DOE/NASA CONTRACTOR REPORT

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INSTALLATION PACKAGE FOR A DOMESTIC SOLAR HEATING AND HOT WATER SYSTEM

Prepared from documents provided by

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For the U. S. Department of Energy

U.S. Department of Energy

Solar Energy

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1. Solar Collector Installation

The manner in which the solar collectors are installed can make the difference between success and failure in achieving our goal of a cost-effective solar system. Fundamental guidelines which should lead to a successful installation follow:

Azimuth

The collectors should face southwards as shown in Figure 1. The use of a compass indicates magnetic north (and south) and a correction is needed to locate true south. A surveyor's plot plan will have true north indicated. If it is impractical to face the collectors southwards, a small difference between the collector azimuth and true south has a minor effect on the energy that can be collected as shown in Figure 2. A 45 degree difference between the azimuth and true south will reduce the collected energy by about 30%. Because of the increase in the temperature of the stored solar energy during the day, a westerly azimuth tends to be preferable to an easterly azimuth; however, local climatic conditions may be more optimal in the morning than in the afternoon in which case an easterly azimuth would be superior.

Tilt

Selection of the collector tilt angle (shown in Figure 1) is based on consideration of cost factors and collection efficiency. The collection efficiency is primarily dependent on the availability of solar insolation which in turn is dependent on the tilt angle. Aligning the collector so its surface is normal to the sun's rays at any one time maximizes the solar insolation available to the collector at that time. However, during the year relative position of the sun changes so that the sun's rays are inclined with respect to the collector and the full potential of the available insolation cannot be realized.

Tilt, cont'd.

An optimum tilt can be selected so that during the year an optimum amount can be collected. The calculated results shown in Figure 3 illustrate the effect of tilt on the solar insolation available to the collector. Different optimum tilts arise depending on the primary use of the collector; for space heating the optimum tilt is approximately equal to the local latitude plus 15 degrees, whereas when the use is primarily for heating hot water the optimum tilt is approximately equal to the latitude plus 5 degrees.

The optimum tilt is also dependent on climatic conditions, and system design details. Weather data on the monthly percentages of solar insolation available allowing for cloudiness can be used to refine the results given in Figure 3. System influences on the optimum tilt are varied and involve the demand profile, storage capacity and method of control. In spite of all the complicated factors relating system performance to tilt angle, experience has shown that the simple guideline of latitude + 15 degrees for space heating and latitude + 5 degrees represents a practical choice for the tilt angle.

Cost factors enter in retrofit situations and departures from the optimum tilt that will reduce the collected energy may be acceptable by simplifying the collector attachment to a roof.

Shading

Shading of the collector will result in a direct loss of solar energy collection otherwise possible. Critical shading angles tend to occur at the winter solstice, Dec. 21, when the sun elevation above the horizon is lowest. The angle between the sun and the local horizontal (ground) at noon on Dec. 21 is called the altitude and is;

Winter Solstice Noon Altitude = 66.5 - latitude, (in degrees). For example, if the latitude is 42 degrees, the altitude is 24.5 degrees and a typical shading situation is shown in Figure 4. During the winter solstice, the sun is southeast of the collector at 9 am and southwest of the collector at 3 pm, and the altitude at these times is about one-half the altitude at noon. If a shading problem is suspected, a plot plan, south, east and west elevation sketches of the site should be studied to ensure a minimal amount of shading.

At the summer solstice, June 21, the sun is high in the sky and the noon altitude is; Summer Solstice Noon Altitude = 113.5 - latitude (in degrees). For example, if your latitude is 42 degrees, the noon altitude is 71.5 degrees, and a potential shading situation is shown in Figure 5.

Duct Runs

The length of duct runs should be minimized to avoid excessive thermal losses and installation costs. The flow rate through the duct should not exceed 600 FPM. Insulating this duct with 4 inches of fiberglass is recommended.

An additional factor is the gage and choice of duct material. The minimum gage required should be used. When the collector is started, the cold ducts absorb heat so when the collector is shut off the heat stored is wasted, so it is important to use minimum acceptable gages.

The use of aluminum ducting would reduce the heat storage loss by 40% and is recommended when the benefit can be derived at a reasonable cost. On cloudy days, the ducts are repeatedly heated and cooled and the importance of minimizing the overall duct weight is even more pronounced.

Duct Runs, cont'd.

The number of elbows should be minimized to avoid excessive pressure drops. Mitered elbows should not be used unless turning vanes are provided. Full radius elbows are recommended. The pressure drop per 100 ft of duct is .05 in w.g.. For each elbow the loss is .006 in w.g..

Duct temperatures will not exceed 250° F in continuous operation. Duct joints should be joined with rivets or sheet metal screws so that the joint integrity will be maintained during thermal expansions and contractions. All ducts should be insulated with at least 4 inches of fiberglass insulation.

Collector Mounting

Three basic collector types, "A", "B", and "C" are available which permit a wide range of arrangements as shown in Figure 6. The features of the 3 collector types are shown in Figure 7. The 3 types represent small variations of common frame and common duct assemblies.

The "A" collector has an electrical box for insertion of the thermostat sensors used to control the collector. The "A" collector has standard 8" x 16" sheet metal starting collars for the inlet and outlet connections. Studs are provided for bolting an adjacent "B" collector. Air duct extensions on the duct sides overlap the duct joints when the collectors are butted together.

The "B" collector is used to vary the length of a collector run. The "B" collector can be omitted, or as many as 6 "B" collectors can be butted together to form a long run.

The "C" collector is used to complete a run. The four-step sequence of installation is shown in Figure 8.

The first step is dependent on the dwelling construction and arrangement selected (see Figure 6). The length of collector run should be selected to avoid roof overhangs, and generally located to achieve an architecturally pleasing appearance and/or to avoid shading. Specifically, the inlet and outlet collars located on 16" centers should span a rafter so the penetrations required do not interfere with a rafter. The center line between the inlet and outlet is 18 inches from the end of the collector. The first bracket should be located on the first rafter outboard to the outlet connection. The bracket locations should be selected to provide at least two per collector. The brackets are to be lagged to the rafters with at least 4-1/4" x 3" lag screws. The foot of the bracket should be precoated with roofing cement, the lag bolts overcoated with roofing cement and the edges of the bracket filleted with roofing cement. Additional precautions shall be taken as required to ensure that there will be no water penetration into the dwelling.

A weather-tight roof curbing for the duct penetration through the roof must be provided. This enclosure must be flashed to the roof and cemented to prohibit water penetration.

The collectors can be raised to roof via a sling as shown in Figure 8. If a simple hoisting sling is used, each leg should be 8 feet and an anchor type hook used to connect to the 3/4" hoisting holes located in the collector flanges. If a close hookup is desired, the use of an 8 foot strong-back with short cables and anchor hooks can be used. The attachment brackets are provided with Zee clamps at the lower ends. Lowering the collector mounting edge into the lower Zee and rotating the collector until it is flat allows the collector to be slid up to the adjacent collector for mating. Lubricating the Zee eliminates galling while sliding the collector. After the collectors have been mated, the flanges bolted and sealed, the collectors are bolted to the brackets on both the upper and lower mounting flanges.

All the collectors in a row can be brought to the roof and captured via 2 Zee's each.

With all the collectors raised to the roof, the assembly of the joints is begun. The "A" collector is bolted to the supports. Before butting the "B" and "A" collector bases together, a liquid gasket such as Dow Corning 781 is applied. Silicone foam rubber tape, 3/16" x 1/2" with adhesive on one side is installed in the recessed pocket around the ducting on each mating face. The collectors are slid together, engaging the ducts and butting the flanges.
A flexible sealant such as DC 781 is used to caulk the flange joint as required.

If two 'B" collectors are being used, attaching the 2nd "B" collector to the first is done identically as described above.

Closing the "C" collector is done in the same manner as a "B" collector. Use flexible sealant as required to weatherproof the joint.

The joint between collectors should be flashed by folding a strip of aluminum foil with adhesive backing over the joint prior to bolting.

A 1/2" thin-wall box-wrench is recommended for tightening the bolted flanges.

Weep holes are recommended to be located at each corner of the lowest edge of each collector, and are nominally 1/8" diameter.

2 ETM INSTALLATION

A typical ETM installation is shown in Figure 9. The ETM is located to minimize duct runs and to interface conveniently with the warm air furnace. The ETM is shipped in two parts; the blower and motor assembly and the flow control assembly. The flow control assembly is 31" x 29" by 46" high, and contains 2 damper motors, 4 dampers, connecting ducting, and the heat exchanger. The blower and motor assembly is 22" x 17" and 22" high. The blower and motor assembly has a weather cover, which can be removed to check and adjust the drive belt, motor and sheaves.

ETM Mounting

The two assemblies should be uncrated, inspected for damage and located in the approximate area where the ETM is intended to be placed. The two assemblies are joined by sliding the blower assembly into place so that the rectangular discharge duct and round inlet ducts line up. The discharge connection is an overlapping sheet metal fit which can be joined by either lifting the flow control assembly and lowering it on to the blower discharge, or by folding out one side of the mating ETM duct and refolding once the blower is in place. The discharge connection is finished with a flexible sealant as DC 781 and/or fastening with sheet metal screws. The round duct connection is made with the drawband provided.

The foundation support for the ETM assembly should be as rigid as possible. Both assemblies should be fastened down to the foundation. The base should be shimmed if the foundation is uneven to avoid distorting the supporting frame.

ETM Duct Connections

The ETM inlet air duct carrying the house return air has a 8" x 16" connection, using drive cleats on the short side and "S" cleats on the long side. The ETM discharge air duct carrying air to the collector has an 8" x 16" connection using drive cleats on the short side and "S" cleats on the long side. A plenum is mounted above the heat exchanger. A plenum detail is shown in Figure 9. The height of the plenum is dependent on the head room available and so the plenum is not supplied. The plenum has an inlet connection carrying air from the collector and an outlet connection carrying air to the main distribution trunk; these connections should not be on the same side of the plenum, but can be either on opposite or adjacent sides. The duct connections to the ETM should avoid mitered 90° joints whenever possible.

ETM Piping Connections

The heat exchanger connections are 1/2" F.P.T. There are two circuits which are to be connected in parallel using 3/4" piping. A temperature and pressure relief valve should be installed between the heat exchanger and any shut-off valve with a vent pipe conforming to local codes. Unions and gate valves should be located for convenient installation. A dirt leg should be provided for occasional maintenance.

ETM Electrical Connections

The ETM requires 120 V a.c. for the blower motor and the two damper motors. The ETM frame must be grounded. Conduit must be used to connect the ETM to the control panel as shown in Figure 10. The terminal board connectors are labelled inside the controller enclosure. The blower and damper rotations

ETM Electrical Connections, cont'd.

must be verified. The 120 V blower connection is TB2-8; the inlet damper motor 120 V connection is TB2-6; the outlet damper motor 120 V connection is TB2-7. The ETM neutral connection is TB2-9.

ETM Insulation

After the ETM is installed, it must be insulated with at least 4 inches of fiberglass insulation rated to 250° F. Board type insulations are recommended in the vicinity of the damper linkages; the damper motors are to be left exposed. The blower bearings and motor are to be protected by insulating the baffle spearating the blower and motor enclosures.

3. ELECTRICAL

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The control schematic is shown in Figure 11. A control enclosure is provided containing all the additional relays necessary to accommodate the solar system operating modes and furnace interfaces. The state of each damper is:

Mode	D1	D2	D3	D4
1. Direct solar heating	open	closed	closed	open
2. Heating by stored energy	open	closed	open	closed
3. Energy storage	closed	open	closed	open

The thermostat settings are:

Room Thermostat	Adjustable
Collector TSTAT	Close on use to 100°F, open on fall to 90°F.
Storage TSTAT	Close on rise to 100°F, open on fall to 90°F.
Diff. TSTAT	Open on rise to 180°F, close on fall to 170°F.
	Close on DT+ 20°F, open on DT=+ 10°F.
Furnace Discharge TSTAT	Opens on Rise to 110°F, Closes on fall to 90°F.

Auxiliary Furnace Interfaces

The interfaces between the auxiliary furnace and the solar system are:

1) Separate circuit breakers and emergency shut-offs.

2) 1st. stage of room thermostat powered by 24 V ETM transformer.

3) 2nd. stage of room thermostat powered by 24 V furnace transformer.

4) Activation of stage 2 of the room thermostat starts the furnace burner via the burner relay control.

5) Furnace discharge TSTAT opens on rise inhibiting Modes 1 and 2 so that simultaneous solar and furnace space heating cannot occur; this is done to avoid excessive delivery temperatures.

6) Activation of stage 1 of the room thermostat in Mode 1, the direct solar space heating mode, causes both the furnace and collector fans to start. The furnace fan switch is in parallel with a relay in the ETM so it is powered in Mode 1 and Mode 2.

Space Heating Control Logic

Whenever there is a demand for space heating, priority is given to using available solar energy first; if the available solar energy cannot sustain the demand then the auxiliary furnace burner is started. Solar energy can be delivered either directly, or from thermal energy. Relays control the solar energy supply in the following way:

1) Priority is given to direct space heating by solar, so if stage 1 of the room thermostat closes, and if the collector thermostat is closed, then the solar and furnace fans are powered. Dampers divert building air to collector.

2) If stage 1 of the room thermostat is closed, the collector thermostat is open, and the storage thermostat is closed, then the solar and furnace fans are powered. Dampers divert building air to heat exchangers.

3) If stage 1 of the room thermostat closes and both the collector

and storage thermostat are closed, preference is given to the direct heating mode by locking out the storage delivery mode.

4) If neither the collector or storage thermostats are closed, no solar heat will be delivered and as the room temperature falls, stage 2 of the room thermostat is closed starting the furnace burner.

Circulator Control Logic

Two circulator pumps are used to circulate water bi-directionally between the storage tanks and the heat exchanger. When stage 1 of the room thermostat is closed, the collector thermostat is open and the storage thermostat is closed, then the stored solar energy is used to supply space heating. A circulator is started to circulate water from the upper level of the tanks (to take account of stratification) to the heat exchanger.

A circulator is required to reverse the flow when heat is stored. The differential thermostat controls the storage mode in that collector air temperature must be at least 20° F above the storage temperature to enable the storage mode to start.

Electrical Connections

The electrical connections are shown in Figure 10.

1) Two-stage Thermostat

Disconnect the present thermostat and install the two-stage thermostat. Stage 2 is connected to the furnace oil burner control exactly in the same way as the single stage thermostat. Stage 1 is connected to terminals TB-1 and TB1-2 located in the electrical enclosure.

2) Collector Thermostat

The collector sensor assembly shown in Figure 12 consists of the collector thermostat, a differential thermostat thermistor and a weather tight enclosure. The sensor assembly is installed at the three-quarter point of the collector slant height in an "A" type collector. The collector thermostat is a hermetically sealed high quality snap-acting thermostat with a high temperature rating. The thermistor has a copper housing with a hole punched in it for direct attachment. The sensors are located in the air stream behind the absorber just upstream of the final return bend prior to discharge from the collector. The location of the sensor allows for temperature stratification prior to start-up and causes all control functions to be based on the discharge temperature of the air from the collector.

The collector thermostat is connected to terminals TB 1-3 and TB 1-4 in the electrical enclosure.

3) Storage Thermostat

The storage thermostat is installed at one storage tank as shown in the piping diagram. It is to be connected between points TB 1-5 and TB 1-6.

4) Differential Thermostat

Probes for differential thermostat are located at the top of one storage tank and at one type "A" collector. The bolt-on probe in the collector is to be connected to the differential controller. The immersion sensor on the storage tank is to be connected to the differential controller. The differential thermostat power connections are shown in Figure 10.

5) Circulator Pumps

Interface with the circulator pumps is accomplished by connecting the pump motor wires as follows: TB2-2 is common; TB2-1 for mode 2 circulator; TB2-3 for mode 3 circulator.

6) Furnace

Interface with furnace is accomplished by connecting stage 2 of the room thermostat to the furnace thermostat connections. A furnace discharge thermostat is installed in the discharge duct and connected to TB1-7 and TB1-8.

7) Power Supply Branch Circuit

Power supply branch circuit connection may be made to the same "side" of circuit as furnace branch circuit if convenient. Provide a chassis ground. Connect AC neutral to TB2-14 and line, 120 V 60 cps to TB2-13. The line current should be run through an EMERGENCY shutoff, which should be located adjacent to furnace emergency shutoff. The circuit for the solar heating system should carry a 15 amp circuit breaker.

4. PIPING

A typical piping schematic is shown in Figure 13. The storage tanks should be located convenient to the ETM. The following equipment is to be installed:

1) Storage tanks, as required (1.5 gal/ft^2 collector), connect in parallel so DHW draw is from top.
2) Two centrifugal circulators, storage mode draws from bottom; heating mode draws from top.
3) Pressure/temperature relief valves for ETM heat exchanger to prevent damage if gate valves left closed.
4) Vacuum relief valves to prevent cross-connections.
5) Expansion tank, pre-pressurized to 40 PSI; 100 PSI limit.
6) Pressure regulator to 40 PSI if municipal supply pressure is higher.
7) A backflow preventer to avoid heating cold water and/or losing stored energy.
8) A mixing valve to prevent over temperature on DHW.
9) Gate valves to isolate components for convenient maintenance.
10) Provide a bypass to the DHW heater for maintenance of the storage system.

The connections between tanks and other fixed end points must allow for thermal expansion. The tanks are insulated with an R=30 batt on the sides and top;: no additional insulation is used on the bottom, relying on the insulative qualities of the water to limit the heat loss. The piping and fittings must be insulated with 3/4" thick sleeve-type pipe insulation. The air ducting should be insulated with at least 4-inches of fiberglass insulation rated to 250°F.

5. EQUIPMENT REQUIRED

SOLAFERN ETM - Model 600: Includes blower, blower motor, heat exchanger, 4-dampers, 2-damper motors. One required for nominal flow rate of 600 CFM.

SOLAFERN CONTROL PANEL: Includes 24 V transformer, protection fuses, differential TSTAT, circuits, control relay bank prewired, test switches. One required per system.

SOLAFERN SOLAR COLLECTOR TYPE A: Collector used to start a row, includes inlet and outlet duct attachment collars, end plate and internal flow baffles. One required per row.

SOLAFERN SOLAR COLLECTOR TYPE B: Interconnecting collectors within a row, open ends, as required by row length.

SOLAFERN SOLAR COLLECTOR TYPE C: Collector used to terminate a row, includes internal flow baffle and end plate.

SOLAFERN COLLECTOR SENSOR PACKAGE: Assembly of all weather electrical box, collector insertion probe with thermostat and differential sensor attached. One required per system.

CIRCULATOR PUMP: 6 GPM @ 8 ft. head integral pump assembly.

EXPANSION TANK: Size to accept expansion over temperature range 50° F to 180° F and operating pressure 40 to 80 PSI. Pressurized bladder-type approved for DHW. Relief valve setting 100 PSI. Supplied as either 1 or 2 tanks depending on storage size. AMTROL type ST EX-TROL or equal.

MIXING VALVE: Bronze body, temperature range 110° - 170° F, rating 6 GPM, 1/2" sweat fittings, AMTROL Model 420 or equal.

AIR VENT: Pressure range 0-100 PSI, fast venting positive shutoff - AMTROL Model 701 or equal. Vertical mount at system high point.

PRESSURE RELIEF VALVE: Set for 100 PSI.

CHECK VALVE: Brass, 1" NPT, TEEL 2 x 612 or equal.

VACUUM BREAK: One per tank to avoid cross-contamination; allows for draining of tanks.

PRESSURE REDUCER: Drops cold water supply pressure to 40 PSI, no bypass. Used to maintain pressure control between 40-80 PSI allowing for expansion.

COLLECTOR BOLTING HARDWARE: Nine 5/16" diameter 18 THD 7/8" lg. stainless bolts per joint.

INSTALLATION ZEES: Optional, to assist installation and to clamp collectors. Two required per collector.

BATTENS: Optional for collector - roof type installations, 2 batten assemblies per collector.

MOUNTING BRACKETS: Optional, custom made to order for roof or ground mounting.

STORAGE THERMOSTAT: Snap acting thermostat set to close on rise to 100° F and open on fall to 90° F; hermetically sealed to strap on storage outlet piping.

STORAGE TANKS: 120 gallon approved for DHW; SEPCO CS - 120-N or equal.

6. OPERATION

The system consists of six modular subsystems:

1. Air-heating Solar Collector Subsystem
2. Solar Energy Transport Subsystem
3. Water-heating Energy Storage
4. Control Subsystem
5. Auxiliary Warm Air Furnace
6. Auxiliary Domestic Hot Water Heater

The system can supply space heating and domestic hot water as required. The proportional amount of heating provided by the solar system is dependent on the size of the solar subsystems. The size of the solar collector subsystem is developed by ganging individual collectors in rows and manifolding rows together. The number of collectors in a row and the number of rows are selected to suit the building. The energy storage system is sized by selecting the appropriate number of storage tanks and manifolding them. The energy transport functions are packaged into an energy transport module (ETM) containing the dampers, damper motors, blower and the heat exchanger. The air flow is adjusted by selecting the correct motor size for the belt driven blower and adjusting the variable drive pulley sheaves.

There are five operating modes:

Mode 1: Direct Solar Heating of Air Used for Space Heating.

Mode 2: Heating of Air Used for Space Heating by Stored Solar Energy.

Mode 3: Storage of Solar Energy for Later Use.

Mode 4: Heating of Air Used for Space Heating by the Auxiliary Furnace.

Mode 5: Heating of Domestic Hot Water.

The three solar modes are shown in Figure 14.

All modes are automatically controlled by thermostats:

1) Two Stage Room Thermostat

The first stage calls for space heating by solar heated air either directly or from storage. The second stage controls the space heating by the auxiliary furnace.

2) Collector Thermostat

The collector thermostat enables Mode 1 to function when the collector is sufficiently warm.

3) Storage Thermostat

The storage thermostat enables Mode 2 to function when the storage is sufficiently warm, but the collector is not warm.

4) Differential Thermostat

The differential thermostat enables Mode 3 to function when the collector is sufficiently warmer than storage.

The control system selects the operating mode as shown in Figure 15. Mode 5 can operate anytime, drawing heated water from storage and further increasing the water temperature by the auxiliary heater as required.

When there is no demand for heat and the storage temperature increases, a preset temperature limiting thermostat shuts down the operation. The system is reset automatically when a demand lowers storage temperature.

Periods of Low Demand

During the summer and low demand periods, the storage may achieve its limiting temperature of 180° F, in which case the collector fan is automatically turned off, and the collector is in a no-flow condition. The collector is designed to withstand the no-flow condition.

7. MAINTENANCE

1. Lubrication

Lubricate the blower motor and pump motor annually. The dampers utilize bronze Oilite bushings. The ETM blower has permanently lubricated sealed ball bearings.

2. Electrical

Fuses are provided for each major electrical component to provide trouble-shooting information. The failure of a fuse very likely does not indicate that a component has become unserviceable, but serves as a warning that the component may be consuming excess power. Upon the failure of a fuse, the component should be checked for performance, and the component's load should be checked to assure proper working conditions.

3. Mechanical

a. The collector should be checked initially every month, and finally annually, to assure that the inner face of the glazing has not become contaminated by condensate from collector material outgassing, cigarette smoke or other pollutants. If the glass is found to be dirty, it should be removed and cleaned.

b. The heat exchanger may become clogged if the furnace filter is not properly maintained. It can also become grimy and dusty if the furnace return air is contaminated with cooking grease, etc. This can be a cause of excess blower power consumption and inhibited heat transfer.

c. If hard water is a local oroblem, then the heat exchanger may eventually become clogged with precipitating particles. This will inhibit heat transfer

3. Mechanical, cont'd.

reducing the heat exchangers effectiveness. The water pressure drop in the heat exchanger will increase, causing slightly increased pump power consumption. The use of a water softener may be helpful in preventing this problem.

d. The blower drive belt should be adjusted to develop a proper balance between heat transfer and fan power. The collector flow should not exceed furnace air flow, but otherwise should be about 60 CFM per collector.

4. Glass Breakage

If glass breakage occurs, then the collector should be temporarily protected against moisture penetration by stretching and taping a heavy gauge polyethelene sheet (available at local hardware store) over it. If the collector is in a no-flow condition, the cover should be opaque to avoid the possibility of melting it. It is important that direct handling of the absorber be avoided as the oils found on finger-tips can degrade the coating; the use of gloves is recommended when cleaning broken glass away from the absorber.

Replacing glass involves unbolting the glazing frame and removing it intact. The glass can then be installed by a professional glazier. The glass is 46" x 96" x 7/32" tempered low-iron glass. Removal of the glazing frame involves breaking sealed connections at the flanges and at the short ends of the absorber. The seal is broken by slitting the sealant along the joints. Prior to replacing the cover, sealant as DC 781 should be placed along the flanges and the short ends of the absorber.

5. Trouble Shooting

A number of test switches and fuses are provided within the electrical enclosure.

Fuses

Pump, blower and damper motor fuses are provided so if a fuse is blown, each item can be checked to ascertain if it is at fault. The switches remove power to each of the motors.

Thermostat Switches

Thermostat failure can be checked via collector TSTAT, storage TSTAT, differential TSTAT and room TSTAT bypass switches.

If the system refuses to start then:

1) check fuses.
2) be sure power is on.
3) check thermostat settings, and finally,
4) trouble-shoot as described above.

6. Flashing

The collector flashings should be inspected each year and after severe storms. Silicone sealant should be used to caulk potential leaks and the flashings should be kept in good repair.

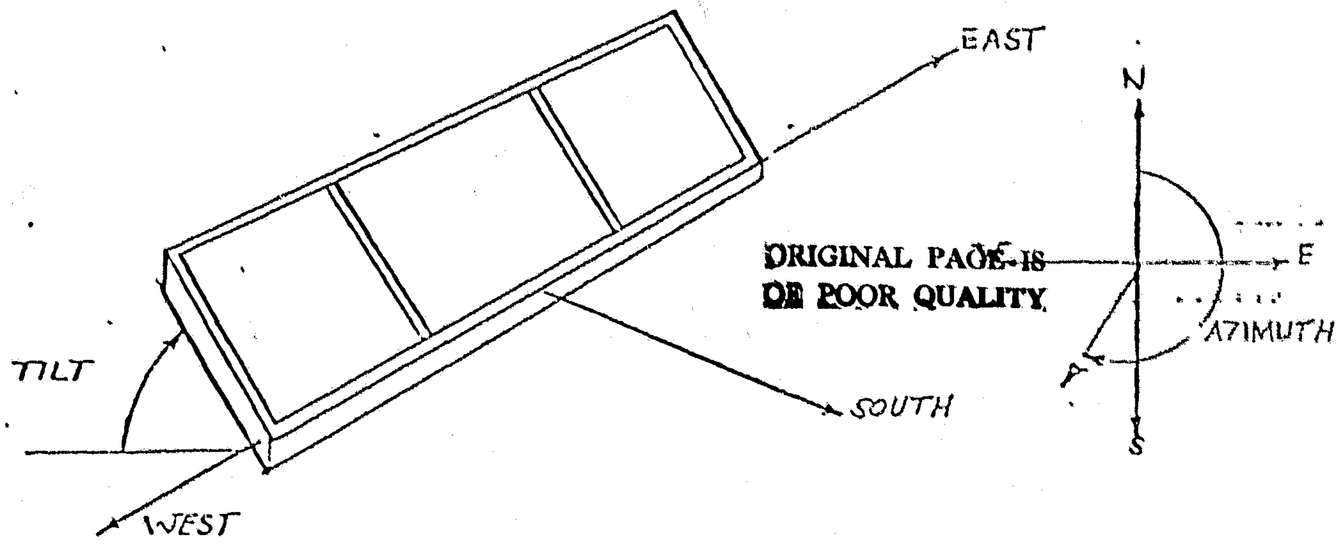

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FIGURE 1 COLLECTOR TILT & AZIMUTH

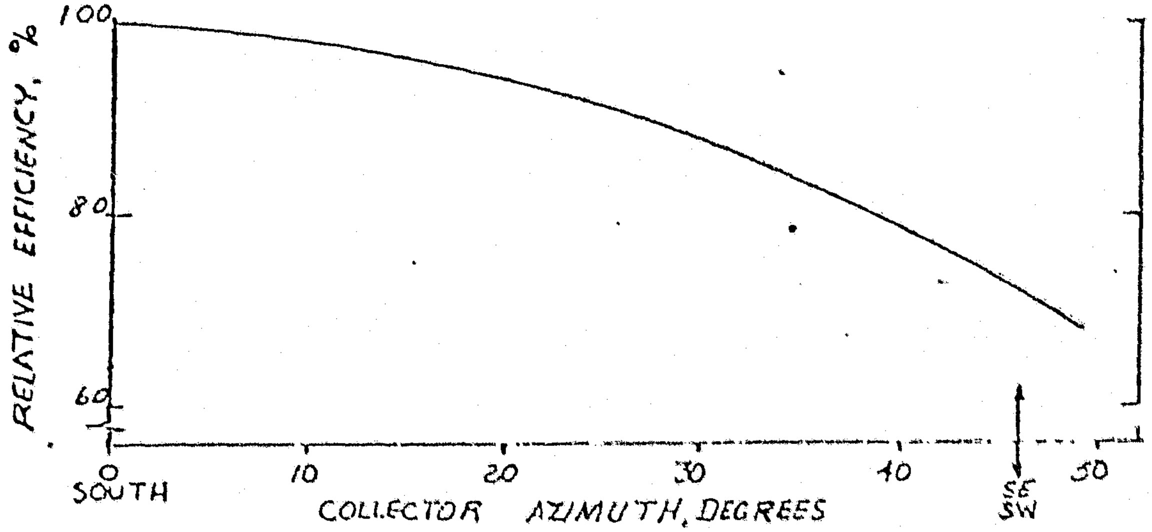


FIGURE 2 EFFECT OF COLLECTOR AZIMUTH ON SYSTEM EFFICIENCY

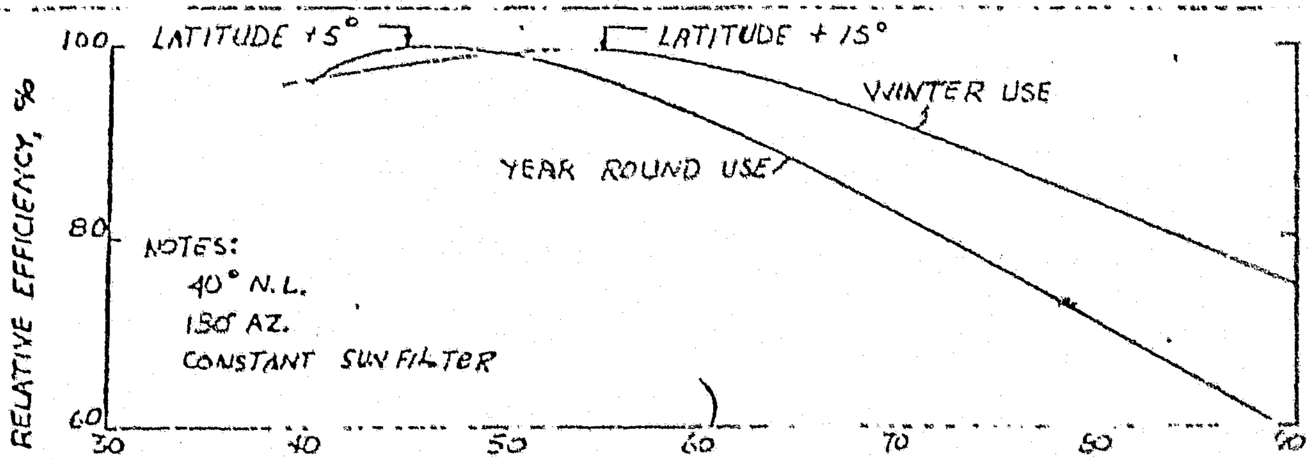


FIGURE 3 EFFECT OF COLLECTOR TILT ON SYSTEM EFFICIENCY

FERN ENGINEERING
BUZZARDS BAY, MASSACHUSETTS
U.S.A.

DRAWN
APPD
DATE

EFFECTS OF COLLECTOR AZIMUTH & TILT

DWG. NO.
REV.

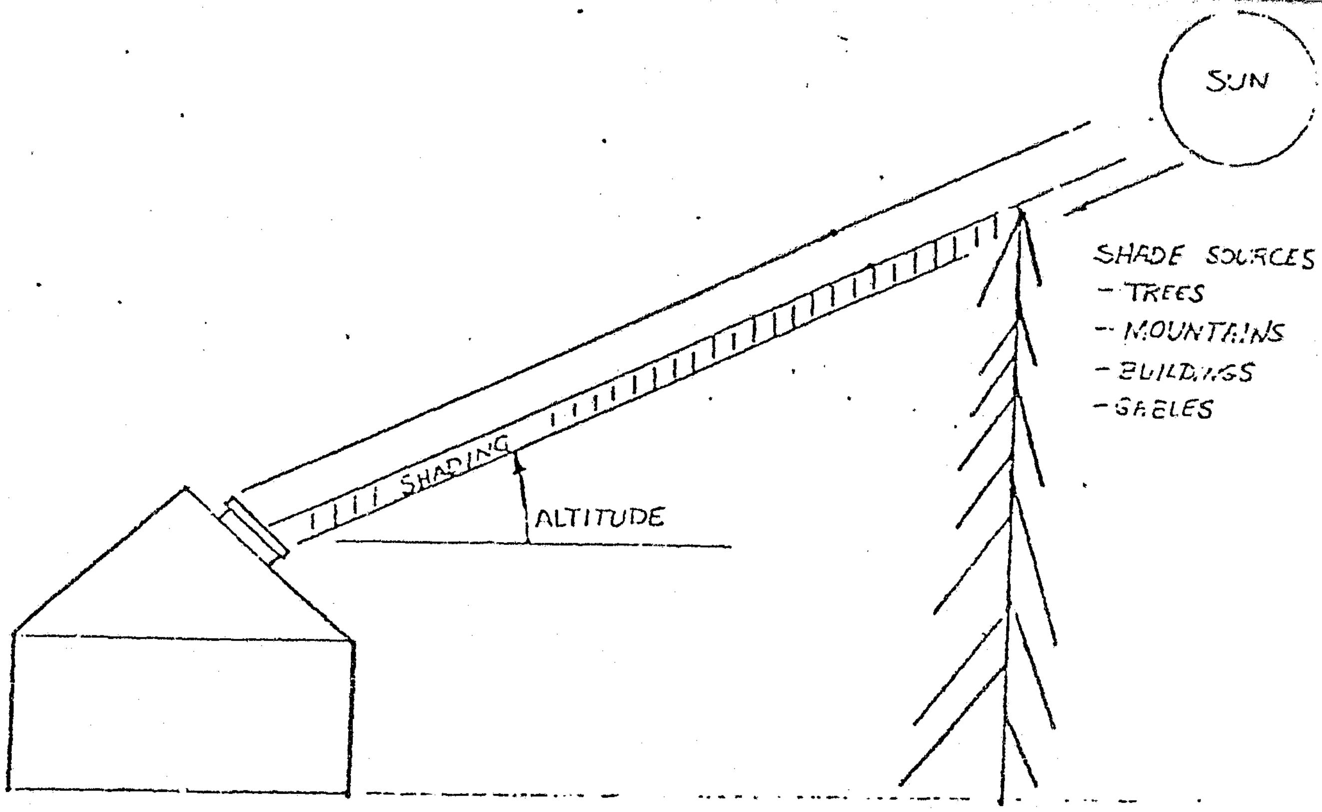


FIGURE 4 SHADOW AT WINTER SOLSTICE

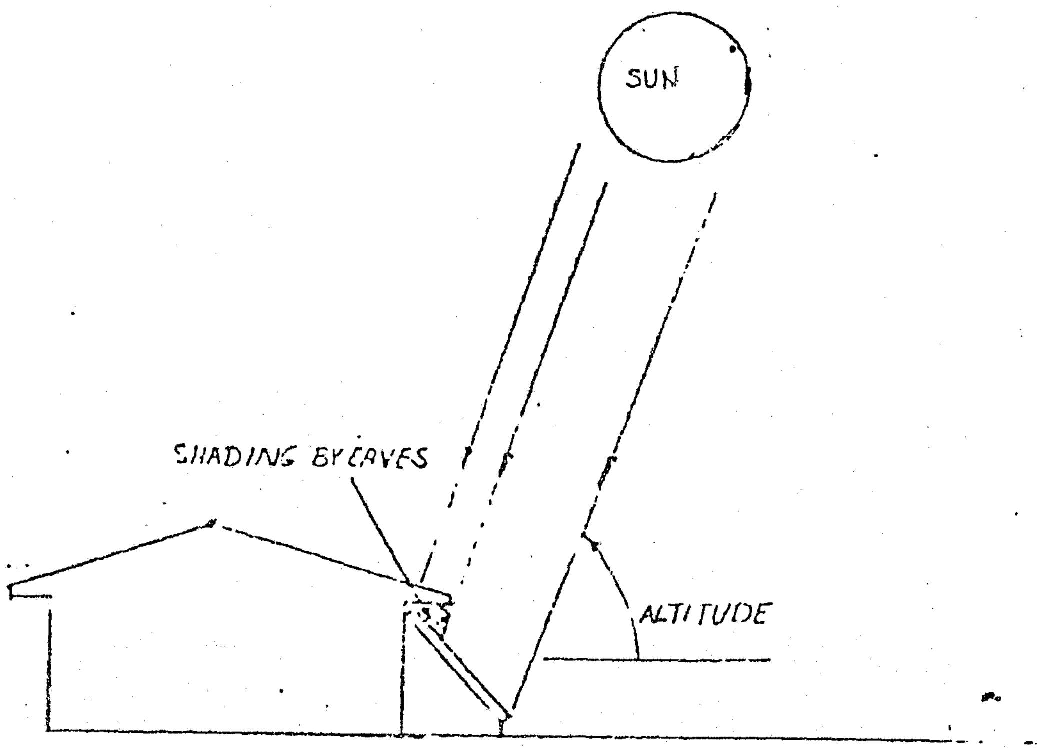
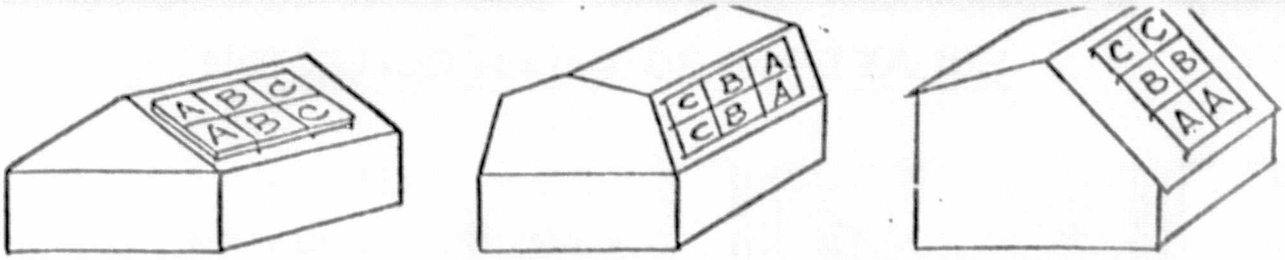


FIGURE 5 SHADOW AT SUMMER SOLSTICE

FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APP'D DATE	SHADOW CONSIDERATIONS DWG. NO.	REV.

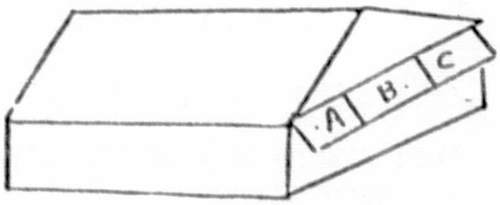


CAPE GAMBREL SALT BOX

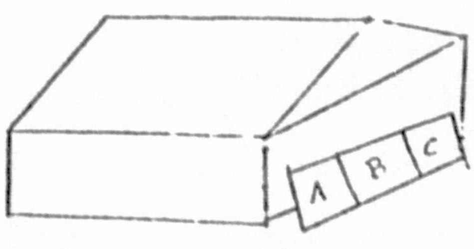
6 a ROOF MOUNTED , ELEVATED OR INTEGRATED

RANCH FLAT ROOF

6 b ROOF MOUNTED , OPTIMUM TILT



6 C WALL MOUNTED

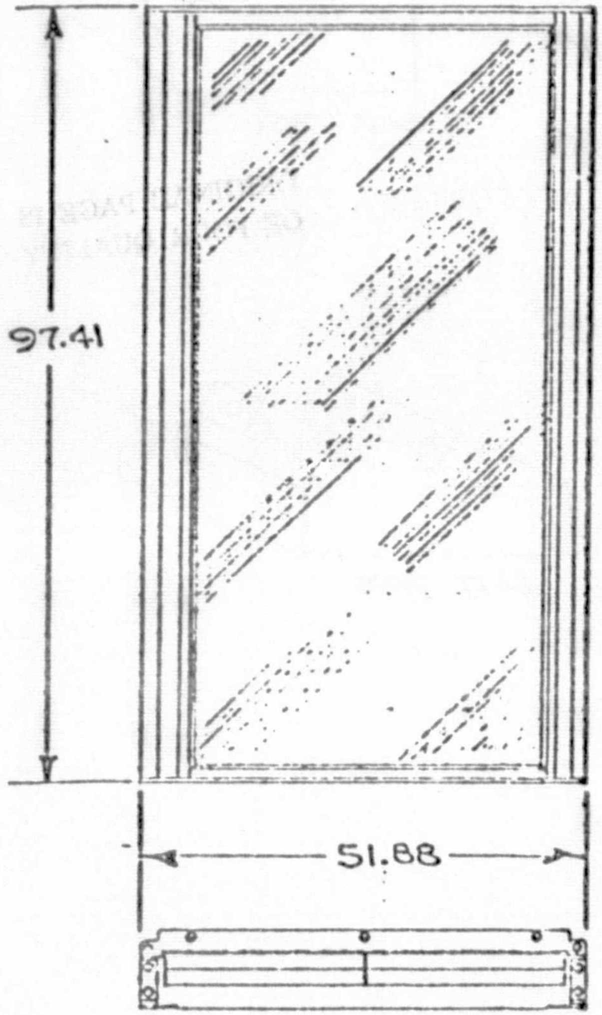


6 d GROUND MOUNTED

FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APPD DATE	COLLECTOR ARRANGEMENTS DWG. NO. FIGURE 6 REV.

MAKEPEACE P-1017

SOLAFERN-30 SOLAR COLLECTOR

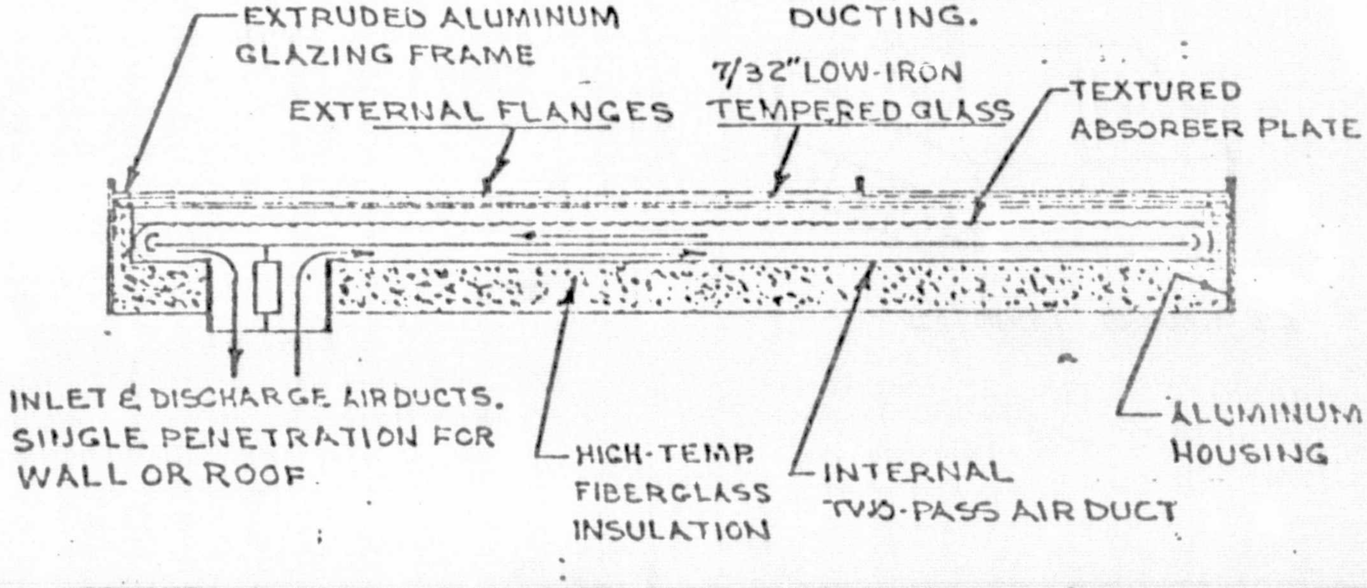


SPECIFICATIONS:

- SIZE: 97.41" X 51.88" X 9.5"
- WEIGHT: 190 LBS.
- COVER: LOW-IRON TEMPERED GLASS.
- EFFECTIVE AREA: 30 SQ. FT.
- HOUSING: ALUMINUM.
- HEAT TRANSFER FLUID: AIR.
- MOUNTING: ROOF, WALL OR GRADE MOUNTED WITH CONTINUOUS EXTERNAL FLANGES.
- MANIFOLDING: COLLECTORS MOUNT END TO END WITH SIMPLE EXTERNAL FLANGES.

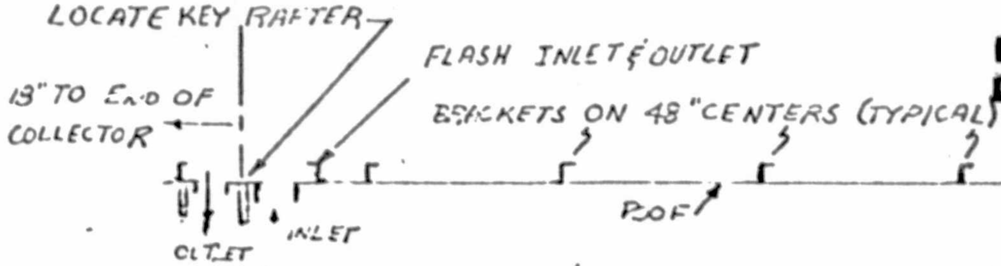
COLLECTOR TYPES:

'A'-CONTAINS INLET & DISCHARGE DUCTING.
'B'-CONTAINS THRU-FLOW DUCTING.
'C'-CONTAINS RETURN FLOW DUCTING.

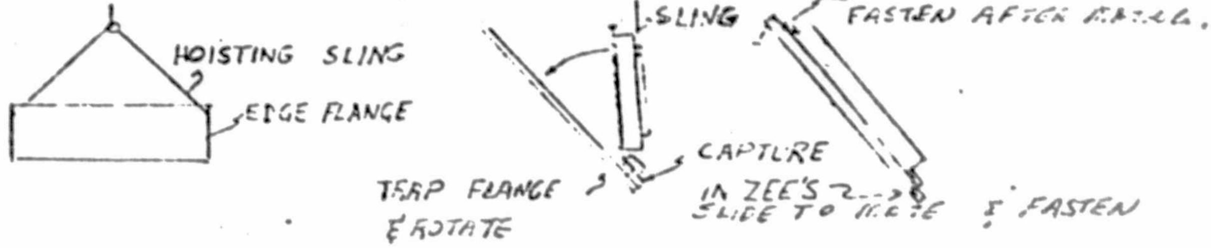


SOLAFERN LTD. BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN DDL APPD DATE 8-3-77	SOLAFERN-30 COLLECTOR SPECIFICATIONS DWG NO. 724-55-001 REV.

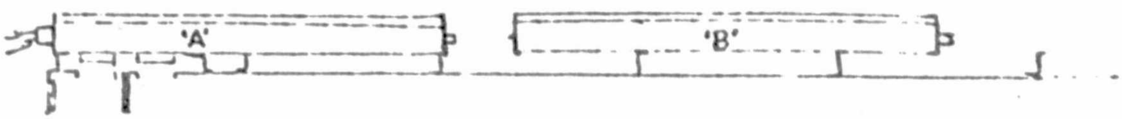
Figure 7



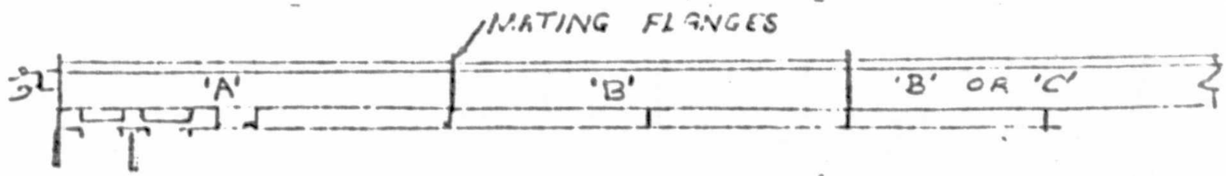
STEP 1 INSTALL BRACKETS & MAKE ROOF PENETRATIONS



STEP 2 RAISE COLLECTORS FOR HIGHEST ROW AND CAPTURE ON ROOF



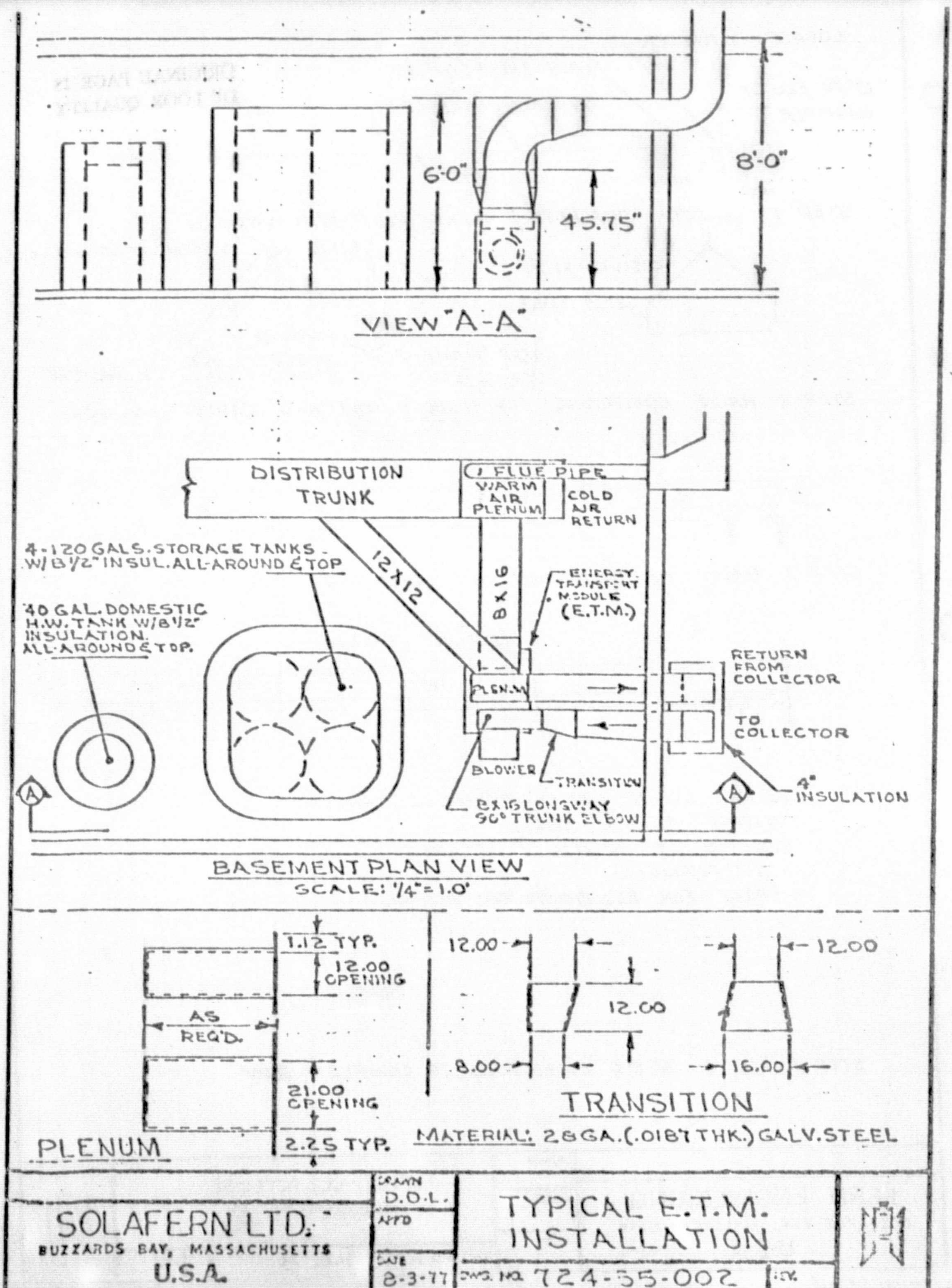
STEP 3 LOCATE AND BOLT DOWN 'A' COLLECTOR



APPLY SEALANT GASKET TO MATING FLANGES
INSTALL SILICONE GASKET
SLIDE 'B' TO MATE 'A' FLANGE
BOLT FLANGES
REPEAT FOR ADDITIONAL COLLECTORS

STEP 4 INSTALL 'B' & 'C' COLLECTORS TO COMPLETE ROW

FERN ENGINEERING - BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN	INSTALLATION SEQUENCE		
	APPD			
	DATE	DWG. NO. FIGURE 8	REV.	



ORIGINAL PAGE IS OF POOR QUALITY
6'-0"
45.75"
8'-0"
VIEW "A-A"
DISTRIBUTION TRUNK
FLUE PIPE
WARM AIR PLENUM
COLD AIR RETURN
4-120 GALS. STORAGE TANKS W/8 1/2" INSUL. ALL-AROUND & TOP
12X12
8X16
ENERGY TRANSPORT MODULE (E.T.M.)
40 GAL. DOMESTIC H.W. TANK W/8 1/2" INSULATION. ALL-AROUND & TOP.
PLENUM
RETURN FROM COLLECTOR
TO COLLECTOR
BLOWER
TRANSITION
4" INSULATION
8X16 LONGWAY 90° TRUNK ELBOW
A
A
BASEMENT PLAN VIEW
SCALE: 1/4"=1.0'
1.12 TYP.
12.00 OPENING
AS REQ'D.
21.00 OPENING
2.25 TYP.
PLENUM
12.00
12.00
12.00
8.00
16.00
TRANSITION
MATERIAL: 28 GA. (.0187 THK.) GALV. STEEL
SOLAFERN LTD.
BUZZARDS BAY, MASSACHUSETTS
U.S.A.
DRAWN D.O.L.
APPD
DATE 8-3-77
TYPICAL E.T.M. INSTALLATION
DWG. NO. 724-35-002
REV.

Figure 9

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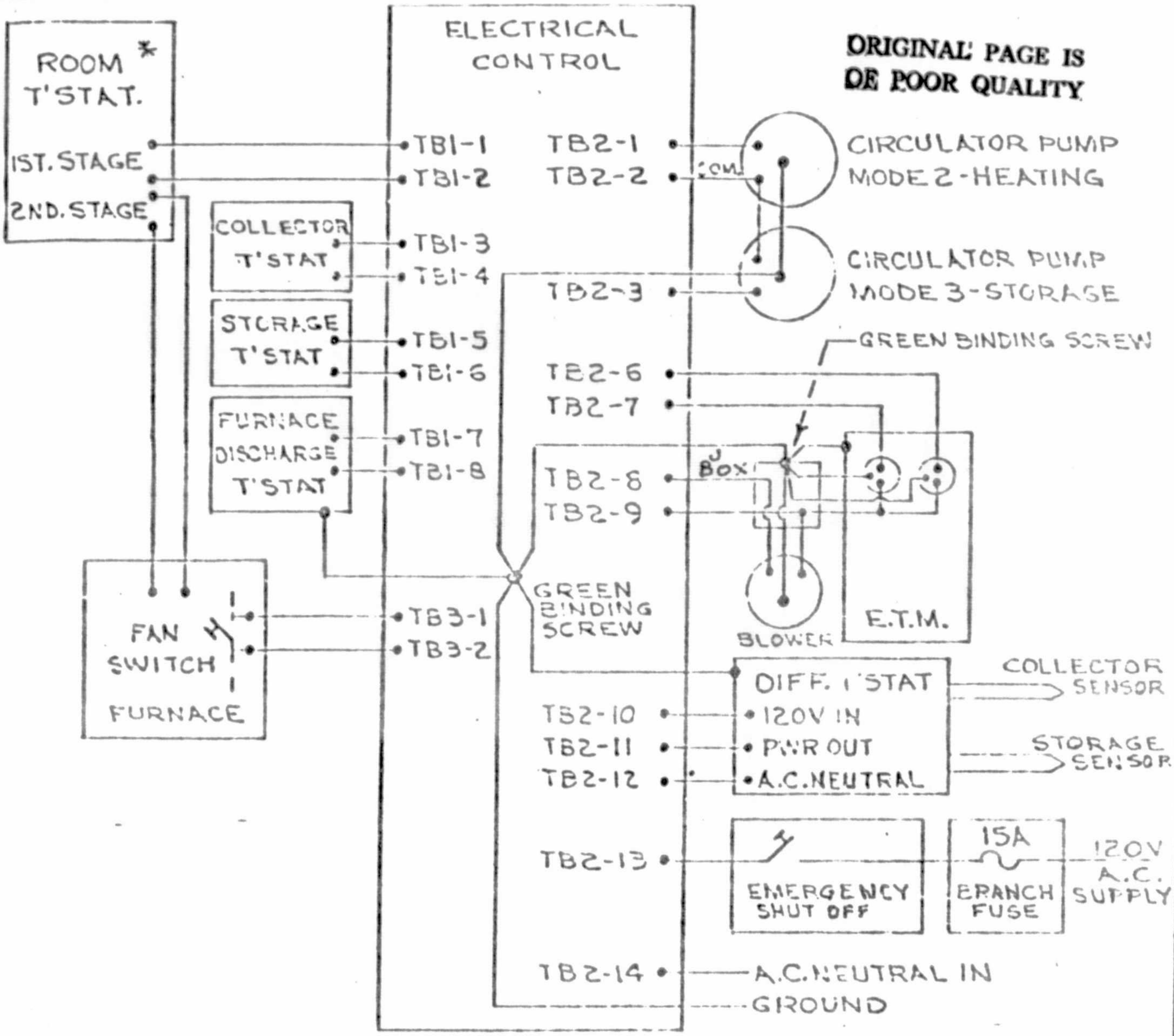
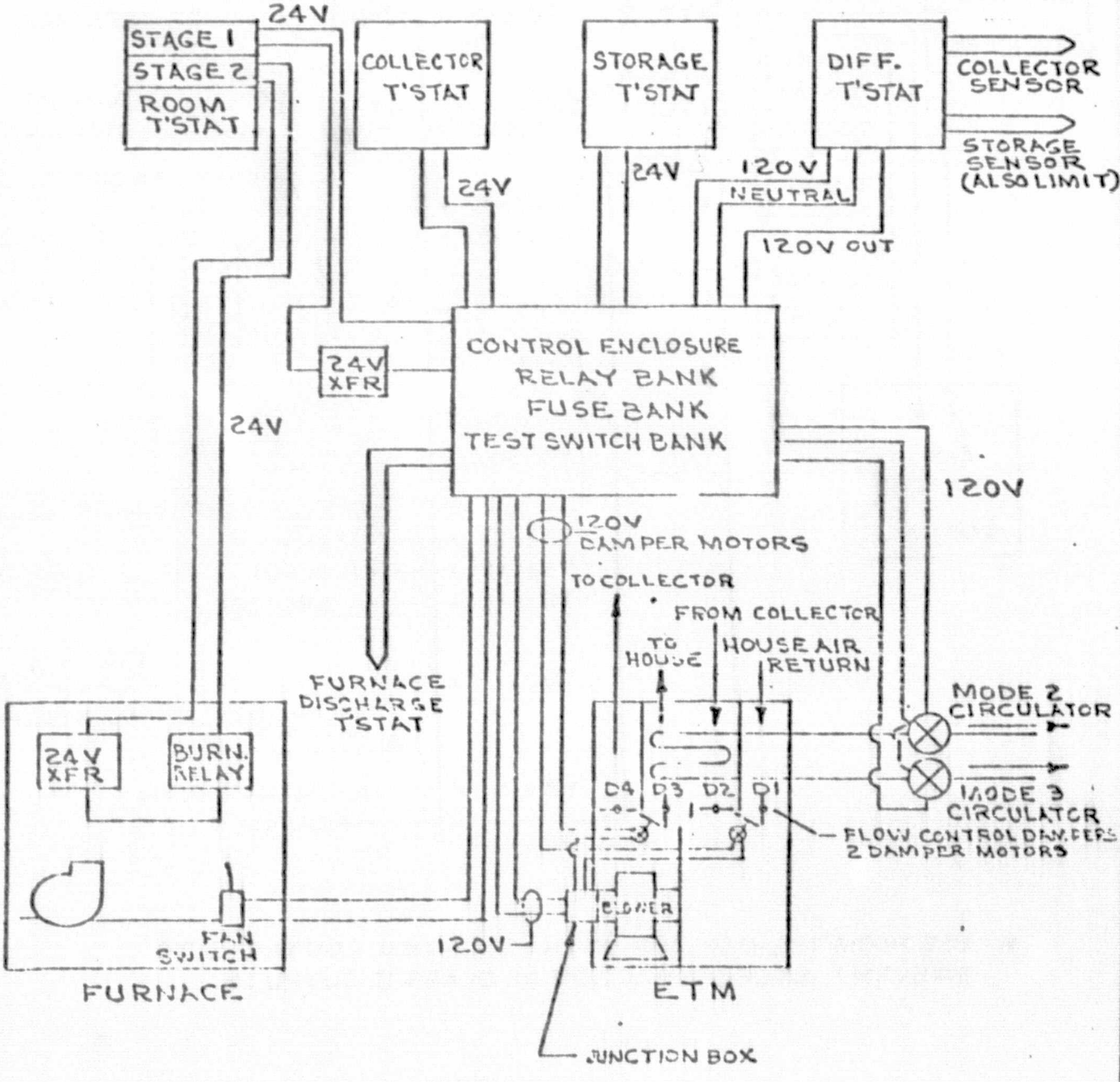
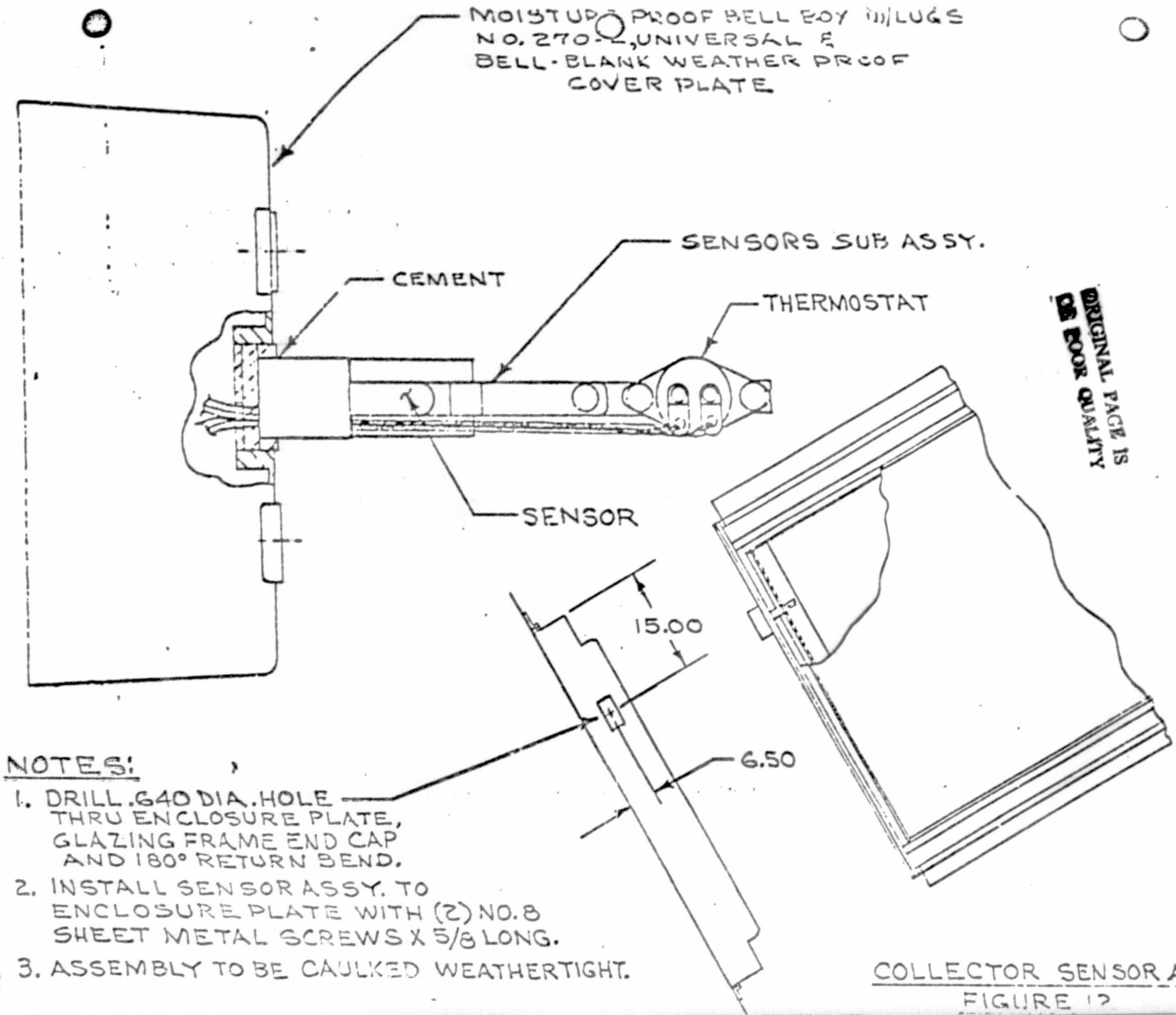


* USE ROOM THERMOSTAT WITH ISOLATED CONTACTS TO PREVENT INTERCONNECTION OF CLASS II OUTPUTS.

FERN ENGINEERING - BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN / APPD / DATE	WIRING DIAGRAM	
		DWG. NO. FIGURE 10	REV.



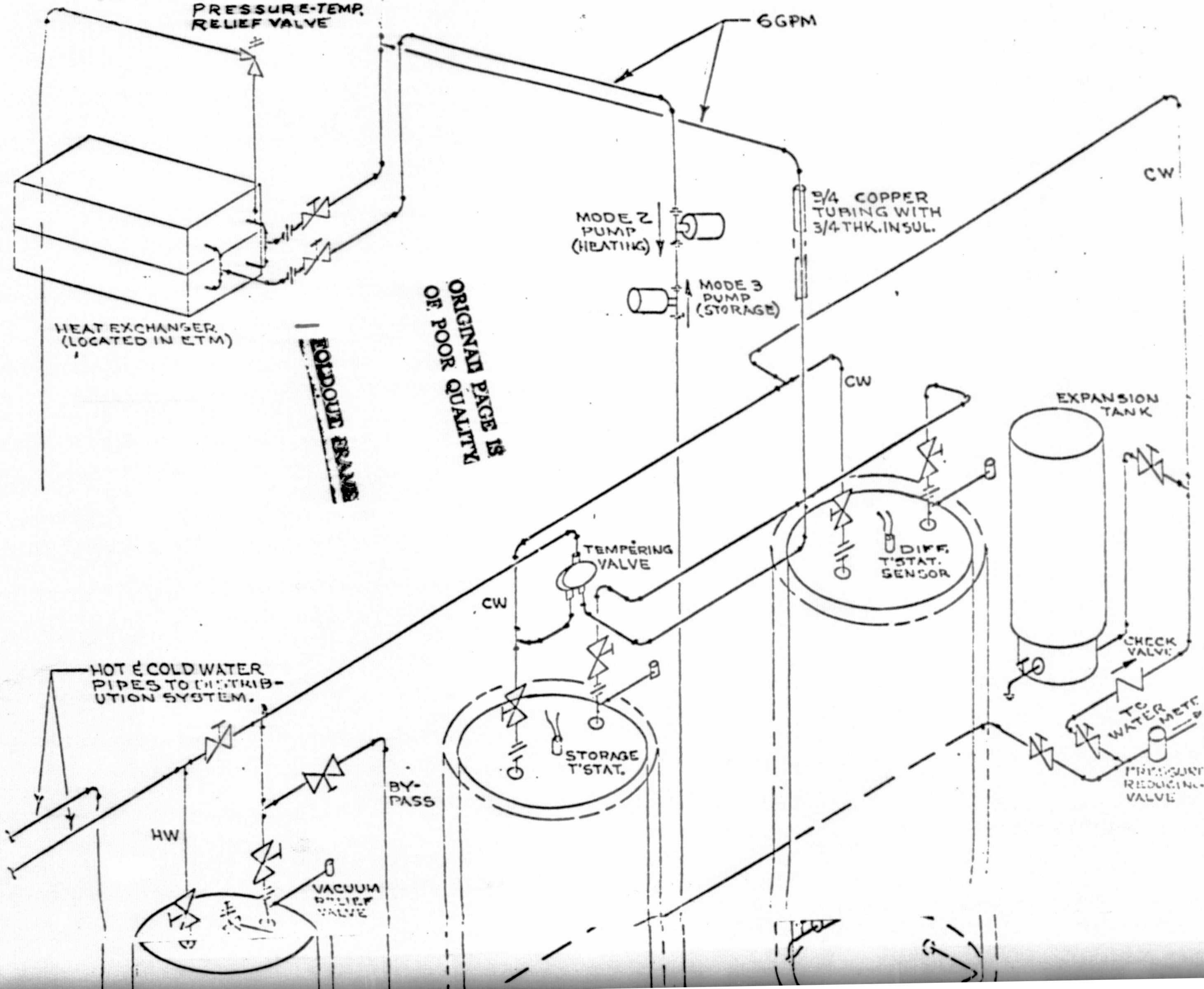
FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN APPD DATE	CONTROL SCHEMATIC DWG. NO. FIGURE 11 — REV.

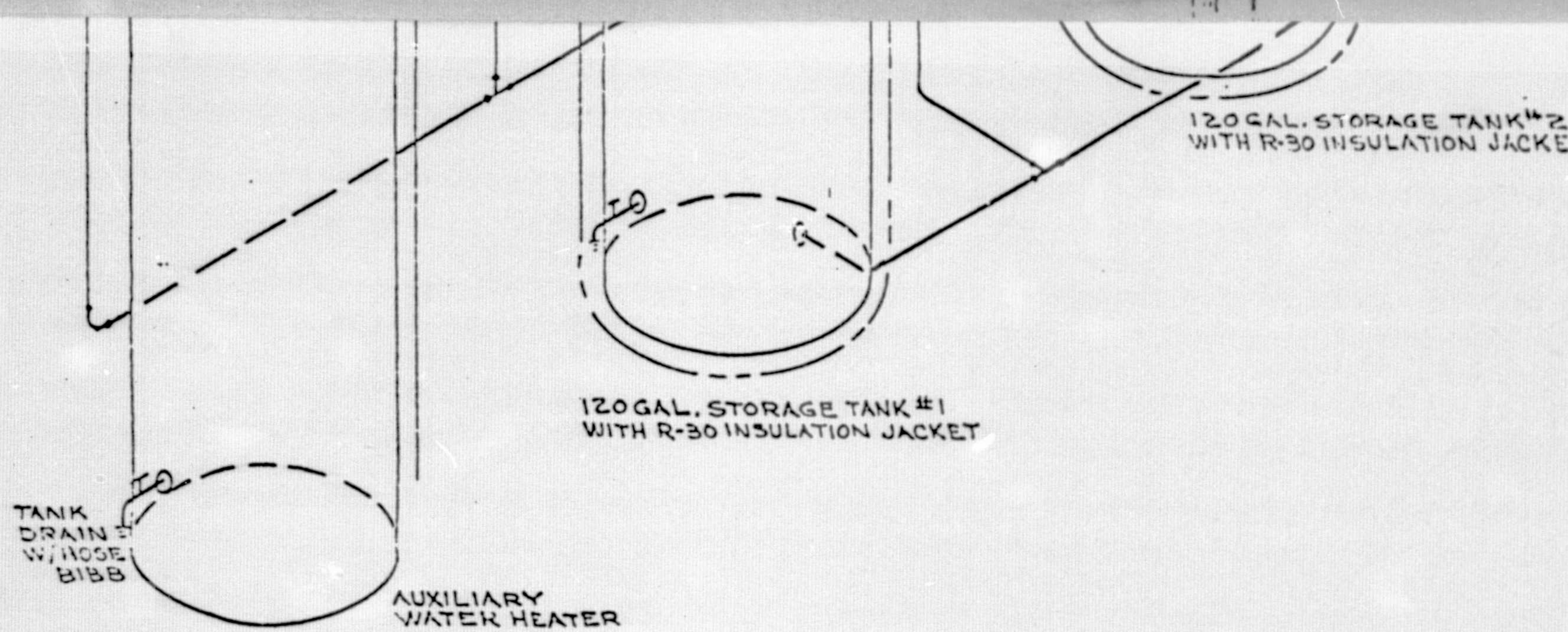


NOTES:

1. DRILL .640 DIA. HOLE THRU ENCLOSURE PLATE, GLAZING FRAME END CAP AND 180° RETURN BEND.
2. INSTALL SENSOR ASSY. TO ENCLOSURE PLATE WITH (2) NO. 8 SHEET METAL SCREWS X 5/8 LONG.
3. ASSEMBLY TO BE CAULKED WEATHERTIGHT.

COLLECTOR SENSOR ASSY.
FIGURE 12


PRESSURE-TEMP. RELIEF VALVE
6GPM
HEAT EXCHANGER (LOCATED IN ETM)
MODE 2 PUMP (HEATING)
MODE 3 PUMP (STORAGE)
3/4 COPPER TUBING WITH 3/4 THK. INSUL.
CW
CW
EXPANSION TANK
TEMPERING VALVE
DIFF. T'STAT. SENSOR
CW
CHECK VALVE
HOT & COLD WATER PIPES TO DISTRIBUTION SYSTEM.
STORAGE T'STAT.
BY-PASS
HW
VACUUM
VALVE



NOTES:

1. INSTALLATION MUST ALLOW FOR THERMAL EXPANSION OF [illegible]
2. 1/2" COPPER TUBING UNLESS OTHERWISE SPECIFIED.

PIPING SCHEMATIC

FIGURE 13

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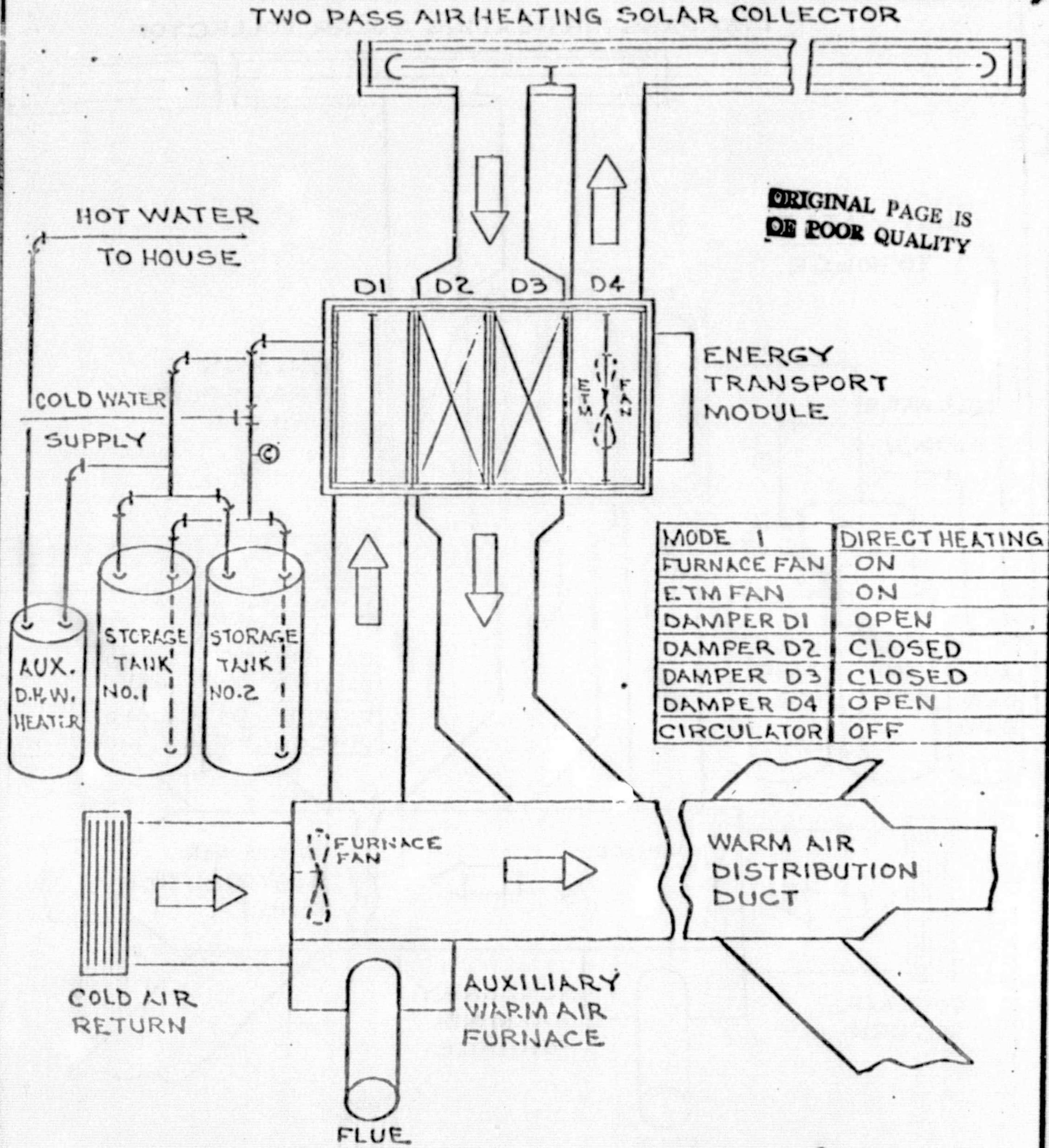
FOLDOUT FRAME 1



MODE 1	DIRECT HEATING
FURNACE FAN	ON
ETM FAN	ON
DAMPER D1	OPEN
DAMPER D2	CLOSED
DAMPER D3	CLOSED
DAMPER D4	OPEN
CIRCULATOR	OFF

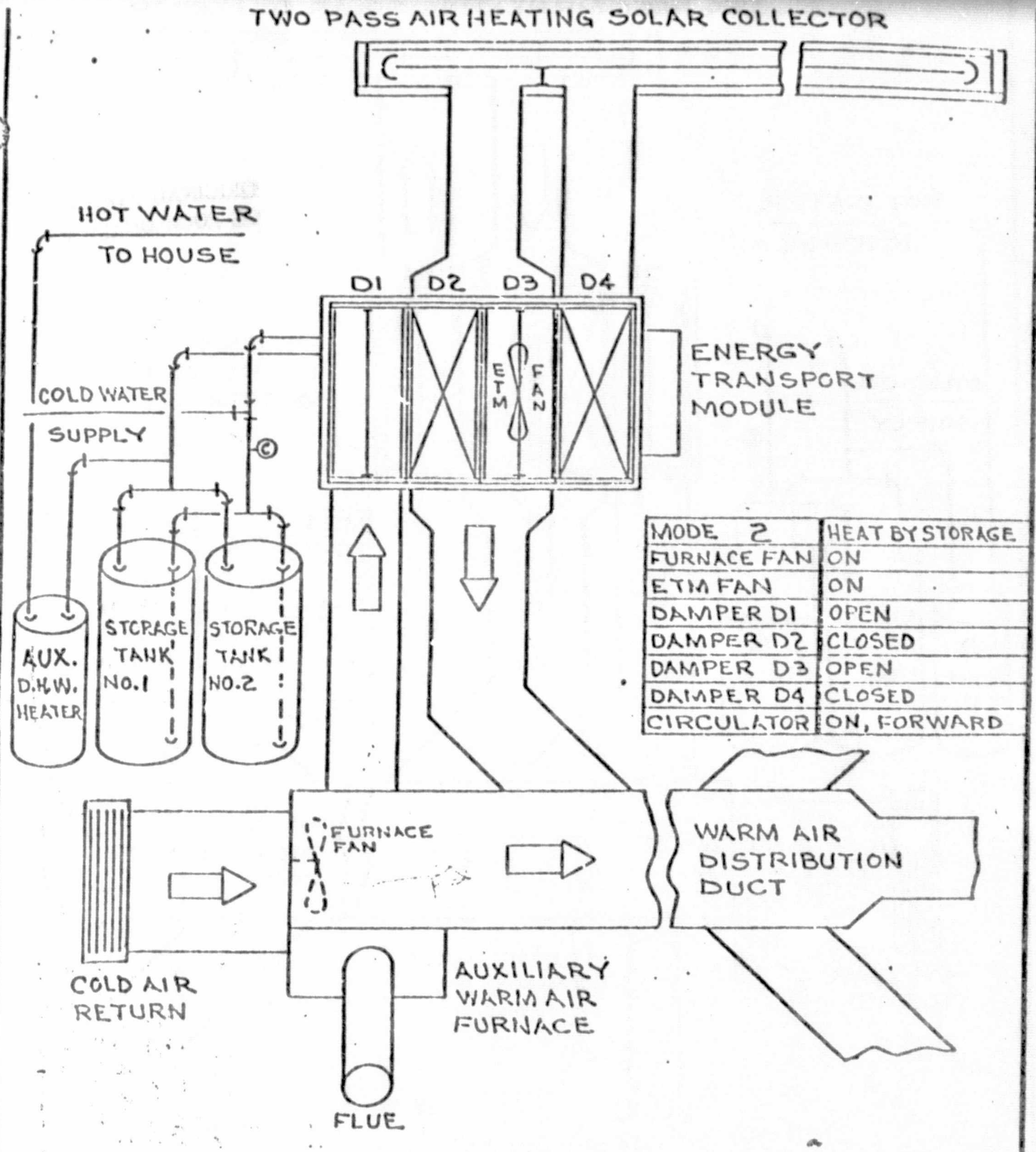
Parallel auxiliary furnace

FERN ENGINEERING
BUZZARDS BAY, MASSACHUSETTS
U.S.A.

DRAWN
APP'D
DATE

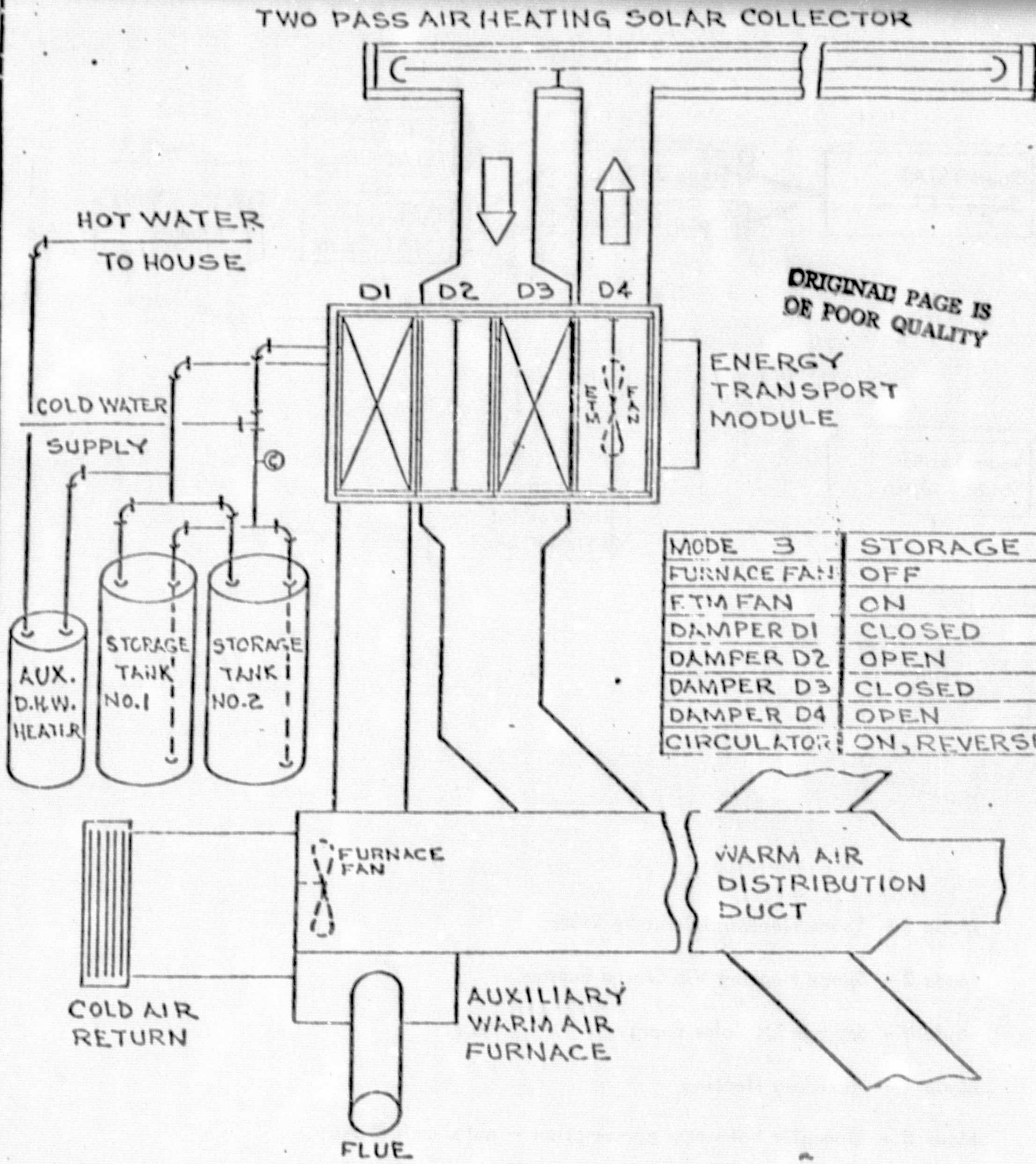
SPACE HEATING - DIRECT
SYSTEM OPERATION
MODE 1

DWG. NO. FIGURE 14 SH. 1



MODE 2	HEAT BY STORAGE
FURNACE FAN	ON
ETM FAN	ON
DAMPER D1	OPEN
DAMPER D2	CLOSED
DAMPER D3	OPEN
DAMPER D4	CLOSED
CIRCULATOR	ON, FORWARD

FERN ENGINEERING BUZZARDS BAY, MASSACHUSETTS U.S.A.	DRAWN NTD DATE	SPACE HEATING - FROM STORAGE *SYSTEM OPERATION* MODE 2 DWG NO FIGURE 14 SH. 2 REV.



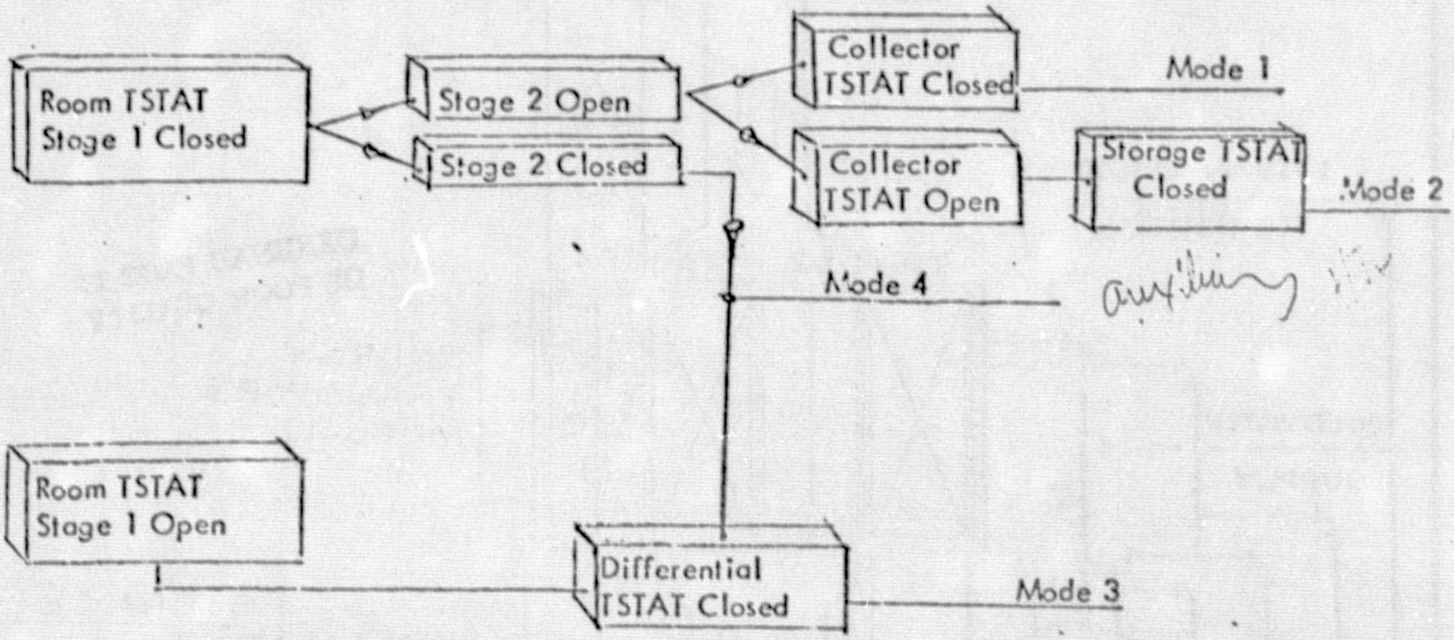
MODE 3	STORAGE
FURNACE FAN	OFF
ETM FAN	ON
DAMPER D1	CLOSED
DAMPER D2	OPEN
DAMPER D3	CLOSED
DAMPER D4	OPEN
CIRCULATOR	ON, REVERSE

FERN ENGINEERING
BUZZARDS BAY, MASSACHUSETTS
U.S.A.

DRAWN
NTD
DATE

HEAT TO STORAGE
SYSTEM OPERATION
MODE 3

DWG NO. FIGURE 14 SH.3



Mode 1 - Space Heating Direct By Solar

Mode 2 - Space Heating Via Stored Energy

Mode 3 - Storage Of Solar Energy

Mode 4 - Auxiliary Heating

Mode 5 - Domestic hot water consumption - not shown above.

FIGURE 15 OPERATING MODE SELECTION

HAZARD ANALYSIS

CONTRACT:	NASA 8-32246	DOCUMENT NO. 5002	
SUBJECT:	Systems Hazard Analysis	JOB NO. 198	
AUTHOR:	P. Levine	DATE: December 29, 1976	
		Revision Date: March 3, 1977	

1. Scope

This document is intended to partially fulfill the System Hazard Analysis of the data requirements No. 504 - 18.

2. No Flow Condition

The temperatures (degrees F) developed in the collector under no flow conditions are as follows :

	No Reflector Summer Condition	With Reflector Winter Condition
Outer Cover	203	215
Inner Cover	288	340
Absorber	358	430

The choice of materials is predicated on these temperature levels to preclude a fire or fume hazard.

3. Wind Load

A peak wind load of 56 PSF is the baseline design limit.

4. Glass Cover

Tempered glass is used for the cover.

5. Water Temperatures

Solar storage water temperature is limited to 190 ^{o}F.

6. Damper Obstructions

There are no dampers placed in the ducts or flue of the back-up heating system.

7. Water Pressure

A pressure regulator is specified if municipal water pressure is greater than 80 psi.

8. Expansion Tank

An expansion tank is provided with back-flow check valve to preclude the possibility of hot water being discharged in the cold line and also to limit the pressure buildup to 80 psi.

9. Vacuum Breakers

Vacuum Breaker vents are provided to guard against cross-connection contamination.

10. Pressure/Temperature Relief Valves

Pressure/Temperature Relief Valves are provided between heat sources and shut-offs to preclude damage to the water system.

11. Use of Urethane

The use of urethane is restricted to regions having temperatures within the allowable temperature limits. No exposed urethane is permitted in the system.

12. Electrical Shock

Three wire grounded housing system prevents electrical shock from energy transport module. 24 volt control system limits danger of thermostat wiring.

13. Electrical Failure

See No. 24 of this report.

14. Blower Overload

Blower overload is prevented by electrical interlock switch preventing blower operation while dampers are not properly in position.

15. Welded Relay Contacts

Welded relay contacts would be hazardous to the reversible circulator pump wiring. Separate fuses provide isolation of circulator pump.

16. Water Leakage in E.T.M.

A splash pan protects electrical enclosure from spilling water. A drain hole is provided at bottom of E.T.M.

REVISION - ADDITIONS TO HAZARD ANALYSIS

17. Pressure Reducing Valve Failure

In the event of failure of this valve, system pressure could reach the setting of the pressure-temperature relief valve, causing it to bleed water from the system. This fault could go unnoticed, occasionally spilling small amounts of water.

18. Expansion Tank Failure

System water expansion is on the order of 5 gallons. Should the expansion tank fail to receive this expansion, it would bleed through the pressure-temperature relief valve.

19. High Temperature Surfaces within the building are insulated to prevent heat loss, and are not a hazard to building occupants. Warning markings will be placed on ETM to caution repairmen of danger of burns from hot water in heat exchanger and pump. Other hot surfaces in ETM are not considered dangerous to repairmen.

Installation instructions will require that collectors be installed in an accessible location upon a roof or in a fenced off area, to prevent hazard of burns.

20. Fire Hazard

All system components are of noncombustible or fire retardant materials, with the exception of the isocyanurate insulation used. In the collector the isocyanurate is isolated from air passages by .030" aluminum duct wall.

The cellotex TF-400 in 1.63" thickness has a flame spread rating of 30.

21. Emergency Shut-off-Electrical

An emergency electrical shut-off is located within the living space adjacent to the back-up furnace emergency shut-off, in accordance with local code. This switch does not interfere with back-up system operation.

22. Main Shut-off - Water

A manual shut-off valve is located at the water supply branch with which to isolate the solar heating system from the water supply. A solar bypass valve is also provided to make water available to the DHW heater while the solar heating system is out of service.

23. Back Flow

Back flow of solar heating system water into cold water piping is prevented by a check valve in solar heating branch piping.

24. Electrical Failure

Solar system is on separate branch circuit from furnace to avoid disruption of existing circuit in retrofit installation. This arrangement places 4 live wires, part of furnace circuit in the electrical enclosure. This is a necessary interface permitting the operation of the blower, and preventing simultaneous operation of solar and back-up systems. The wires will be marked to indicate they are live wires on furnace circuit.

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25. Fuse/Component/Linkage Failures

Fuse, component or linkage failures within the solar heating system will result in loss of performance. The occupant is able to observe the performance of the system. No special failure indicators are provided in this system.

a) Solar blower motor, fuse, or belt failure will result in a no-flow air condition. Pump or back-up blower and dampers will be in operation, but no heat will be delivered.

b) Solar pump, pump motor, or fuse failure will result in a hot or cold water condition in heat exchanger. The "cold" temperature limit in the heat exchanger is room temperature, and the high temperature is the limit of the pressure temperature relief valve. As the water bleeds through the valve, it is replaced limiting heat exchanger temperature to 210 F.

c) Solar damper motor failure can result in improper diverting of air flow in each of the three modes. First, while system operates in direct solar heat mode, heat could cycle to collector only, (with D2 open and DI closed, failed).

Water might boil in heat exchanger as in b) above. Second, while heating house from storage (if damper D3 is closed and D4 is open, failed). Air could flow over collector instead of heat exchanger, perhaps bringing about prompt furnace turn on and consuming extra fuel. Third, in the storage mode, (if D1 were open and D2 closed, failed) collector would heat the house instead of heating storage. Whereas this would create a serious environment problem, an interlock switch is placed on D1 preventing delivery of solar heat to house when it is not needed.

d) Failure of back-up blower, or shut-down of furnace will result in recirculation of most of collector or storage heat. Since a significant fraction of this heat would be delivered to the building by natural convection through the duct, this is not a serious problem. However, higher air and register temperatures will occur, depending on the particular installation.

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