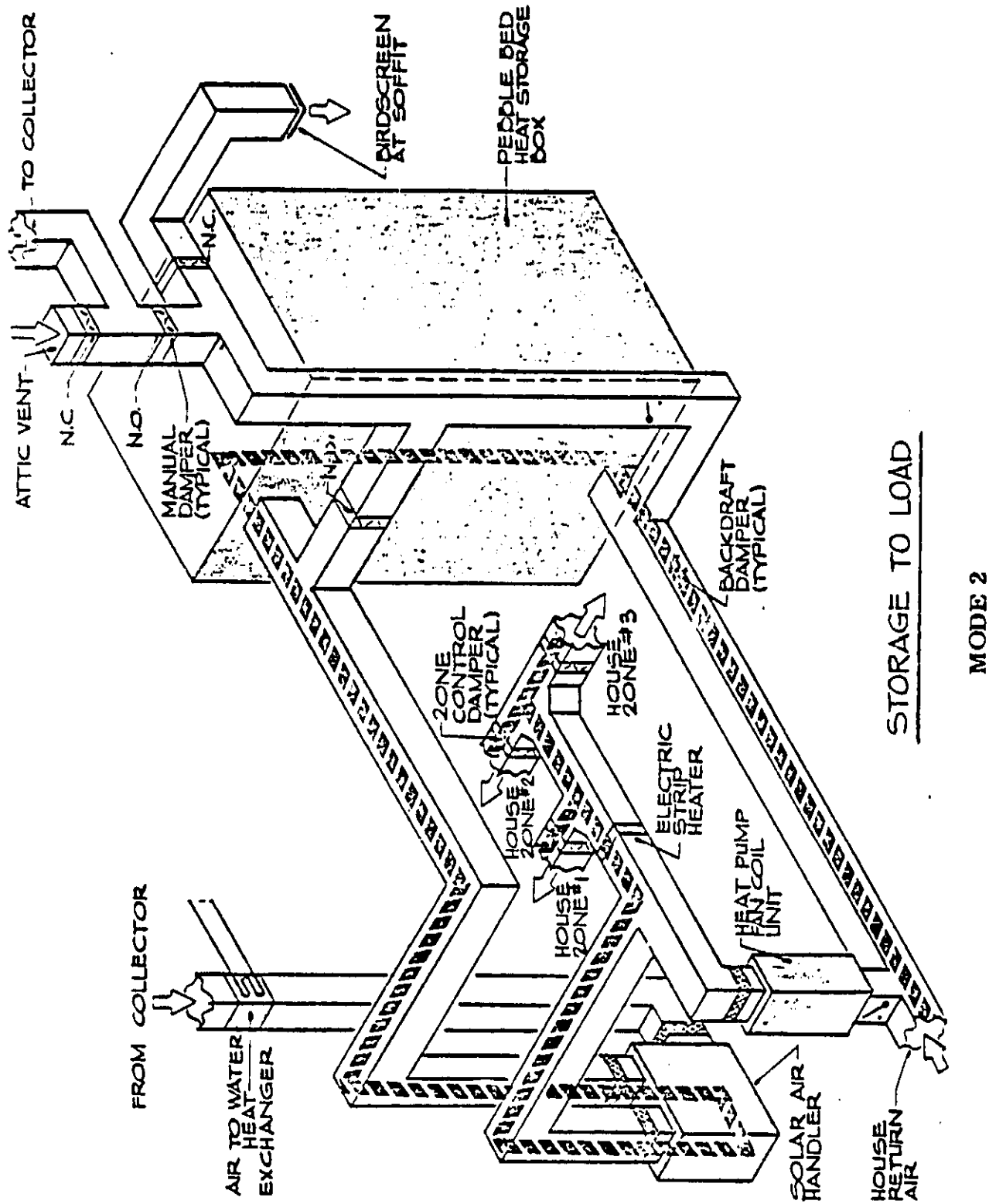


FIGURE 22

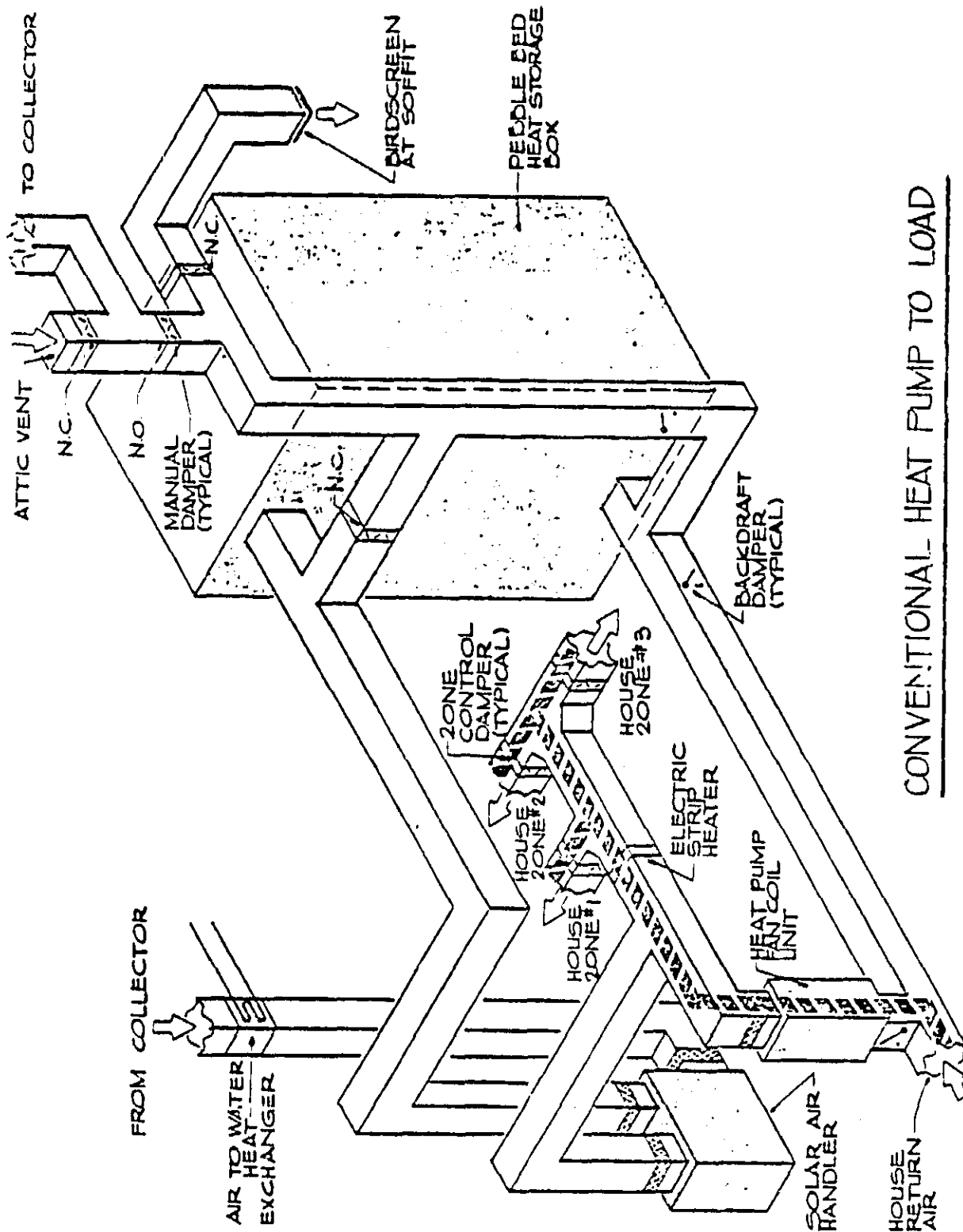
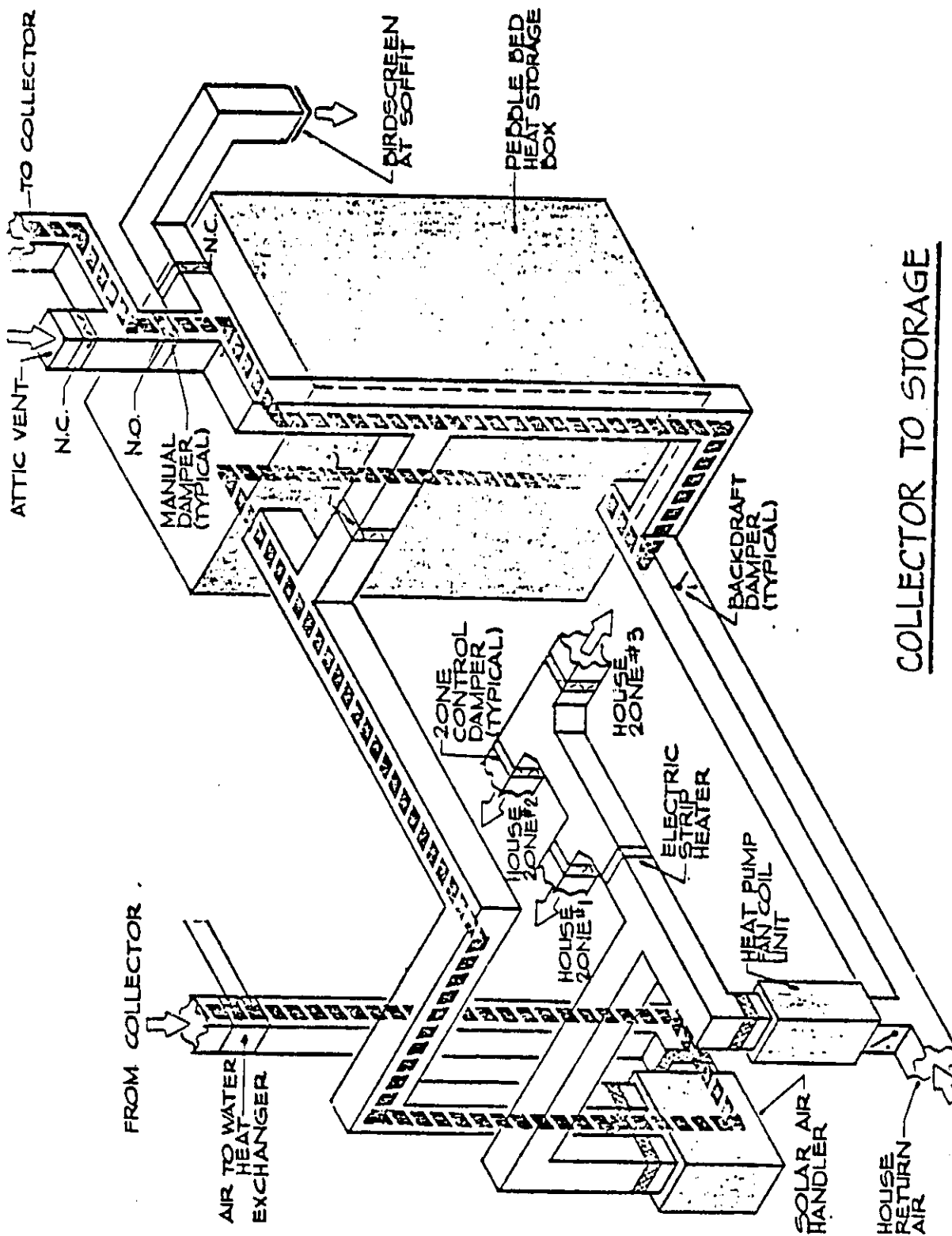


FIGURE 23

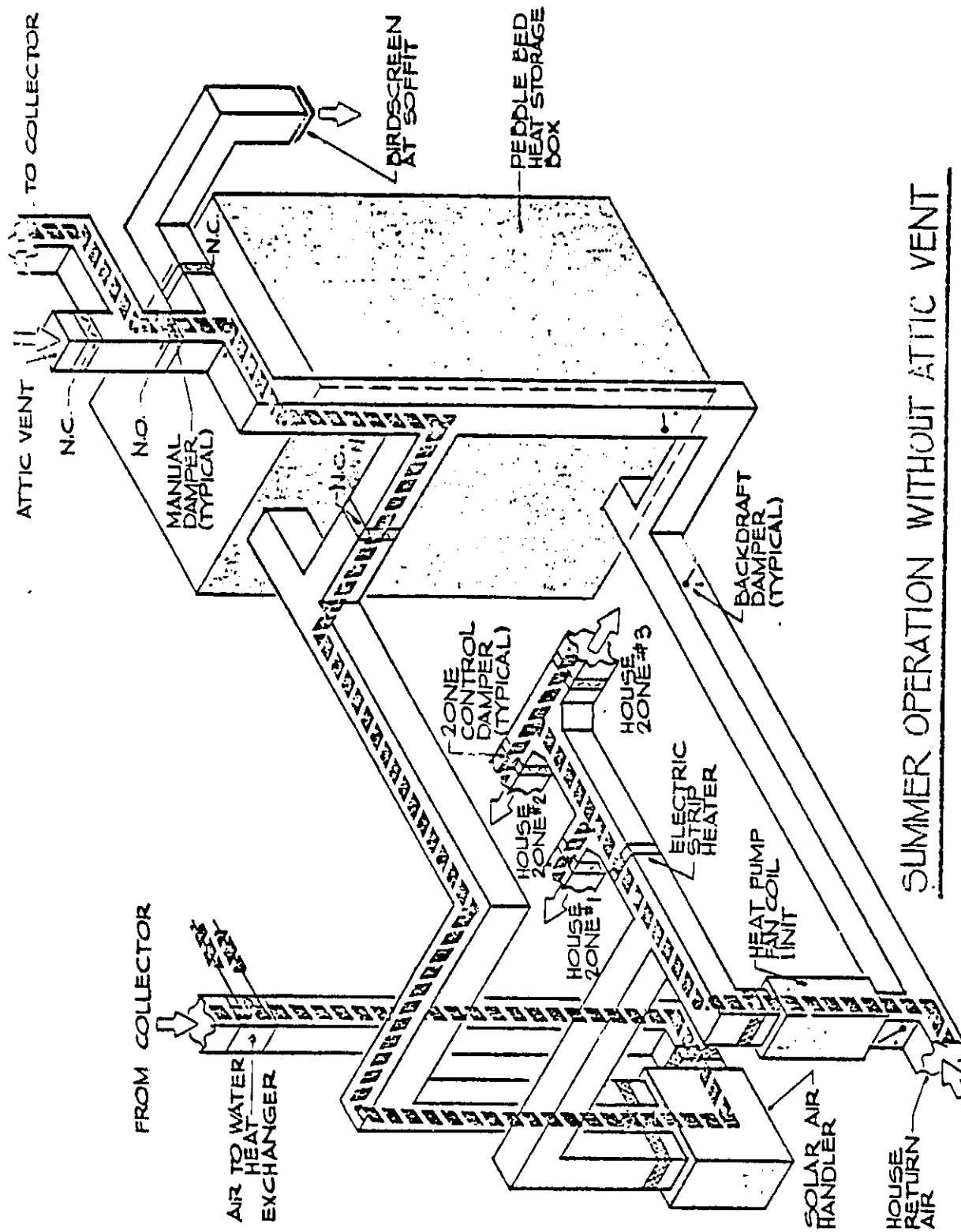




# COLLECTOR TO STORAGE

MODE 4

FIGURE 24

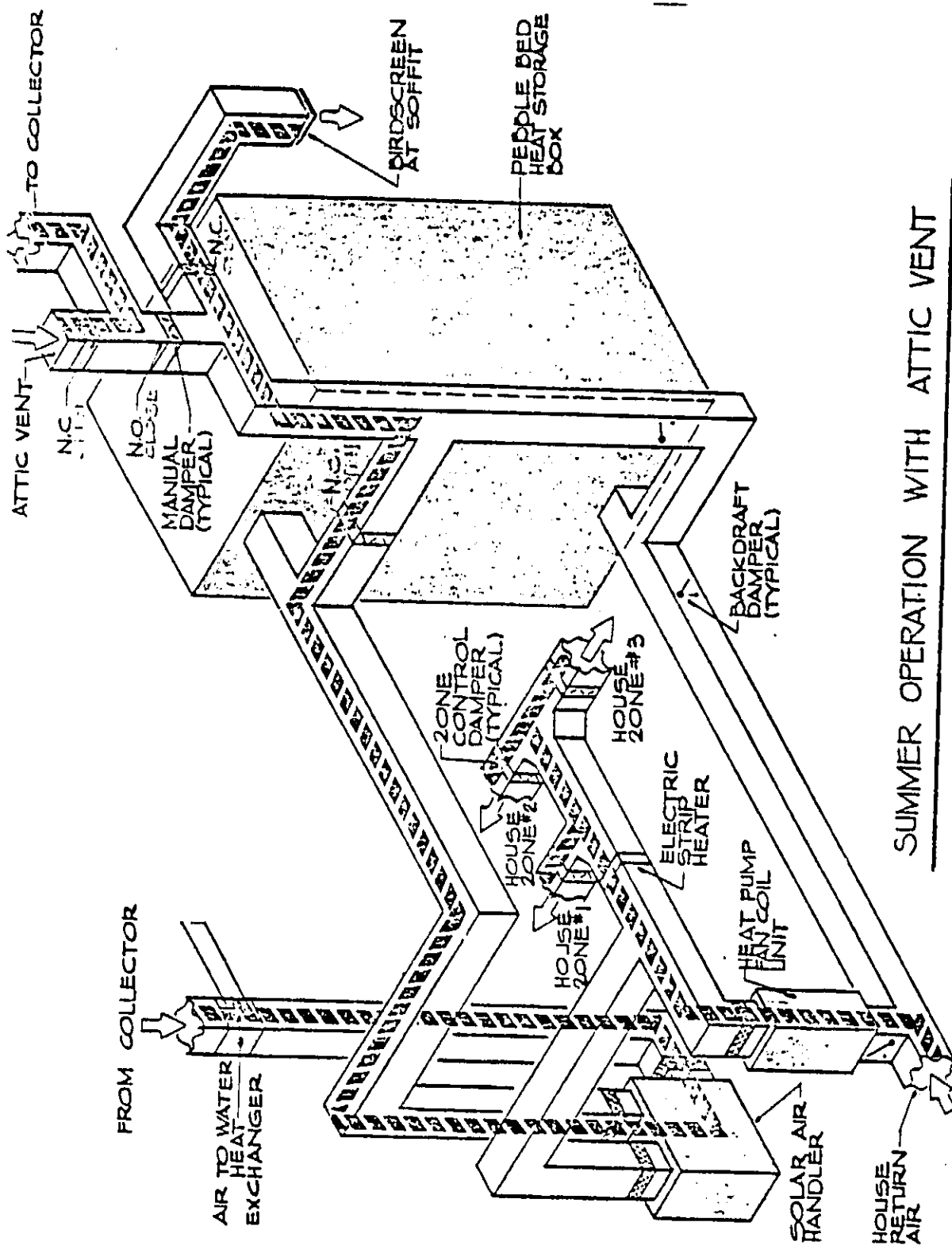


SUMMER OPERATION WITHOUT ATTIC VENT

MODE 5

FIGURE 25

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SUMMER OPERATION WITH ATTIC VENT

MODE 6

FIGURE 26

# Operation & Maintenance Manual SIMS Prototype System 1

Prepared for the  
GEORGE C. MARSHALL  
SPACE FLIGHT CENTER  
Huntsville, Alabama

December 10, 1976

Contract No. NAS8-32036  
MSFC No. DR501-19  
IBM No. 7933628



WYLE LABORATORIES

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## OPERATIONAL AND MAINTENANCE MANUAL

### SECTION 1 - DESCRIPTION AND DESIGN INTENT

#### CONTENTS

	Pages
A. Typical System Illustration	3
Principal Elements	4
Applicable Documents	5
B. Solar Heating System and Sub-system	6
Diagrams	7
Energy Storage Sub-system	8
Energy Transport Sub-system	9
Back Draft Dampers	10
Control Sub-system	11
Auxiliary Energy Sub-system	12
C. Solar Hot Water System	12
Domestic Water Heating Schematic	13
Hot Water and Control Sub-systems	14
Solar Heating and Conventional	
D. Solar Heating and Conventional Systems Interface	15
E. Design Intent	15

## OPERATIONAL AND MAINTENANCE MANUAL

### SECTION 2 - OPERATING SEQUENCE AND PROCEDURES

#### CONTENTS

A. Solar Heating System	17
1. Related Systems Check Before Start Up	17
2. Sequence of Operation - Description and Diagrams	18
B. Hot Water Subsystem	23
1. Related Systems Check Before Start Up	23
Domestic Water Heating Schematic	24

# OPERATIONAL AND MAINTENANCE MANUAL

## SECTION 3 - MAINTENANCE INSTRUCTIONS

### CONTENTS

	Pages
Preventive Maintenance	25
Cleaning - General	25
Filters	26
Belts	27
Lubrication	27
Valves	27
Insulation	27
Serial Numbers	27
Water Heaters	27
Pre-Heat Tank	27
Strainers	28

Section I - Solar System/Mechanical System  
Description and Design Intent

A. General

Figure 1 is a pictorial illustration of an integrated solar heating and hot water system, as designed for installation on a single family dwelling in the 1,500 to 2,500 square foot range. The system and components can be scaled up or down to accommodate a wide range of heating and hot water requirements for other single family, multi-family or commercial buildings without significant change to the design concept.

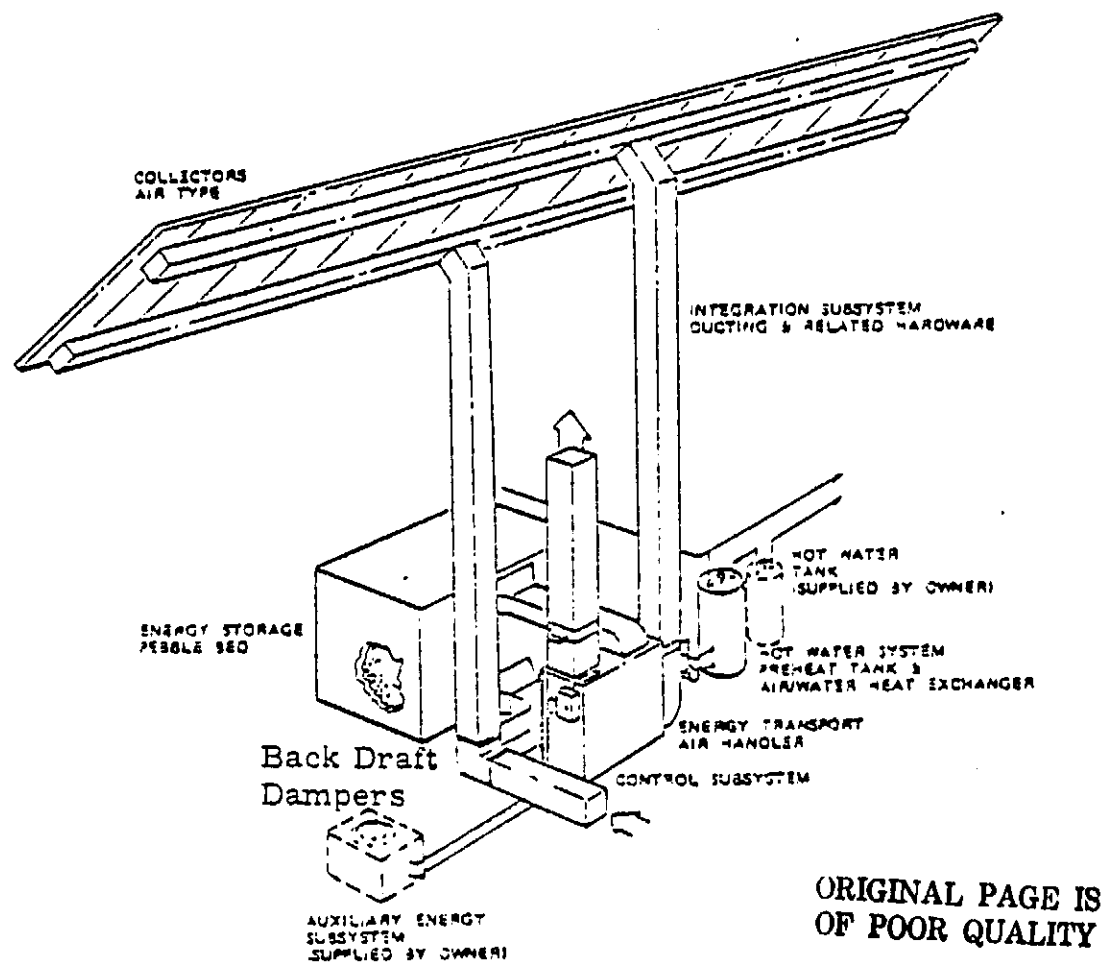


Figure 1 - Typical Solar Heating and Hot Water System using Air type collectors.

Principal elements of the system are: 1) flat plate air type solar collectors, 2) a pebble bed for thermal storage of collected solar energy, 3) an air handling unit to move and direct the air through the energy transport system, 4) an air-to-water heat exchanger and circulating pump to allow for transfer of heat from the collector/storage circuit to the domestic hot water circuit, 5) a domestic hot water pre-heat tank for storage and transfer of collected energy into the conventional domestic water heater, 6) an air-to-air heat pump and electric strip heaters to supply auxiliary energy during periods of insufficient solar insolation, and 7) a ducting system to convey the solar heated air between system components and into the heated space. These elements are shown in Figure 2.

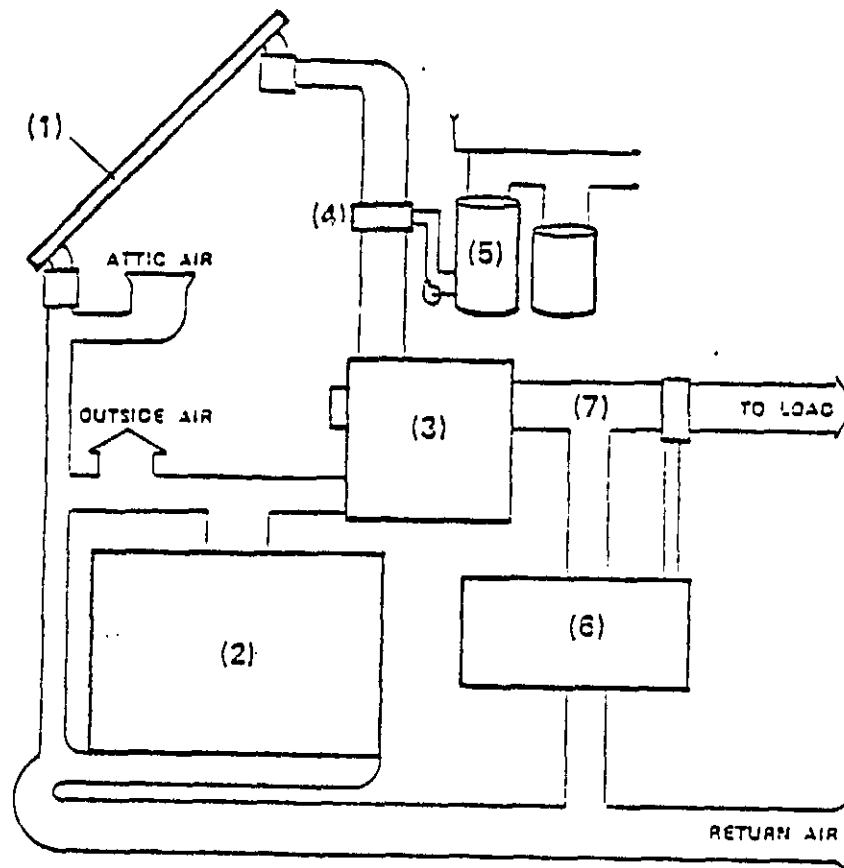


Figure 2 - Principal Elements of system.



## Applicable Documents

### Title

System Performance for SIMS Prototype SHAC System - Design No. 1	7933444
System 1 Design - Heating and Hot Water	7933608
Collector Subsystem Specification	7933609
Energy Storage Subsystem	7933610
Energy Transport Subsystem	7933611
Hot Water Subsystem	7933612
Control Subsystem	7933613
Auxiliary Energy Subsystem	7933614
Integration Subsystem	7933615
Installation Drawings	
Installation Manuals	
Operation and Maintenance Manuals	

## B. Solar Heating System

### 1. Description of System

The Solar Heating System utilizing air as the circulating heat transfer medium is designed to provide approximately 58% of the total heating requirements of the heating season. The following subsystems are integrated to form the Solar Heating System:

#### a. The Collector Subsystem

The solar collector is Solar Energy Products, Mode EF-212, air heating panels. The basic collector module is a 2 ft. by 12 ft., rectangular, single glazed unit. Collector modules are ganged to form collector arrays and will be connected with manifold and feeder ductwork. The collector will be GFE (government furnished equipment) and constructed on site.

(See Figure 3.0 and 4 on the following page.)

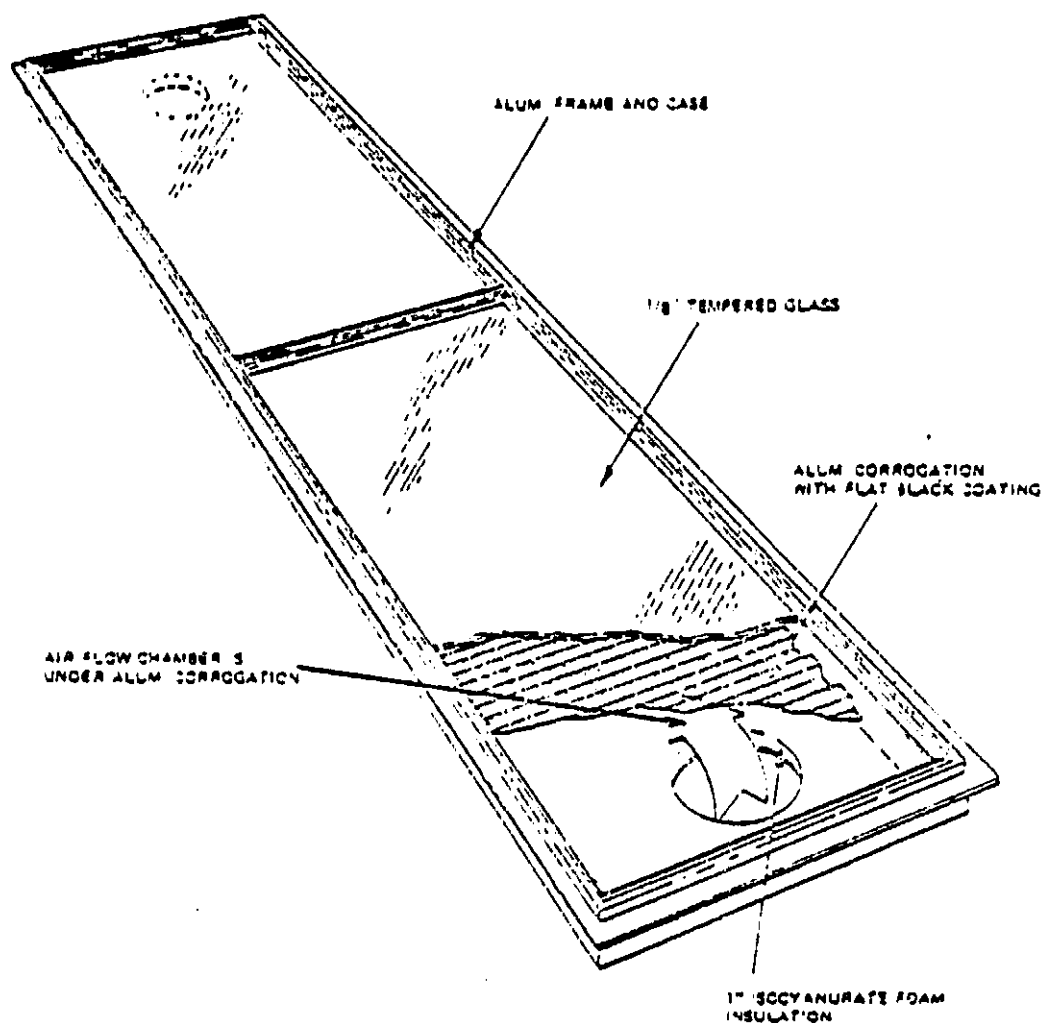


Figure 3 - Solar Energy Products, Model EF-212 Collector (Air type)

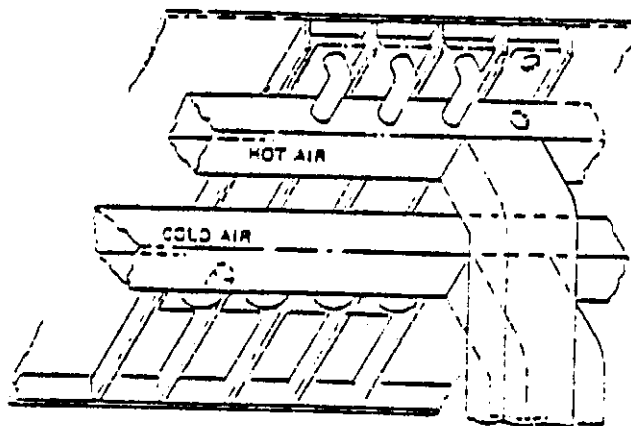


Figure 4 - EF-212 Air Collector Interconnections

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b. Energy Storage Subsystem

When solar energy is available but not required to heat the building space, the energy storage unit provides a means of storing the heat. The stored heat can later be drawn from the storage unit and used to heat the building space when heat is not available from the collectors.

The storage will consist of pebbles (river rock) of  $3/4''$  to  $1-1/2''$  in size in a suitable container and constructed on site.

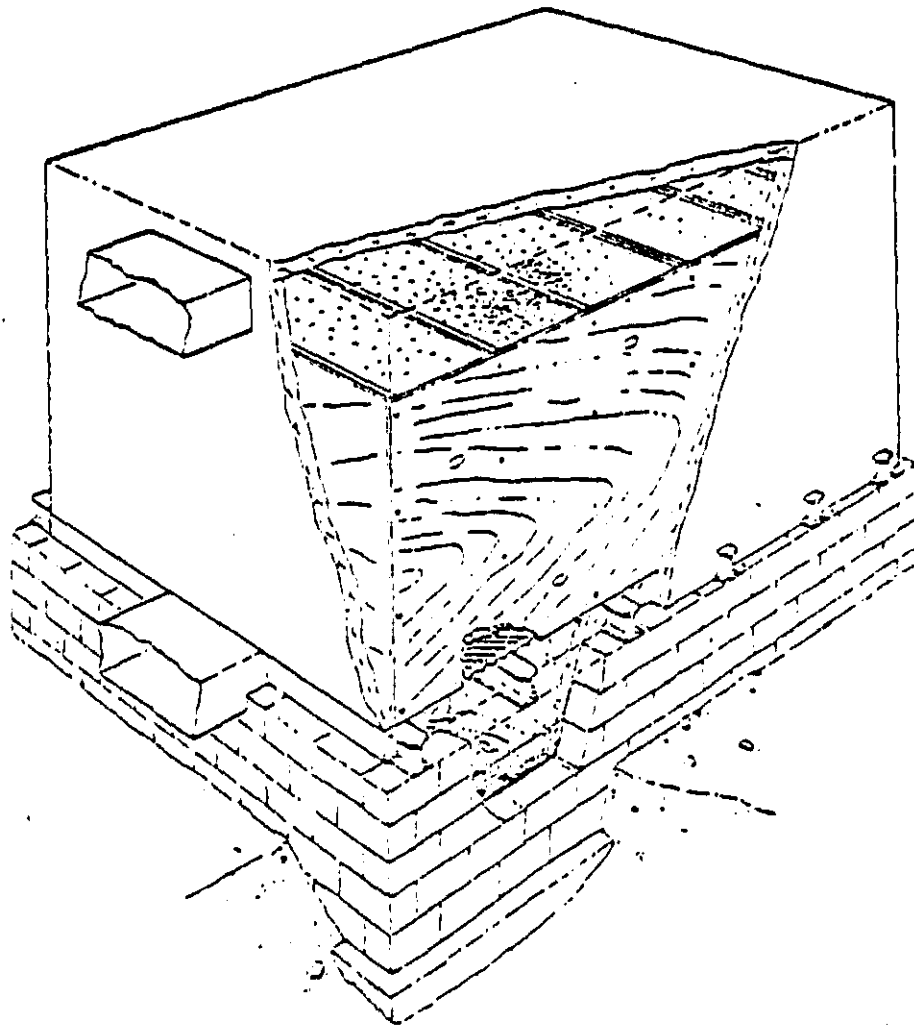


Figure 5 - Pebble Bed Heat Storage

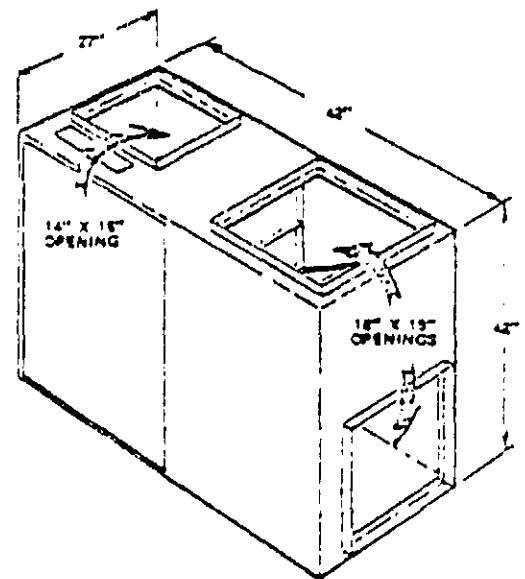
### c. Energy Transport Subsystem

The Solar Control Corporation Series 20 Air Handler shall be as shown in Figure 6. The metal cabinet, 42" L X 42" H x 27" W contains a centrifugal belt driven blower, a 1" HP, 115 V, low noise, high temperature motor and motorized dampers. Operation of the blower and dampers to route the air flow for the various modes of system operation will be achieved through the control subsystem.

THE MOTOR SIZE AND BLOWER SPEED ARE DETERMINED BY THE MAX. LOAD DEMANDS OF THE SYSTEM. MOTORS ARE SPECIFIED IN TABLE "A".  
ALL 115 VAC WIRING IS TO BE UL LISTED.

TABLE "A"

N. P.	MANUFACTURE	STYLE NO.	FRAME TYPE
1/4	WESTINGHOUSE ELECTRIC CORP.	311P002	FH-CC54
1/3	WESTINGHOUSE ELECTRIC CORP.	311P003	FH-CP54
1/2	WESTINGHOUSE ELECTRIC CORP.	311P004	FH-44
3/4	WESTINGHOUSE ELECTRIC CORP.	312P625	FH-454
1	WESTINGHOUSE ELECTRIC CORP.	311P297	FH-454
DAMPER MOTORS WILL BE:			
DAYTON No. 2M231 WITH MAGNETIC TYPE BRAKE REMOVED.			
7 RPM 1100 H. P.			
0.56 FLA, IMPEDANCE PROTECTED			
115 VAC/60 CYCLES, CLOCKWISE ROTATION (SHAFT END)			



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Figure 6 - Solar Air Handler

FABRIC BLADE  
 SLIDE STOP  
 AIR TIGHT  
 VERTICALLY MOUNTED  
 HORIZONTAL MOUNTED  
 16 BPS GA ALUM PLATE  
 9 BPS GA ALUM PLATE

[illegible]

DATE _____	RECEIVED FROM _____
CUSTOMER _____	FRAME MATERIAL USED _____
_____	REMARKS, REMARKS _____
_____	REVISION _____ DATE BY _____
CUSTOMER ORDER NO. _____	_____
AGENTS ORDER NO. _____	_____
JOB _____	_____

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#### d. Control Subsystem

The Control Subsystem provides for sequencing and control of the solar subsystem and heat pump auxiliary to establish operating modes suitable for all conditions of season and solar energy input. The operational modes are:

- Mode 1 - Collector to load
- Mode 2 - Storage to load
- Mode 3 - Heat pump to load
- Mode 4 - Collector to storage
- Mode 5 - Summer operation

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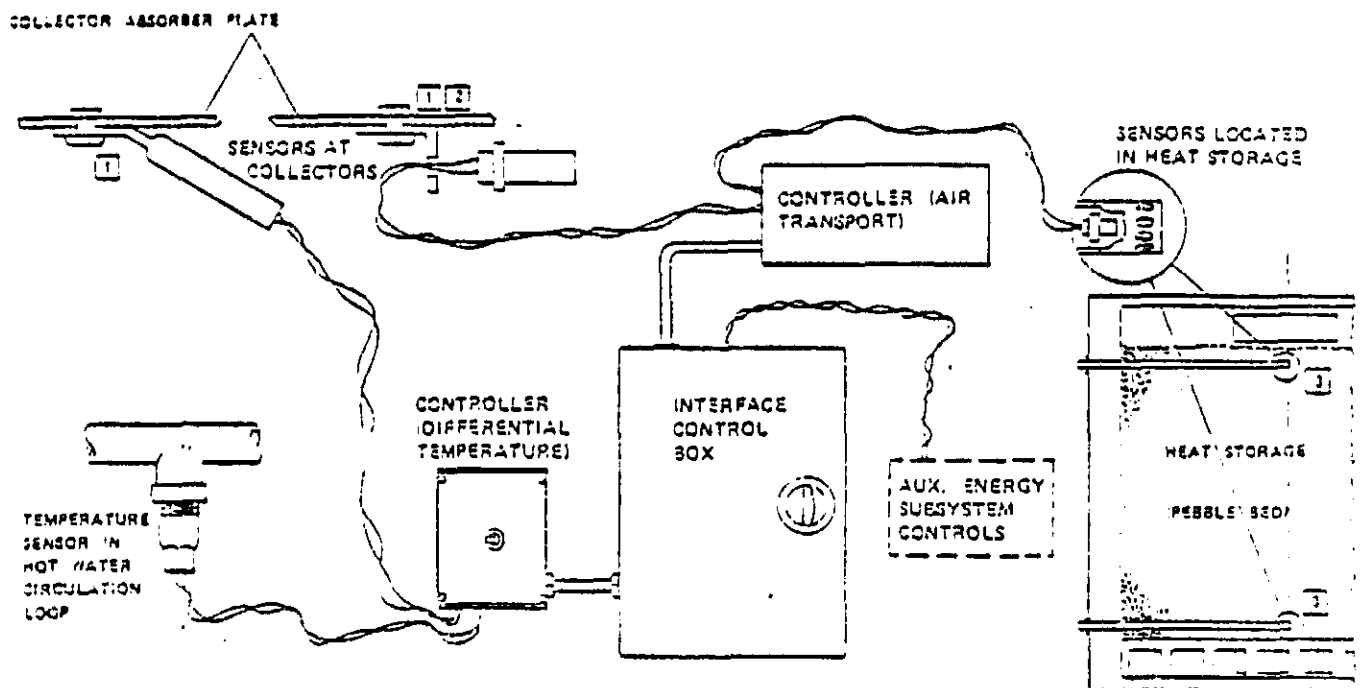


Figure 8 - Control Subsystem and Temperature Sensors

#### Items required:

Connector (Air Transport)  
Connector (Differential Temperature)  
Interface Control Box

Solar Control Corp., ZLA Model 75-  
Rho Sigma Model 106  
IBM 7933619

e. Auxiliary Energy Subsystem

During days when solar energy will not be adequate to heat the building, an auxiliary system is required, designed to provide the entire heating requirements of the building.

The auxiliary heating can be supplied by heat pump, electric resistance strip heater or gas or oil fired furnaces.

For System 1, the heat pump and resistance strip heater will be Owner furnished.

f. Integration Subsystem

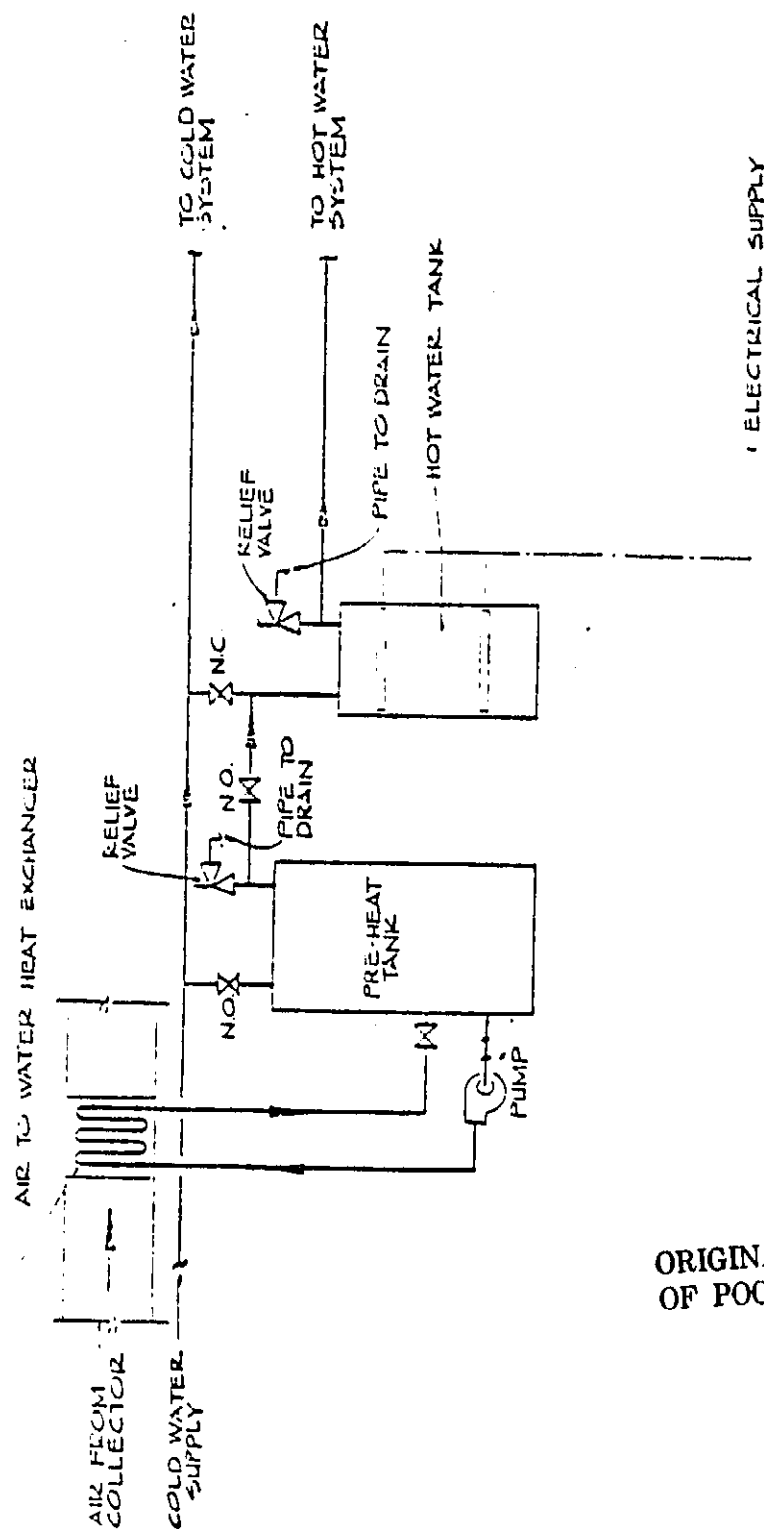
The integrated subsystem for the Solar Heating System will consist of ductwork, insulation and dampers. All of the above items will be constructed on site.

C. Solar Hot Water System

1. Description of System

Water from the bottom of the preheat tank is pumped through the air to water heat exchanger located in the ductwork from the collector when the differential temperature between the collector outlet and the preheat tank is  $20^{\circ}$  F., nominal and terminates when this differential falls to  $3^{\circ}$  F. The heated water is returned to the pre-heat tank. The pre-heat tank shall maintain a maximum water temperature of  $145^{\circ}$  F. City water supply is connected to the pre-heat tank. When the pre-heat tank, through the air to water heat exchanger cannot maintain  $145^{\circ}$  F., the electric hot water heater will raise the hot water temperature to  $140^{\circ}$  F. for supply to the domestic hot water System 14.





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# DOMESTIC WATER HEATING SCHEMATIC

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Figure 9

The following subsystems are integrated to form the Solar Hot Water Systems.

a. Hot Water Subsystem

This subsystem consists of an air to water heat exchanger (Halstead Mitch, SW2-18-18-8, 80 gal. pre-heat tank (W. L. Jackson, S0801, circulating pump (Grundfos, UP 25-42 SF, and conventional hot water heater.

b. Control Subsystem

The hot water differential thermostat (Rho-Sigma-106, furnished by IBM) will form a part of the control subsystem.

c. Integration Subsystem

This subsystem (constructed on site) will consist of piping materials, installation and insulation for the domestic hot water system between the air to water heat exchanger and the pre-heat storage tank, valves, piping accessories (hangers, etc.)

D. Solar Heating System and Conventional System Interface

A conventional heat pump system is incorporated into the heating and cooling system serving the building. The split system air to air heat pump provides conditioned air for cooling during summer operation and provides a heating source during the winter operation. This heating mode is sequenced only after the "collector to load" and "storage to load" is completely exhausted.

E. Design Intent

The system is designed to operate in any region of the United States except the extreme north and south. The following may be used as a guide for system application within the insolation and heating degree day ranges shown below.

Mean Daily Insolation (Typical Winter Mean)	625 to 1475 BTU/FT <sup>2</sup>
--	---------------------------------

Yearly Heating Degree Days	2000 to 6500
----------------------------	--------------

The solar heating system design shall be suitable for a single or small commercial application; provide domestic hot water heating; be of the direct air collector type; use pebble bed for storage; specific air handler for the various modes of operation and interfaced with a conventional heat pump or other types of forced air system as the source of auxiliary energy.

The following are the Design Parameters.

## DESIGN PARAMETERS - TYPICAL APPLICATION

Mean Daily Solar Insolation (Winter)	770 BTU/FT <sup>2</sup>
Yearly Heating Degree Days	3300
Peak Heating Load @ 15° F.	41,250 BTU/HR
Average Annual Heating Load	65 X 10 <sup>6</sup> BTU
% Total Load Supplied by Solar (Heating Season)	58%
Collector Area (effective)	591 ft <sup>2</sup>
Pebble Bed Size	22 tons of pebbles (approximately)
Air Flow (Collectors)	2.5 CFM/FT <sup>2</sup>
Main Duct (Direct Mode-Collector to Load)	1500 CFM @ 1.8 in. SPWC
Maximum Annual Requirement for Auxiliary Energy	31.8 x 10 <sup>6</sup> BTU
Domestic Hot Water Capacity	74 gallons
Minimum DHW Supply Temperature	140°
Maximum DHW System Recovery Time	2.4 hours
DHW Minimum Delivery Rate	1.2 gal/min
Average DHW Heating Load	0.9 x 10 <sup>6</sup> BTU/MONTH
% DHW Load from Auxiliary Energy	57%
Maximum Electrical Power for Solar System Operation	1.0 KW
Maximum Electrical Power for Total System Operation (4-ton heat pump & 20 KW Strip Heaters)	28.0 KW
Maximum Average Annual Electrical Energy Consumption for Total System	6700 KWH

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## OPERATIONAL AND MAINTENANCE MANUAL

### Section II - Operating Sequence and Procedures

#### A. Solar Heating System

##### 1. Start Up

##### a. Related systems

Before starting up the Solar Heating System, the following systems or components must be in operation:

- (1) Control system
- (2) Electrical power

##### b. Solar Air-Mover Air Handling System

- (1) Check filters to be sure they are clean.

Determine the cleanliness of a filter by inspecting it against a light. A dirty filter does not allow light penetration and should be replaced. The filter shall be checked prior to operation in the summer mode.

- (2) Check space thermostat operation.

Proper operation of the space thermostat should be verified periodically. Move the thermostat setting up manually 5° and observe the response from the air handling system. If the thermostat indicator also advances 5° within a reasonable period of time, the thermostat is operating properly. Return the setting to the original position and wait for the thermostat indicator to follow.

- (3) Check controls for proper operation.

Controls: Completely automatic. If SAH fails to run and space requires heat:

- a. Move space thermostat setting 5° higher to activate.
  - b. Check collector and pebble storage temperature differential. If collector temperature is higher, check collector sensor wiring.
  - c. If top of pebble bed storage temperature is higher, check storage sensor wiring.
  - d. If sun is not shining and pebble storage temperature is low, heat pump should be operating in heating mode.
- (4) Check manual damper position.

Manual damper position will be in accordance with damper schedule for the various operational modes as shown in Section II. The position of a damper will be indicated by the damper position indicator external to the ductwork.

- (5) Check operation of back-draft dampers.

The position of the back draft damper can be verified through an observation port.

- (6) Check fan belt tension and adjust as required.

The fan belt should never be too rigid nor too slack. Firm finger-tip pressure on the belt between sheaves should produce about a 1/2" deflection.

- (7) Start fan and verify proper rotation.

On initial start-up, subsequent to belt replacement, or motor sheave adjustment, a tachometer reading of the fan RPM can be made by removing the spring-loaded plug on the side of the air handler exposing the end of the fan impeller shaft.

- (8) Check that hot water circulating line valves are open and that circulating pump is operational. (See Manufacturers Installation and Operating Instructions.)

## 2. Sequence of Operation

The following drawings will illustrate the sequence of operation of the solar heating system.

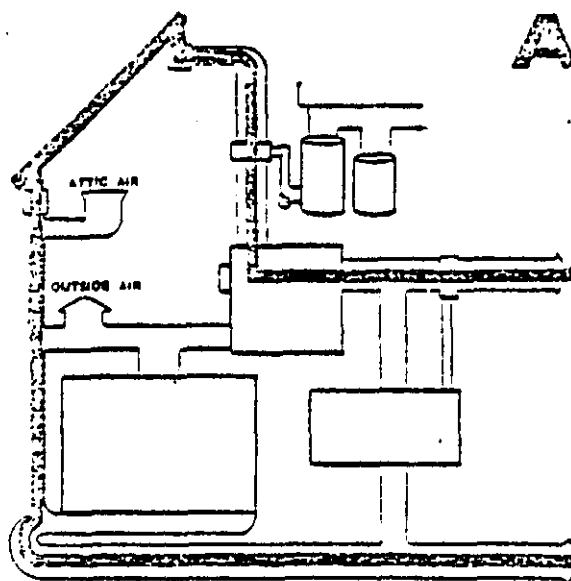
### Mode 1 - Collector-to-Load

Figure A depicts the air flow in the system when the collector subsystem provides the heated air to the building. This mode will be selected when the building thermostat calls for heat and the air temperature from the collector is greater than  $T_{(out)}$  minimum and the collector is on.

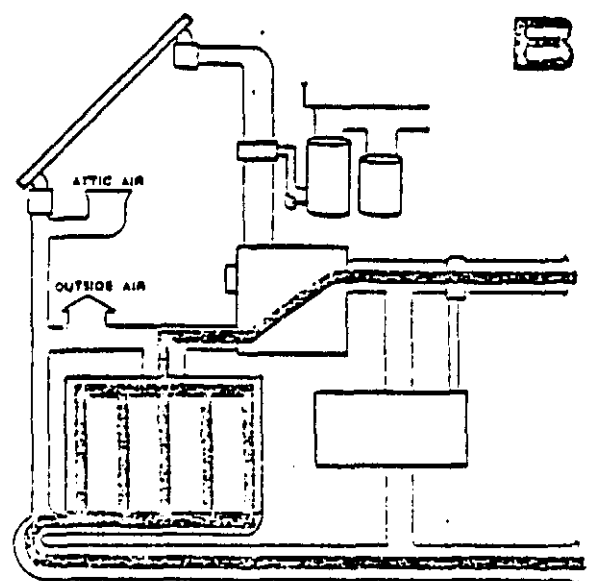
### Mode 2 - Storage-to-Load

The control logic will select this mode of operation if Mode 1 conditions are not met and the temperature in the top of the pebble bed is greater than  $T_{(out)}$  minimum.

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A = Mode 1 - Collector-to-Load



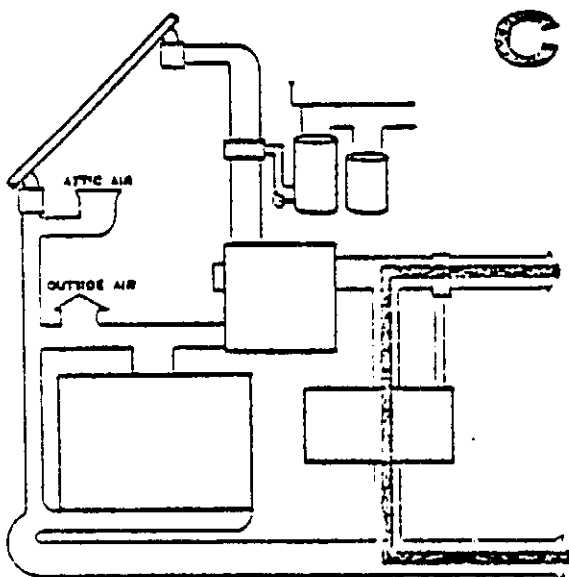
B = Mode 2 - Storage-to-Load

### Mode 3 - Heat Pump-to-Load

When the conditions for Mode 1 and Mode 2 cannot be met, space heating is provided by the heat pump as shown in Figure C. In this mode, Fan F2 is on and the source of heat is the condenser coil of the heat pump.

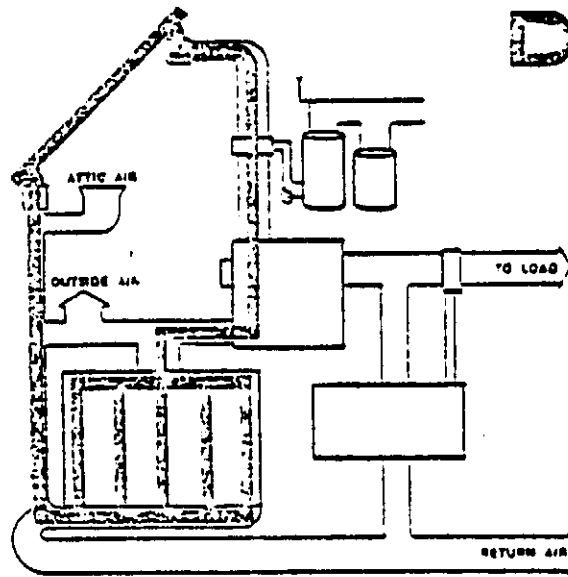
### Mode 4 - Collector-to-Storage

If the building does not require heat or the solar collector cannot provide heated air above the  $T_{(out)}$  minimum but is, nevertheless, collecting usable energy, the system will operate in a collector-to-storage mode, as indicated in Figure D. If the differential temperature between the collector outlet and the bottom of the pebble bed is greater than  $\Delta T_{(in)}$  (approximately 30° F.) - the control logic will place the system in Mode 4.



C

C = Mode 3 - Heat-Pump (Aux. Heat)  
to-Load



D

D = Mode 4 - Collectors-to-Storage

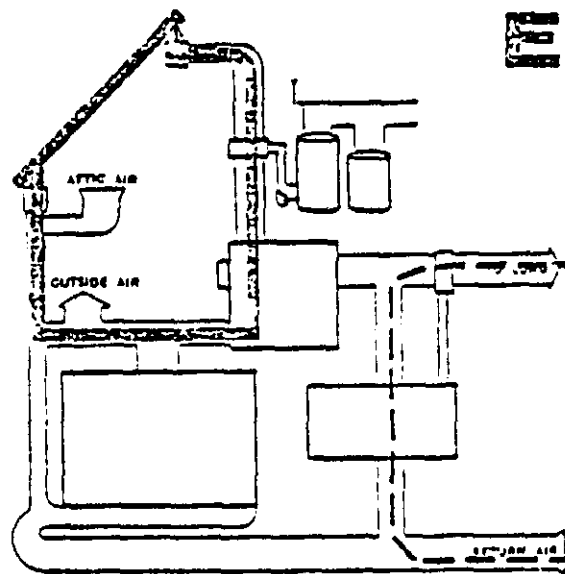


### Mode 5 - Summer Operation

During summer or warm weather operation when space heating is not required, the system will operate in Mode 5, with flow paths as shown in Figure E. The building air distribution is handled by Fan F2 (heat pump) in either a "Cooling" or "Fan Only" mode. In this mode, the solar collection loop will be used for hot water pre-heating only.

### Mode 6 - Summer Operation with Attic Venting

An option exists whereby the attic and outside air dampers MD-2-A and MD-1-A may be opened to provide ventilation of the attic space.



—— HEATING

--- COOLING OR  
FAN ONLY

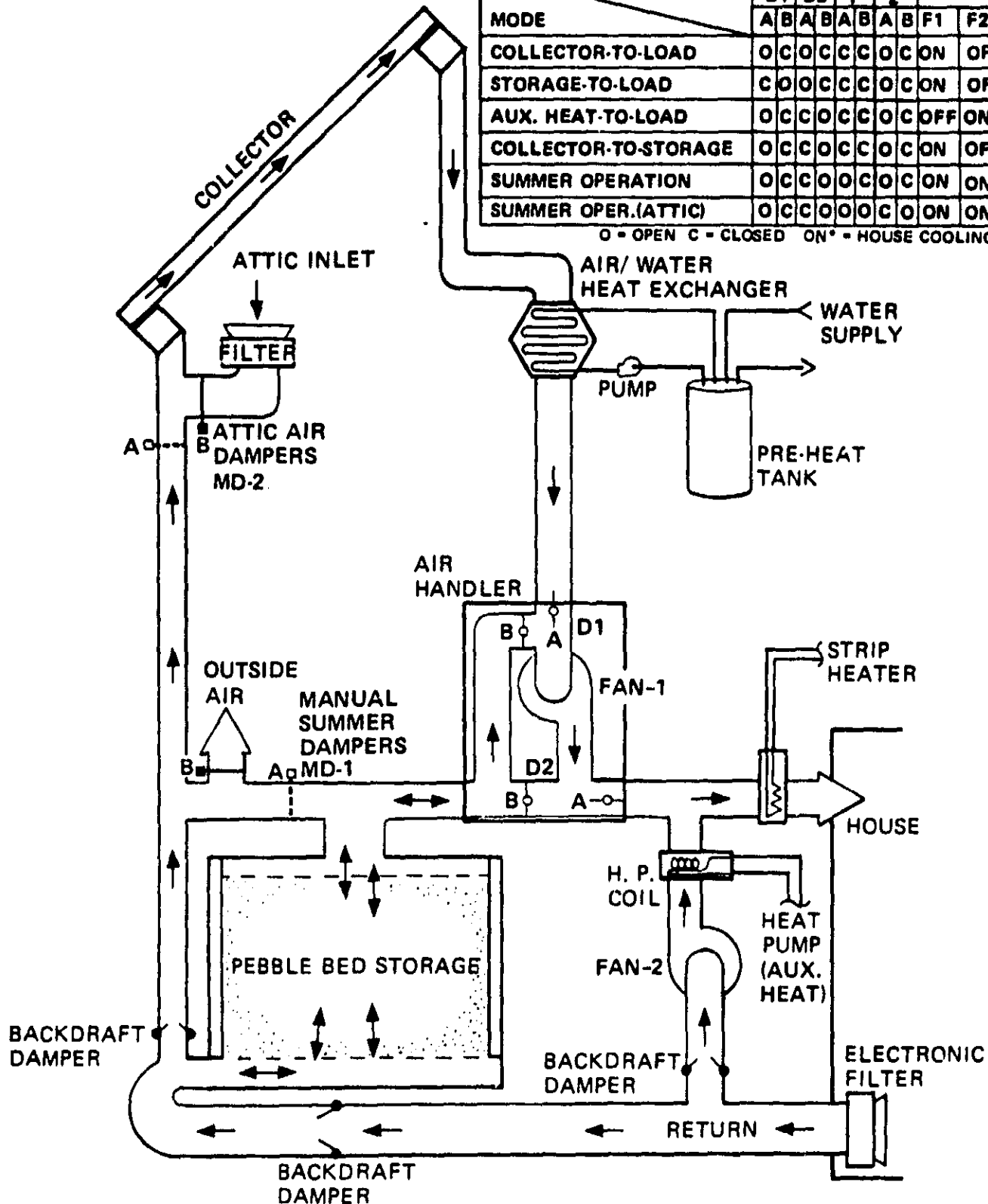
E = Mode 5 - Summer Operation

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# DAMPER SCHEDULE

MODE	D1		D2		MD 1		MD 2		FANS	
	A	B	A	B	A	B	A	B	F1	F2
COLLECTOR-TO-LOAD	O	C	O	C	C	C	O	C	ON	OFF
STORAGE-TO-LOAD	C	O	O	C	C	C	O	C	ON	OFF
AUX. HEAT-TO-LOAD	O	C	C	O	C	C	O	C	OFF	ON
COLLECTOR-TO-STORAGE	O	C	C	O	C	C	O	C	ON	OFF
SUMMER OPERATION	O	C	C	O	O	C	O	C	ON	ON*
SUMMER OPER.(ATTIC)	O	C	C	O	O	C	O	C	ON	ON*

O = OPEN C = CLOSED ON\* = HOUSE COOLING



## **B. Hot Water Subsystem**

### **1. Start Up**

#### **a. Related Systems**

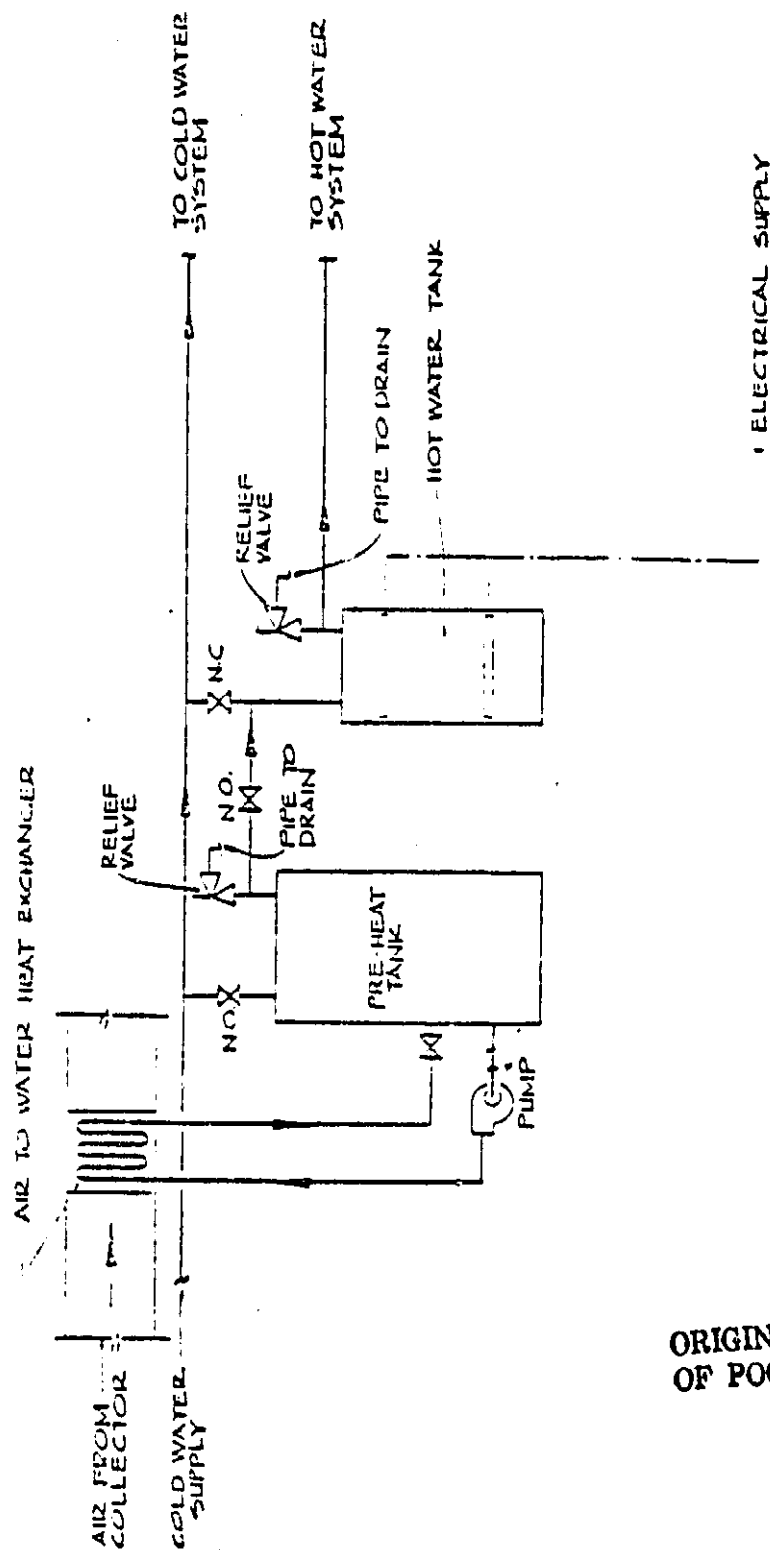
Before the Hot Water Subsystem can be operational, the Control System and Electrical Power System must be in operation. The Hot Water Subsystem circulating pump will be started and stopped automatically based on a pre-determined sequence.

#### **b. Hot Water Subsystem**

- (1) Check temperature - pressure valve for operation
- (2) Check for proper position of system gate valves

#### **c. Control**

The Rho-Sigma differential thermostat provides control of the Domestic Hot Water system.



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# DOMESTIC WATER HEATING SCHEMATIC

NO SCALE

## OPERATIONAL AND MAINTENANCE MANUAL

### Section III - Maintenance Instructions

#### A. General

This section contains general maintenance procedures for the Solar Heating System and Solar Hot Water System. Manufacturer's instruction brochures or books should be consulted for specific detailed maintenance procedures.

#### B. Preventive Maintenance

The most vital part of any maintenance program in keeping mechanical systems in operation, is preventive maintenance, keeping bearings oiled or greased, the equipment clean, pumps packed, adjusting belts and performing tasks which prevent equipment breakdown thus reducing the emergency situations that arise from such breakdowns.

The best way to carry out preventive maintenance is to have regular schedules of cleaning, checking, and oiling. The use of charts or log sheets to record the dates of inspection or work performed is strongly recommended.

#### C. General Cleaning

##### 1. Air Handling Units

The interior and exterior of all air handling units, coils, fan blades, etc. should be thoroughly cleaned with a vacuum cleaner every six months. Any rust spots should be cleaned and painted. Clean screens in drain pan outlets where they occur. The front panel of the S. A. H. is removable for access to all moving parts such as fan, motor and control dampers.

##### 2. Mechanical Rooms

All mechanical rooms should be thoroughly cleaned by vacuuming at least every three months. All equipment should be wiped with a damp cloth and any rusted areas cleaned and repainted.

## D. Filters

### 1. Dirty Filters

The flow of air can, for all practical purposes, actually be stopped by "plugged" filters. Satisfactory operation of units equipped with filters cannot be maintained if the filters are allowed to become extremely dirty.

### 2. Cleaning Schedule

It is recommended that, initially, all filters be inspected every two weeks and cleaned if required. A regular schedule of filter inspection can be set up after a pattern is established and a filter inspection schedule sheet can be inserted as a part of the maintenance log book.

### 3. Cleaning Filters

The directions and recommendations of the filter manufacturer should be followed in cleaning and recoating filters.

### 4. Throw-away type filters should be replaced regularly. Keep at least one complete set of filters on hand as "spares".

## E. Belts

If maintained in proper adjustment, belts should not be a problem.

Belts on all units should be inspected at least every three months.

Belts must be kept clean. If dirty, wipe with a clean cloth. Do not use cleaning fluids as they will damage the belt.

Belts should be run with as little tension as possible. Slight slippage on startup can be permitted. Running belts too tight will shorten their life span and may cause bearings to run hot due to the added strain.

## F. Lubrication

### 1. General

While proper lubrication of all bearings is extremely important to equipment life, a minimum of lubrication maintenance is required for the components of this installation. The stainless

steel H. W. pump is self-lubricated by its internal water circulation. The damper motors have life-time sealed lubrication. Damper shaft bearings and linkages may require an occasional touch of grease if they appear to be dried out or creak during operation. The fan and motor bearing should not require lubrication more than once in two years, but should be inspected annually and lubricated according to the manufacturer's recommendation.

#### G. Pressure Relief Valves

The instructions of the Manufacturer on servicing and adjusting the pressure relief valves should be followed. Valves should be checked monthly for clogged drains and dirt buildup in the body, pop tested every six months, and removed for complete inspection once each year. The relief pressure is factory set; when tampered with, all warranties are void.

#### H. Gate and Globe Valves

All shutoff valves must be checked at least once a year and serviced as required if they are to do their job when needed.

#### I. Insulation

Proper maintenance of all piping and duct insulation is essential. Here, again, preventive maintenance is advised. The canvas wrapping on insulation is easily punctured or torn, the insulation itself easily crushed. Damaged spots in insulation should be repaired as soon as possible in order to avoid extension of the damage and severe heat loss.

#### J. Serial Numbers

It is suggested that a list be made of all major equipment and that this list include the model number, serial number, etc. This list can be put in the maintenance record book in order to facilitate the ordering of any new parts.

#### K. Water Heaters and Solar Pre-heat Tank

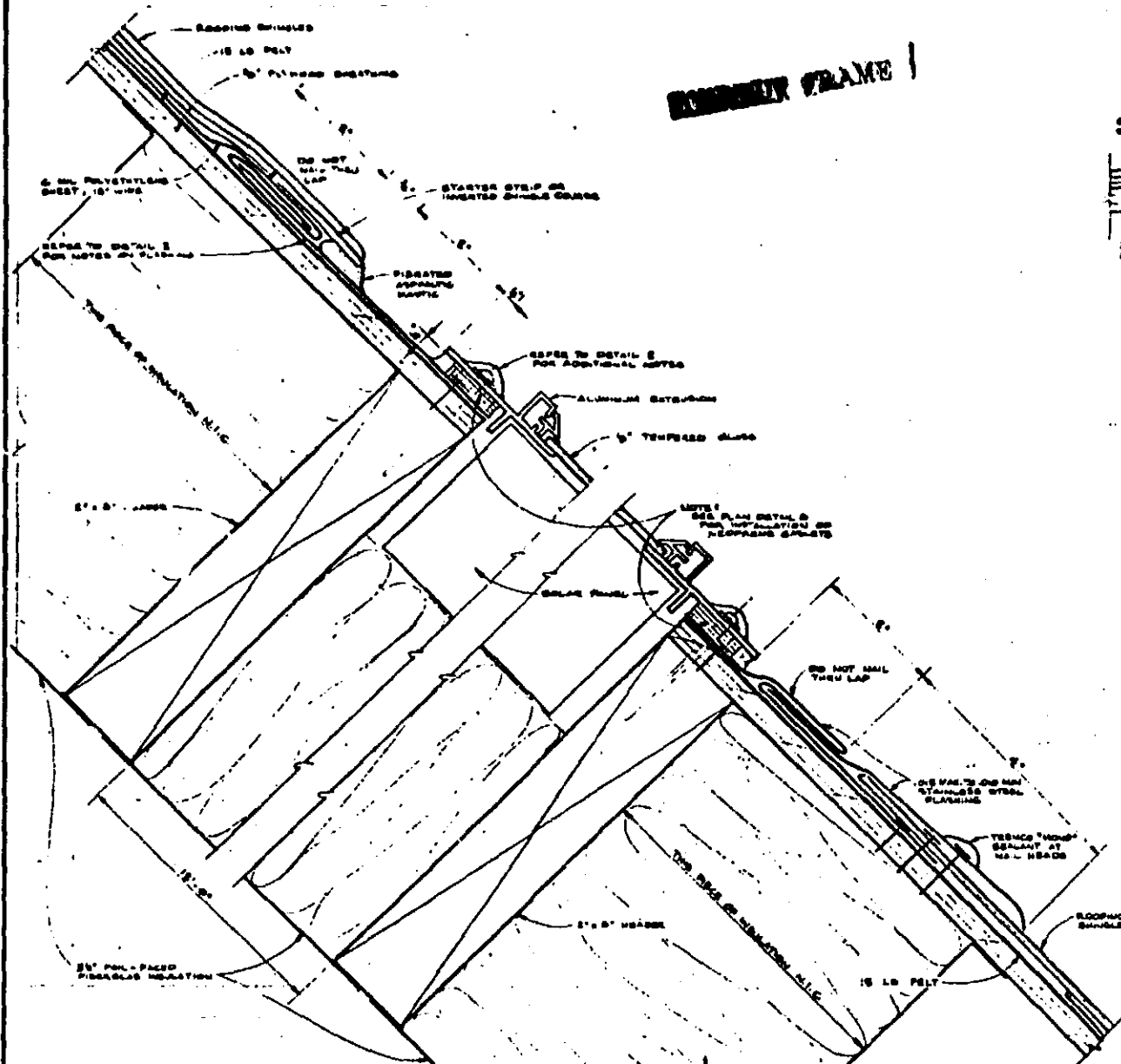
Reference should be made to the instruction manual on the equipment, furnished by the manufacturer.

Solids should be blown out the bottom drain on each water heater weekly unless experience shows that a longer interval between blow downs is satisfactory.

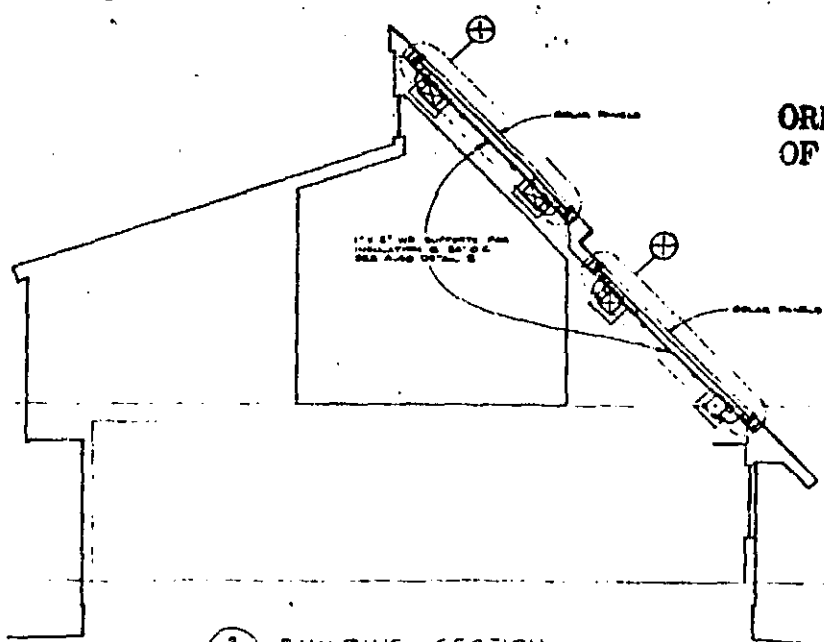
Strainer in the suction side of the circulating pump shall be removed and cleaned (every four months).



**ROOFING FRAME**



① LONGITUDINAL SECTION THRU SOLAR PANEL  
FULL SIZE



③ BUILDING SECTION  
3\"/>

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