Dr. Ben's
Solar Hot Water Systems
Installation Manual

Holocene
Technologies

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Table of Contents

1. Planning the Installation

This manual was written to provide a straight forward procedure for the installation of solar hot water systems. As with any project, a few minutes of planning will save hours of fixing.

1.1 *Site Analysis*

Measure the angle of the collector mounting surface from south with a compass. Correct for the magnetic compass error in your region. It is highly preferable that this angle be within 20 degrees of South for installations in the northern hemisphere. The greater the angle is away from South, the less solar energy will be collected. The placement of the collectors and the tank should be determined as well as the routing for the piping to all components.

1.2 *Collector Tilt*

The collector tilt angle varies according to the application and latitude. For year round applications such as domestic hot water, or combined space heating and domestic hot water, the tilt should be the latitude + 10 degrees, which is approximately half way between the highest summer sun and the lowest winter sun at noon. For special applications, such as vacation retreats used only in the summer, a tilt equal to the latitude is best. For retreats used only in the winter, a tilt of latitude + 20 degrees is best. The tilts are not critical and variations of +/- 5 degrees probably cannot be detected. Holocene Technologies supplies legs of several lengths to assist in tilting collectors.

Measure the roof slope and select the leg length needed for the approximate collector tilt from Table 1.1.

Table 1.1 Collector Leg Length Selection

Roof Slope	Angle	Leg Length	Angle
Flat	0^{o}	16 inches	10^{o}
3/12	14^{o}	32 inches	20^{o}
6/12	26.5^{o}	64 inches	49.6^{o}
9/12	36.9^{o}		
12/12	45^{o}		

1.3 *Materials*

In addition to standard tools and plumbing parts, the following will be needed for a typical installation:

- 3 inch hole saw
- Silicone sealant
- Two neoprene roof flashing boots, OD to fit pipe insulation (2½ inch or 3 inch typical)
- 95/5 plumbing solder
- Two 3½ x 3/8 inch SS frame bolts per collector

2. Tank Installation

The tank should be protected from rain and prolonged freezing temperatures in case of extended power failures. The preferred location is within the insulated area of a building, such as in a garage or basement, or adjacent shed.

The tank must be installed on a floor or surface substantial enough to carry the full weight of the tank plus water. Table 2.1 shows approximate filled weights of five common tanks. Drain pans must be used where required by codes. Do not install the tank in an area where future removal is difficult.

Table 2.1 Approximate Weight of Full Tanks

Tank Size	Approx. Full Wt.	Water Treatment
DBM (12 gal)	170 lbs.	8 oz.
80 gallons	950 lbs.	1 qt
130 gallons	1500 lbs.	0.5 gal
250 gallons	2700 lbs.	1.0 gal
400 gallons	4200 lbs.	1.5 gal
500 gallons	5300 lbs.	2.0 gal

> ***NOTE***
> *All fittings needed at the tank are described in the application section. Extra fittings are not needed and usually cause extra expense and difficulty insulating the lines. Do not use any air vents or valves not specifically called out.*

It is very important to leak test and flush the lines before final connection to the tank. Connecting a permanent fill line to the tank in is not recommended and may violate codes. The tank is easily filled and maintained with the boiler drain valve at the bottom of the tank. Electrical power requirements for the system are based on the number of options installed on the tank. On residential systems, the low power consumption of each option means that a 15 to 20 amp, 110 VAC circuit will be adequate for all standard systems. A separate electrical circuit and breaker are recommended to keep other circuits from affecting the heating system.

> ***NOTE***
> *Do not apply power to the tank until all plumbing and control wiring is complete and the tank has been filled with water.*

After all piping has been completed, flushed, and leak tested, and the wiring finished, the system startup procedure can begin. Make sure the pressurized domestic hot water line and standard water heater are purged and filled with water.

Fill the tank with water using the boiler drain valve under the collector pump(s). See fig. 2.1. A hose with female connections on both ends is required, such as a washing machine hose. First add the WT-1 water treatment in the ratio of 1 gallon WT-1 to 250 gallons of water as shown in table 2.1. Fill the tank until the water level is at the bottom of the site glass on the tank. This allows space in the tank for purging space heating or boiler circuits without overflowing the tank. For domestic hot water only systems, the tank may be filled to the top of the site gauge.

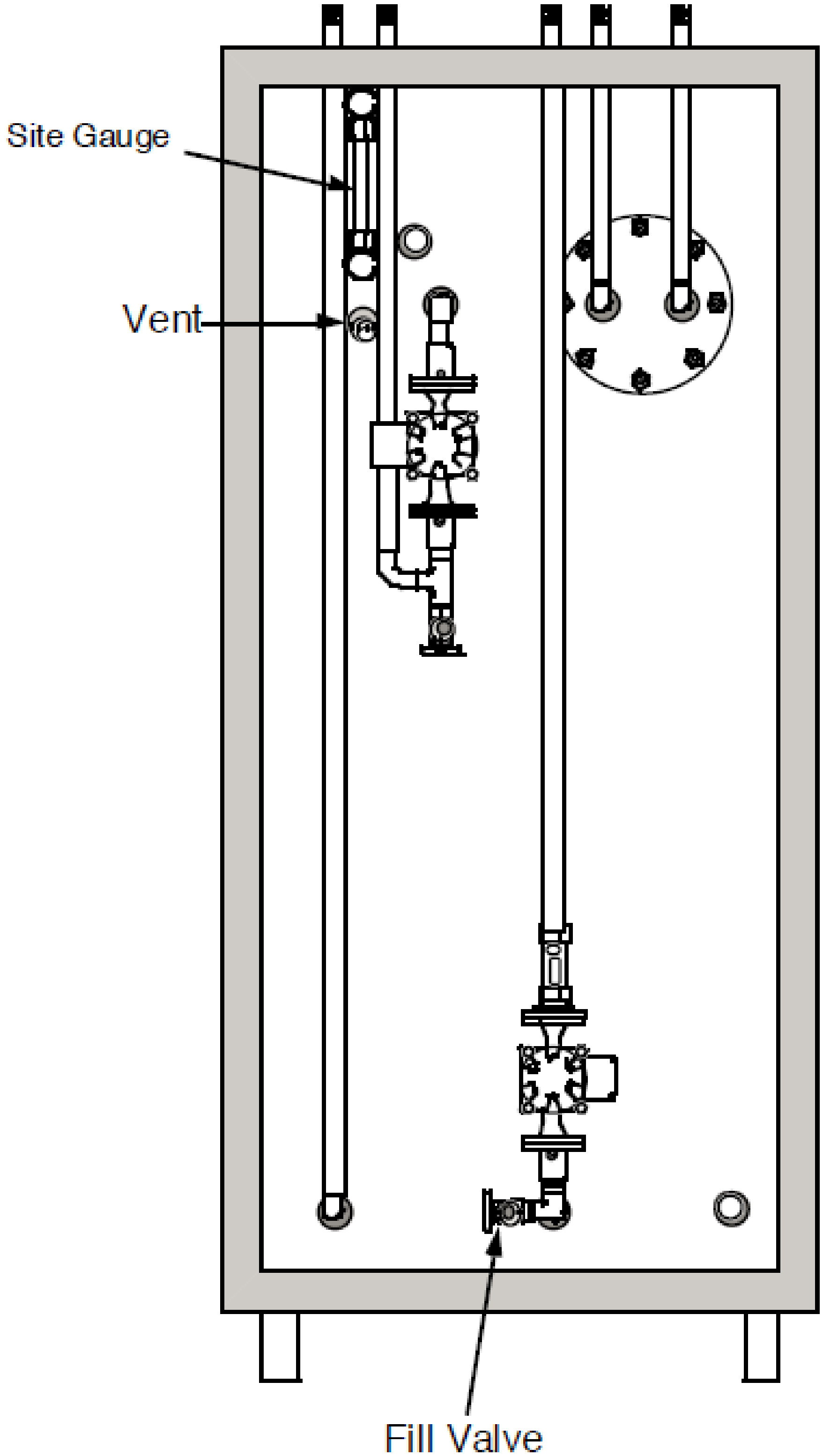


Figure 2.1 Tank Fill Connections

3. Collectors

3.1 *Frame and Collector Mounting*

The collector mounting frame assembly and typical roof mounting methods are shown in fig. 3.1. There are three angles which must be considered when installing an array of solar collectors. The first is the south facing direction and the second is the tilt of the collectors up from the ground, both described in section 1.

The third angle is critical to draining the water from the collectors at the end of the day. It is the drain slope of the collector headers. If there is insufficient drain slope, water standing in the supply header can freeze in the winter and burst the header. If the drain slope is too much, water can be trapped in the stub ends of the return header and cause freezing problems in the winter. The drain slope must be at least 1 inch in 20 feet (approximately 1/4° slope) to assure proper draining, but should not exceed 2 inches in 20 feet to prevent excess water from accumulating in the stub ends. To set the correct drain slope, one end of the collectors is positioned higher up the roof than the other end as shown in fig. 3.2. The specific distance changes according to the pitch of the roof.

To begin, use a chalk line to lay out a level line 10 feet long starting from the lowest corner of the collector array. On the opposite end mark the distance up the roof as shown in table 3.1. Another method is to position a level 1/2 inch above the end of the horizontal line and mark where the level meets the roof. A new chalk line from the starting point to the raised mark will give the proper mounting line for the collector frame.

Table 3.1 Distance Above Level Line to Give 1 Inch in 20 Feet Drain Slope

Roof Pitch	Distance above Level Line
3/12	2 1/8 in.
4/12	1 5/8 in.
5/12	1 3/8 in.
6/12	1 1/8 in.
7/12	1 in.
8/12	7/8 in.
9/12	7/8 in.
10/12	3/4 in.
12/12	3/4 in.

The frame is bolted to the roof through purlins nailed in place between rafters. See fig. 3.1. Be sure to caulk under the feet and around the bolt head with silicone sealant.

For commercial buildings, a typical mounting method uses I-beams supported by pipe sections extending through pitch pockets. The I-beams form a flat surface for mounting the collector frames. The beam structure is fabricated with the proper drain slope built in.

Four mounting clips hold each collector on the frame as shown in fig. 3.1. The bottom clip bolts support the collectors and allow them to slide sideways to facilitate the installation of couplings on the headers.

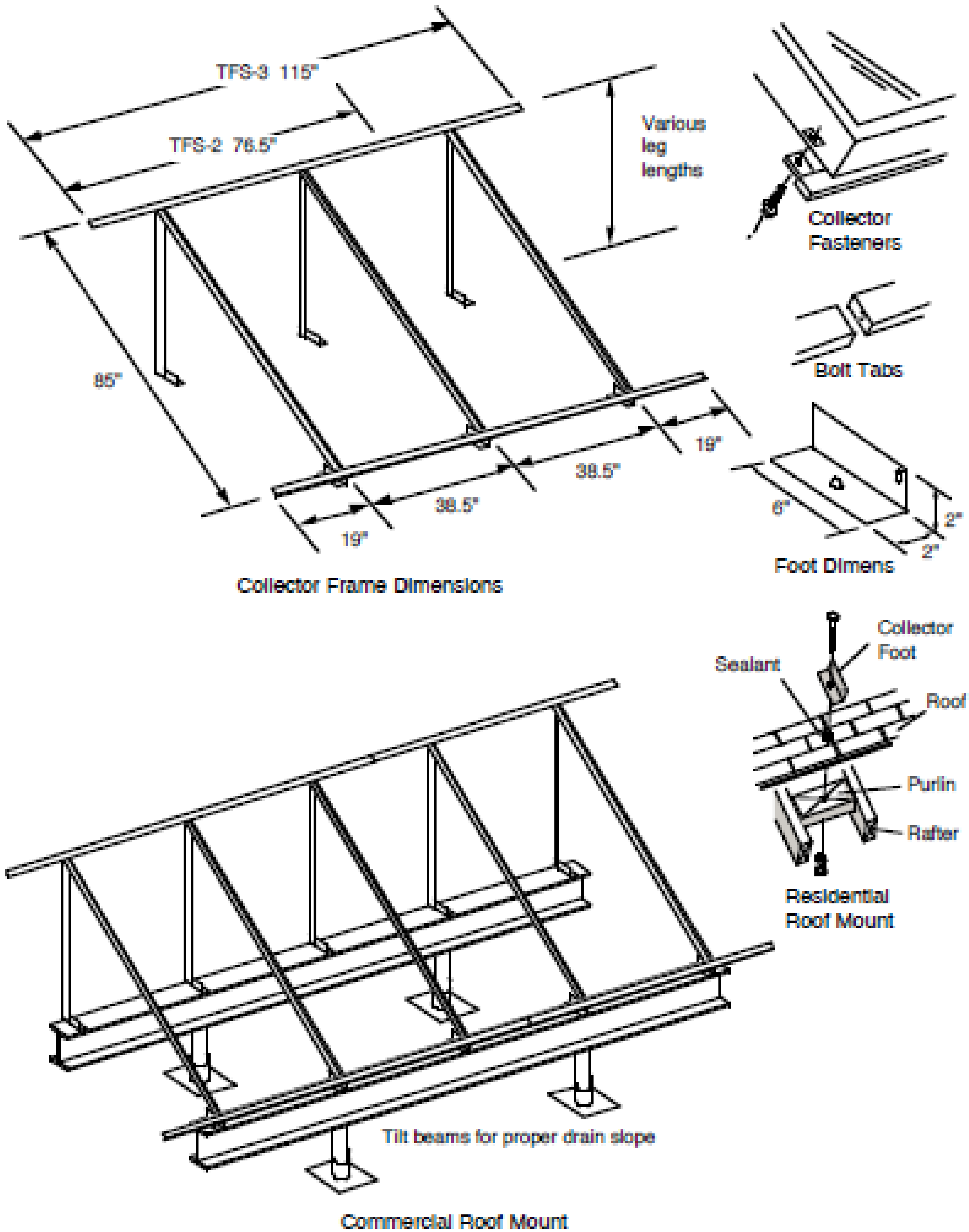


Figure 3.1 Collector Mounting Frames

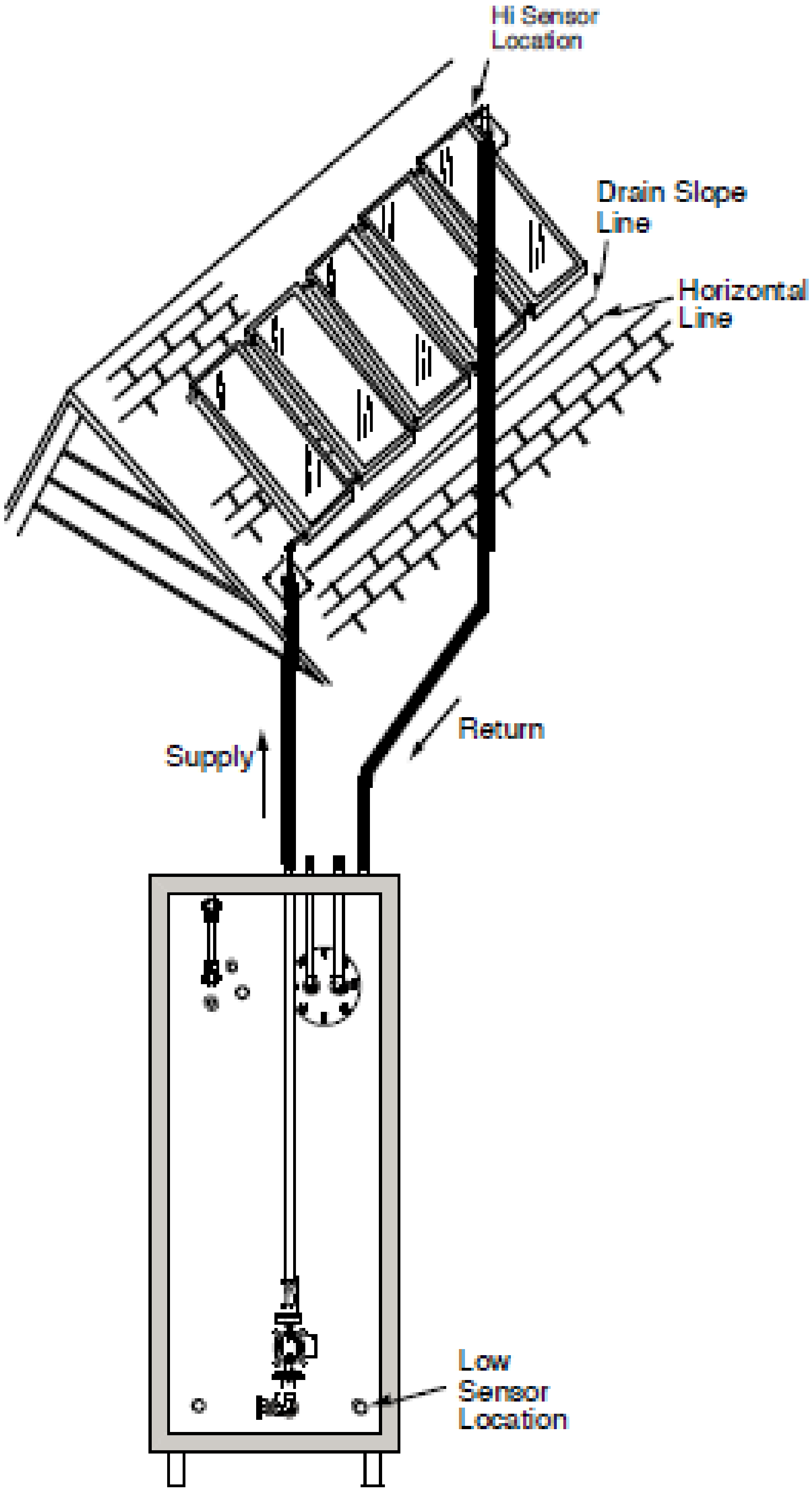


Figure 3.2 Collector Piping Circuit

3.2 *Collector Piping*

Each collector is rated at 0.5 GPM flow rate. Consult the chart below to determine the proper pipe size for different numbers of collectors. Use only copper pipe. Either type L or M is satisfactory since the piping is operated only at atmospheric pressure.

Table 3.2 Collector Circuit Pipe Sizing

Number of Collectors	Pipe Diameter
2-3	1/2 (3/4 in. recommended)
4-12	3/4 in.
12-20	1 in.

For collector piping runs longer than 50 feet one way, use the next pipe size. For roof penetrations in residential type construction, use neoprene roof flashing boots as used for vent pipes. The hole diameter should be the outside diameter of the pipe insulation, usually $2^{1/2}$ to 3 inches.

The piping arrangement for the collector array must follow these rules:

1) Water enters the collector array from the lowest corner.
2) Water exits the collector array from the highest corner.
3) The water from all collectors must rise to a common high point before it is allowed to drain back to the tank.

The rules assure that all the collectors will fill completely before any one drains. 95/5 solder is recommenced for all joints on the collectors.

Fig. 3.3 shows piping routines for different numbers of collectors. Top and bottom collector headers are joined directly together to form common manifolds for the group. Because excessive expansion and contraction of the headers with temperature swings can cause failure in the piping, it is recommended that no more than five collectors be joined together in one group as shown in fig. 3.3(a). However, six collectors may work in a single array if care is used to assure there are no binding points in the piping.

The collectors must have the recommended drain slope toward the supply (inlet) line to drain properly. In addition, the return line must be on the opposite top corner from the supply line to insure uniform flow through all collectors. The diagrams in fig. 3.3 show the path lengths for every fluid circuit are the same, eliminating the need for balancing valves.

Figure 3.3(b) shows two groups of five collectors mounted on a common sloped line. This arrangement is called a "row tilt". A spacing of five inches between groups of collectors allows enough space to bring an insulated supply header between collectors.

Figure 3.3(c) shows two groups of collectors arranged vertically. Notice the return header connections. The water from the lower bank must rise and join with the higher bank to guarantee all collectors are full before any water can return to the tank.

Figure 3.3(d) shows collectors arranged vertically and horizontally. It is a combination of two (b) type circuits placed one over the other. The same result can be achieved with two (c) type circuits placed side by side. The choice depends upon whether there is more horizontal or vertical room for the supply headers.

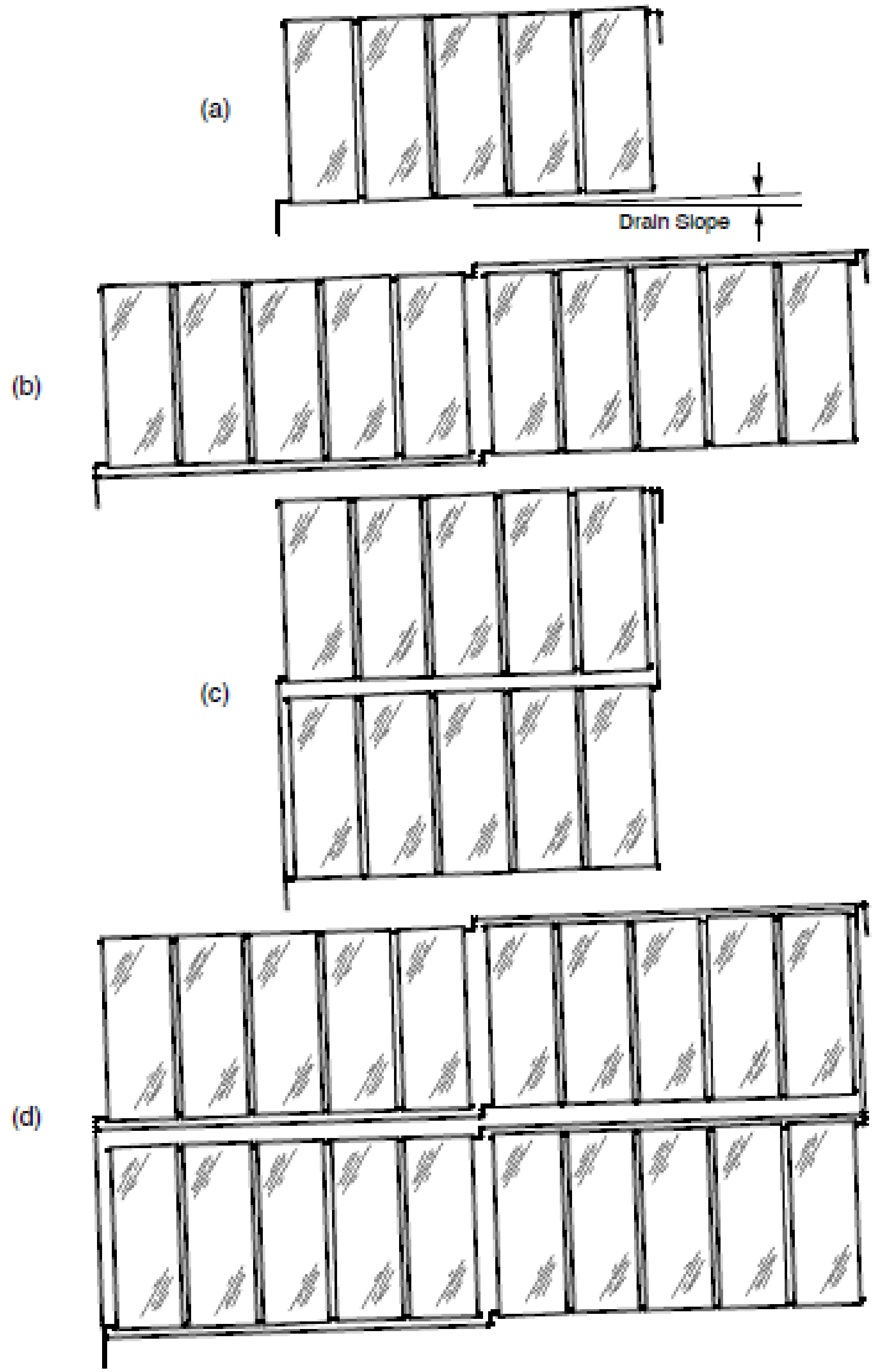


Figure 3.3 Collector Piping Diagrams

Large arrays may require that several rows of collectors be placed on the same level. Figure 3.4 shows two banks of collectors piped as a single array and as separate arrays. In fig. 3.4(a) the banks are joined by a common return line which is elevated from the first bank to the second bank. This line must have continuous upward slope to the high point shown in the figure to insure that all collectors in both banks fill completely before any of them can drain. This piping scheme preserves the filling requirements and eliminates the need for balancing valves.

If an elevated return line cannot be used, then the arrangement in fig. 3.4(b) can be used. In this case, there are separate return lines which join below the collectors into a common return line. Individual balancing valves in the supply lines are required to set the flow rate in each bank. The return lines can be joined as desired, but must maintain a proper drain slope to the tank.

All pipe runs must slope continuously from the collectors to the tank. The **minimum** slope is 1 inch in 20 feet, but should be as much as possible. There must be no traps or sags in the line. Traps cause operational problems where the water stands in the lines.

Avoid running square corners in unfinished areas, go straight across. Most traps are created by using many elbows and right angle turns. Soft copper may be used in situations requiring many turns.

Cap off the lines and leak test before final connection to the tank. Flush the lines with water then connect to the tank. One removable union may be used in the return line to add WT-1 water treatment to the tank, although the boiler drain at the bottom of the tank is recommended.

3.3 *Pipe Insulation*

> ***NOTE***
> *Proper Insulation of the lines is one of the most important steps to good performance and long life. A poorly insulated system can waste half the energy collected and create severe control problems.*

The recommended insulation for outside piping is 1 inch wall isocyanurate foam covered with an aluminum or PVC jacket. Elastic foam products are not recommended because they deteriorate badly in sunlight and at high temperatures. Fiberglass pipe insulation can be used as a second choice, but it has a much lower R value than the rigid foam products.

Insulate all piping between the collectors. Apply silicone sealant between the pipe jacket and the collector box to keep water from getting in and wetting the insulation. All jacket connections and joints should be water tight and lapped like shingles to shed water.

> ***NOTE***
> *Water that gets under the pipe insulation can enter the building through the roof boot.*

Leave the insulation off the return line from the last collector for installation of the collector (Hi) temperature sensor. The insulation is installed over the sensor.

For inside use, isocyanurate foam or fiberglass insulation with either an aluminum or white craft paper covering (called All Service Jacket).

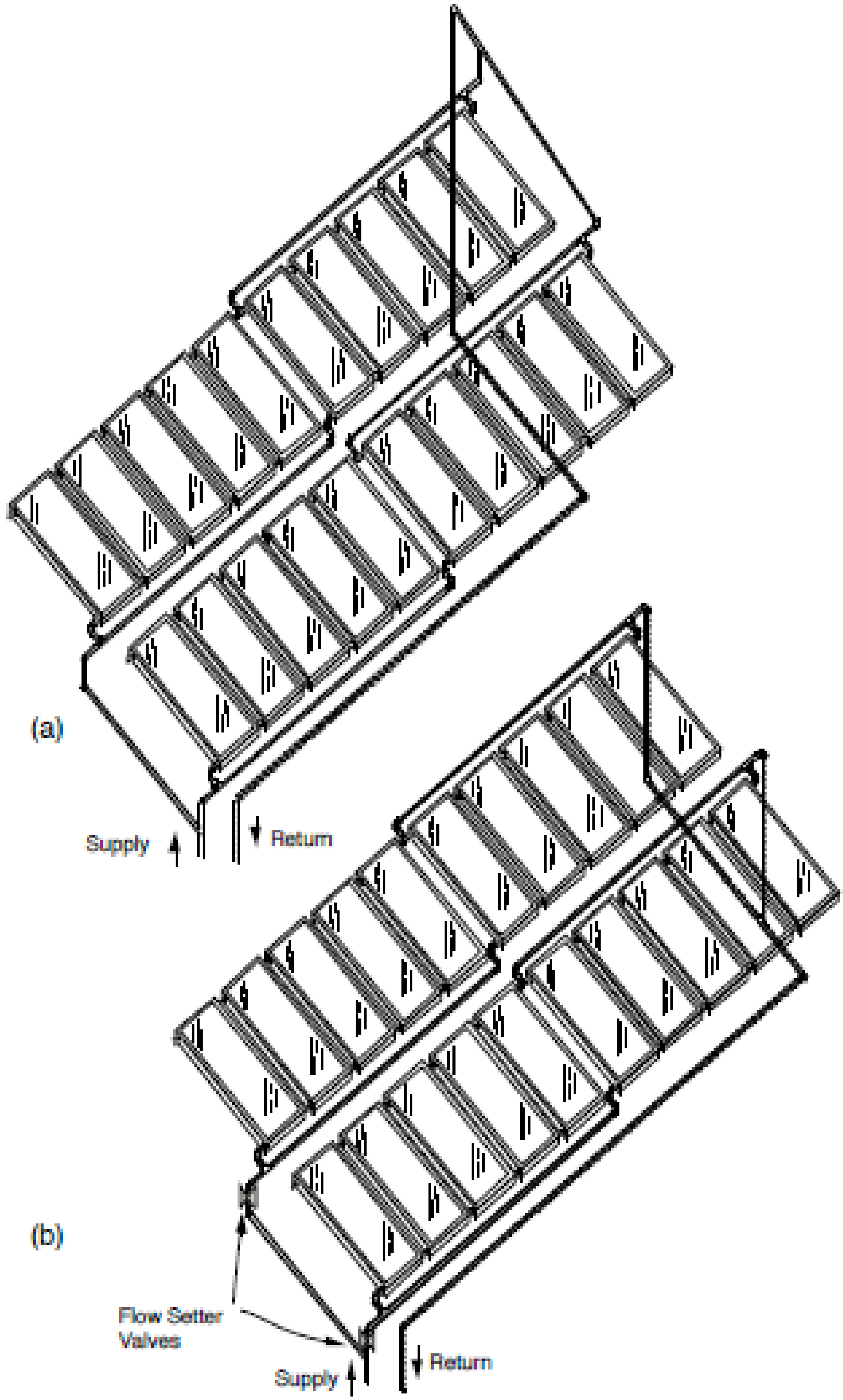


Figure 3.4 Dual Bank Piping Diagrams

3.4 *Solar Controls and Wiring*

Differential controllers (called "Delta-T" controllers) are used to operate the collectors, re-circulator DHW option, pools/spas, and manually fired boilers. The sensors are wired with two-conductor 18-24 ga. bell wire. If the length of the wire is over 50 ft. use 18 ga. Be careful when running sensor hook-up wire through the building to avoid shorting or breaking the wires with staples, or scraping the insulation off on sharp metal edges. Connections are made with crimp terminals or wire nuts. Seal the connectors with silicone sealant to keep water out. Water will corrode the connections and cause control problems.

The differential controllers used with solar thermal systems manufactured by Holocene Technologies use two temperature sensors which perform three functions. Several different controller models many be used, so consult the manufacturer's literature for specific details.

The *high* temperature sensor reads the output of the *heat source*. The heat source may be the collectors, a spa heat exchanger, or the output of a manually fired boiler. On the controller, the terminals for this sensor are marked *collector* or COL.

The *low* temperature sensor reads the lowest temperature of the *heat receiver,* which is the supply temperature to the *heat source*. The low temperature sensor position may be the bottom of the solar tank for collector and boiler circuits, or the return line of the pool for the pool/spa circuits. The terminals on the controller for this sensor are marked *storage*, or STO.

The *low* temperature sensor also performs the function of an *overtemperature (OVT,* for short) sensor on the heat receiver. Its function is to shut off the controller when the maximum temperature is reached in the tank or pool.

When the *high* temperature sensor is 18-20°F warmer than the *low* sensor, the controller turns the circuit ON. This is called the CUT-ON DIFFERENTIAL temperature. When the *high* temperature sensor falls to only 4-5°F warmer than the *low* sensor, the controller turns the circuit OFF. This is called the CUT-OFF DIFFERENTIAL temperature.

When the *low/OVT* sensor reaches its high limit set point, the controller turns the circuit OFF. The circuit cannot turn on again until the OVT sensors falls about 15°F. This range is called the OVT DEADBAND and it prevents the system from rapidly cycling on and off at high temperatures, called *short cycling*.

All sensors must be held tightly against the surface for good thermal contact. They must be insulated very carefully to read only the temperature of the surface, and not the surrounding temperature. Errors in temperature readings can cause improper operation of the controller and poor performance of the equipment.

> ***Caution***
> *Do not operate a controller until all plumbing has been completed and the tank is full of water. Pumps may be damaged if run dry. Do not work on an electric water heater with the power on.*

The *low/OVT* sensor for the collector circuit is installed on the solar tank at the factory. Mount the *high* sensor on the return header leaving the last collector in the array as shown in fig. 3.5.

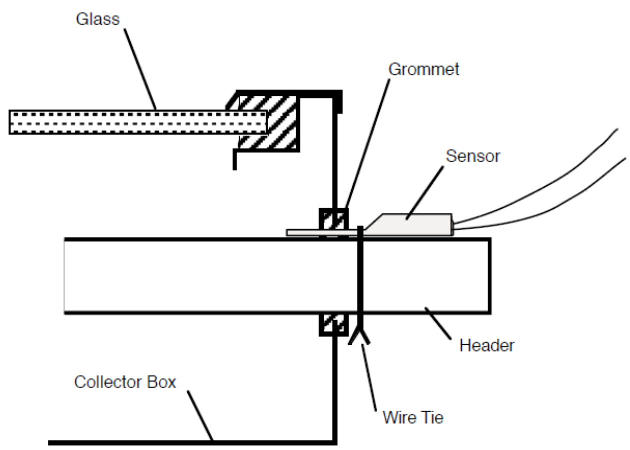


Figure 3.5 Collector Sensor Mounting

Push the flat end of the sensor under the grommet and fasten with a band clamp or a piece of wire with twisted ends. Do not use tape, it will let go under high temperature. Place the clamp over the flat part of the sensor, not the round part to avoid crushing the body of the sensor.

Connect the hook-up wire to the sensor leads. Use wire nuts or crimp connectors and fill with silicone sealant. Cover the sensor completely with the pipe insulation. Push the insulation tightly against the collector box. The hook-up wire may be run on the outside of the insulation and under the outer jacket down to the tank if desired. Caulk the jacket to the collector box with silicone sealant to keep water out. This is the **most** important sensor in the whole system and it must be very carefully installed.

3.5 *Collector System Startup*

The startup of the collector system is done only after everything is completely installed and the tank filled with water. The electrical power may then be connected.

Turn the collector controller *ON* with the manual switch. Allow water to flow until it begins to return into the tank. Set the flow rate with the flow meter above the collector pump(s) to ½ GPM per collector. Turn the controller switch to the *AUTO* position. If the collectors are hot, the system should run by itself. If the system will not run by itself when the collectors are known to be hot, refer to the trouble shooting section.

If the collectors are not hot, the following test will indicate a good controller. With all of the sensor wires installed, set the controller switch to the *AUTO* position. Short circuit the terminals shown below and observe the controller response. Note that a short circuit corresponds to a hot sensor, and an open circuit corresponds to a cold sensor. The third row tests the high limit control.

Table 3.3 Delta-T Controller Tests

HIGH / COL terminals	LOW / STO terminals	Collector Pump is:
OPEN (cold)	OPEN (cold)	OFF (no solar)
SHORT (hot)	OPEN (cold)	ON (proper run)
SHORT (hot)	SHORT (hot)	OFF (Hi limit)

The same test can be applied with the sensor wires removed from the terminals to test wiring and sensor problems.

4. Domestic Hot Water

4.1 Single Pass Piping

There are several options for hooking up domestic hot water circuits. The standard option, shown in fig. 4.1 is called a "single pass" system. The cold water line goes through the solar heat exchanger and then to the inlet on the standard water heater. Solar heated water is supplied on demand to the water heater.

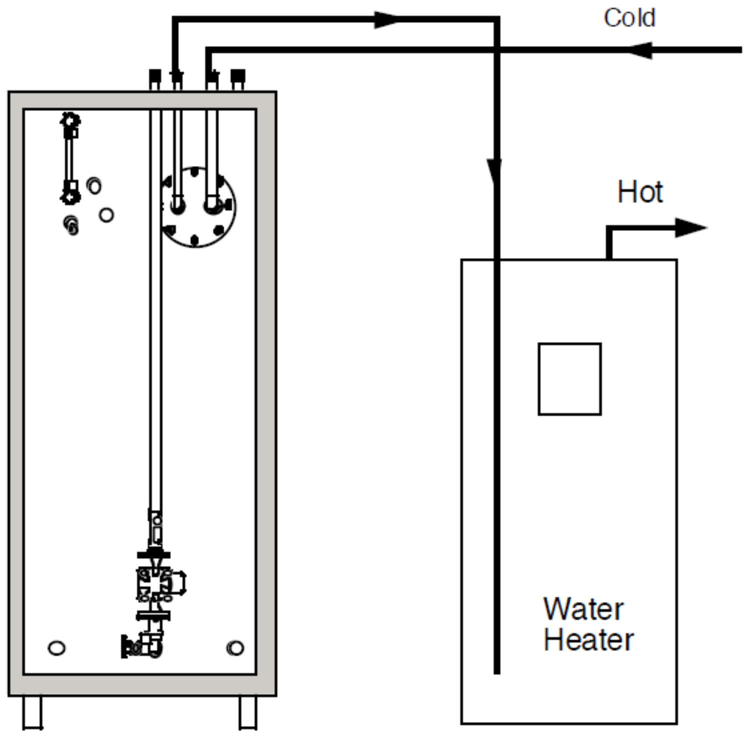


Figure 4.1 Single Pass System Piping Diagram

4.2 Re-circulator Piping

A second option is called a "re-circulator" system, or "recirc" for short. This option has an additional pump and controller installed on the solar tank to periodically transfer solar heat into the standard water heater. Two lines are run from the solar tank to the standard water heater - a supply (cold) line from the bottom of the water heater, and a return (hot) line to the top of the water heater. Figure 4.2 illustrates the piping diagram. The dip tube in the water heater must be cut in half to prevent the solar heated water from short circuiting into the supply line at the bottom. The check valve in the return line from the water heater lets the system act as a single pass unit when the circulator pump is off. The re-circulator option is recommended only for certain special applications. It should not be used with gas water heaters because they heat from the bottom where the (cold) supply line would be located.

The Holocene Technologies drain-back module (DBM) system is a re-circulator by design, because the module itself has no significant storage capacity. In the DBM system, the collector pump and re-circulator pump run together off a single controller.

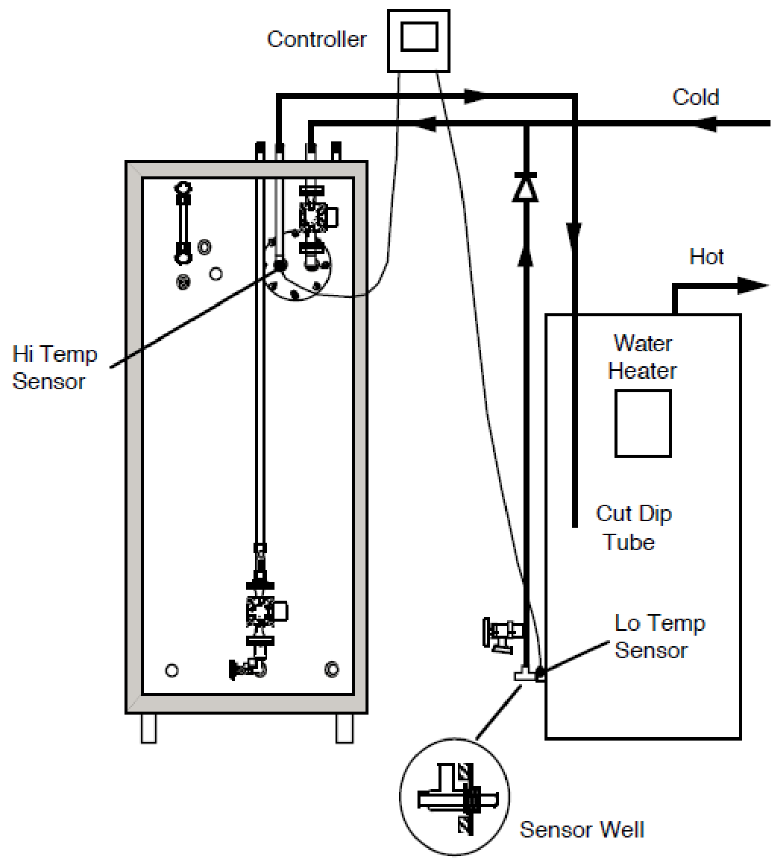
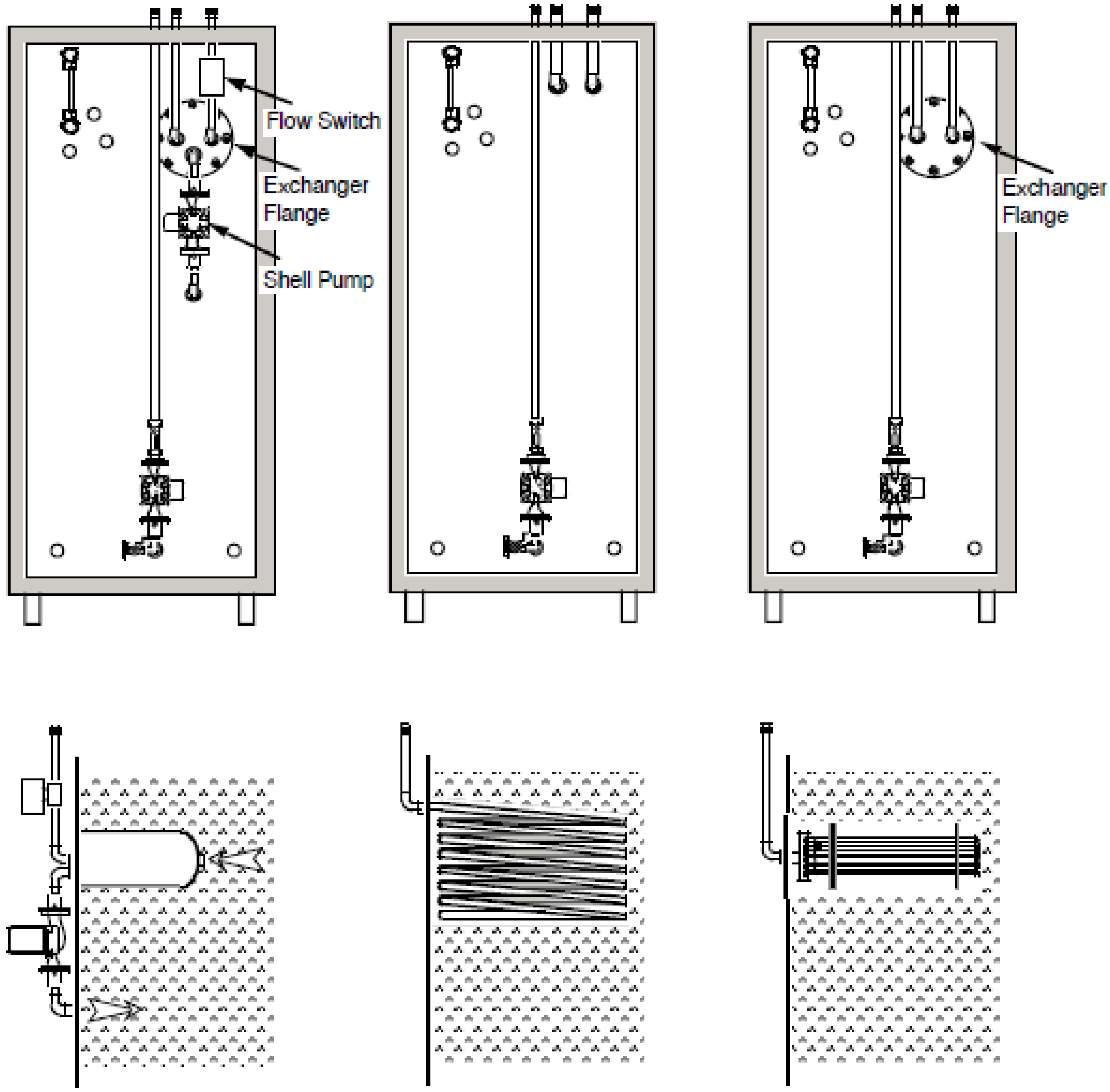


Figure 4.2 Re-circulator DHW Piping Diagram

4.3 DHW System Startup

Three types of DHW exchangers have been used in Holocene tanks as illustrated in fig. 4.3. The original design (a) used a coil-in-shell exchanger with a flow switch in the DHW line to operate a shell circulator pump. When hot water is drawn from a tap, the flow switch turns on the shell pump to circulate tank water through the shell and over the coil inside. The coil is mounted on a removable bolt flange for repair or replacement. Drawing (b) shows a static exchanger built into the tank. Tank water circulates over the outside of the coil by thermo-syphon action when cold water goes through the coil. Drawing (c) is a static exchanger design which is mounted on a removable flange for repair or replacement.

Single Pass Startup: Testing of the DHW system requires that tank installation be complete, the tank full of water, and the pressurized lines leak tight and full of water. Turn on a hot water faucet in the building. Open the solar tank door and grasp the two pipes going in and out of the DHW exchanger. Note the flow of water through the exchanger by the change in temperature of the pipes as the water flows through them. For a type (a) exchanger with flow switch and shell pump, the flow switch should click and turn on the shell pump when the water flow in the line passes 0.5 GPM. If this does not occur, refer to the trouble shooting section.



(a) DHW exchanger with Flow Switch & Shell Pump, removable

(b) Static DHW exchanger, non-removable

(c) Static DHW exchanger, removable

Figure 4.3 DHW Heat Exchanger Types

Re-circulator Startup: Turn the re-circulator Delta-T controller switch to the *ON* position. Observe that the re-circulator pump runs and the water moves through the heat exchanger coil by noting the temperature change in the incoming and outgoing lines.

Automatic operation of the controller can be determined only if the solar tank is 15°F warmer than the bottom of the standard water heater. For a cold system test, refer to the trouble shooting section for testing Delta-T controllers.

5. Space Heating

5.1 Forced Air Systems

Coil Installation: Solar energy can provide space heating by radiant floor, forced air, or radiant baseboard systems. The most common is forced air. The solar space heating coil can be installed in horizontal, up-draft, or down-draft systems. The auxiliary heater can be oil, gas, or electric furnaces, or air or water source heat pumps. In all cases, the solar hot water coil is installed on the return air (cold) side of the standard furnace. The water supply line is connected to the lowest fitting on the coil. This configuration ensures that air trapped in the coil can rise with the flow of water. Coils are installed the same way on multiple zone systems.
Figure 5.1 shows several coil orientations.

Piping: The slope of the piping to the furnace coil(s) is not as critical as that of the collector piping since all the lines should be protected from freezing and are not required to fill and drain on every cycle. However, a slight continuous slope in the lines from the tank to the coils aids in purging air bubbles and helps prevent air locked lines. *Do not install coin vents or any other devices in the lines between the tank and coil(s)*. They will actually cause trouble by introducing air into the line. All valves needed are already installed on the tank.

Cap off the lines at the tank and leak test the piping to the coil. Flush the lines with water then connect to the tank. Removable unions may be used, but are not needed - the lines may be connected directly to the tank.

On systems having two space heating circuits, there is a pump and supply line to each coil, but only one return line to the tank. Refer to fig. 5.1. The two return lines may be connected together at the tank or earlier if convenient.

Controls: Holocene space heating controls utilize the operating circuits of the standard heating system. The wires are run from the house thermostat to the *solar control panel* and then to the standard furnace. Figure 5.2 shows a typical single zone solar control panel with two bulb thermostats, a differential controller, a power buss card, and the UC-1 space heating control card.

When a heating signal comes from the wall thermostat, the solar control panel operates the solar pump, the furnace blower, and the furnace heat source in three standard operating modes.

1) *Solar Only.* When the solar tank is above a certain temperature it can supply all the heat needed for the home. The threshold temperature is set by the left bulb thermostat, *BT1*. When the temperature is above the setting, the *solar control panel* turns on the solar pump and the furnace blower. *BT1* is normally set at 90°F, but can be varied to suit individual conditions.

2) *Solar Assist*. When the tank temperature falls below the setting on *BT1*, it can supply some of the heat needed for the home, but not all of it. In this case, the *solar control panel* turns on the standard furnace heat source in addition to the solar pump. *BT1* is called the *furnace cut-on thermostat*.

3) *Furnace Only*. When the solar tank temperature falls too low, it cannot supply any heat to the home and the solar pump is turned off. This leaves the auxiliary furnace running alone. The solar cut-out temperature is set by the right bulb thermostat, *BT2*.

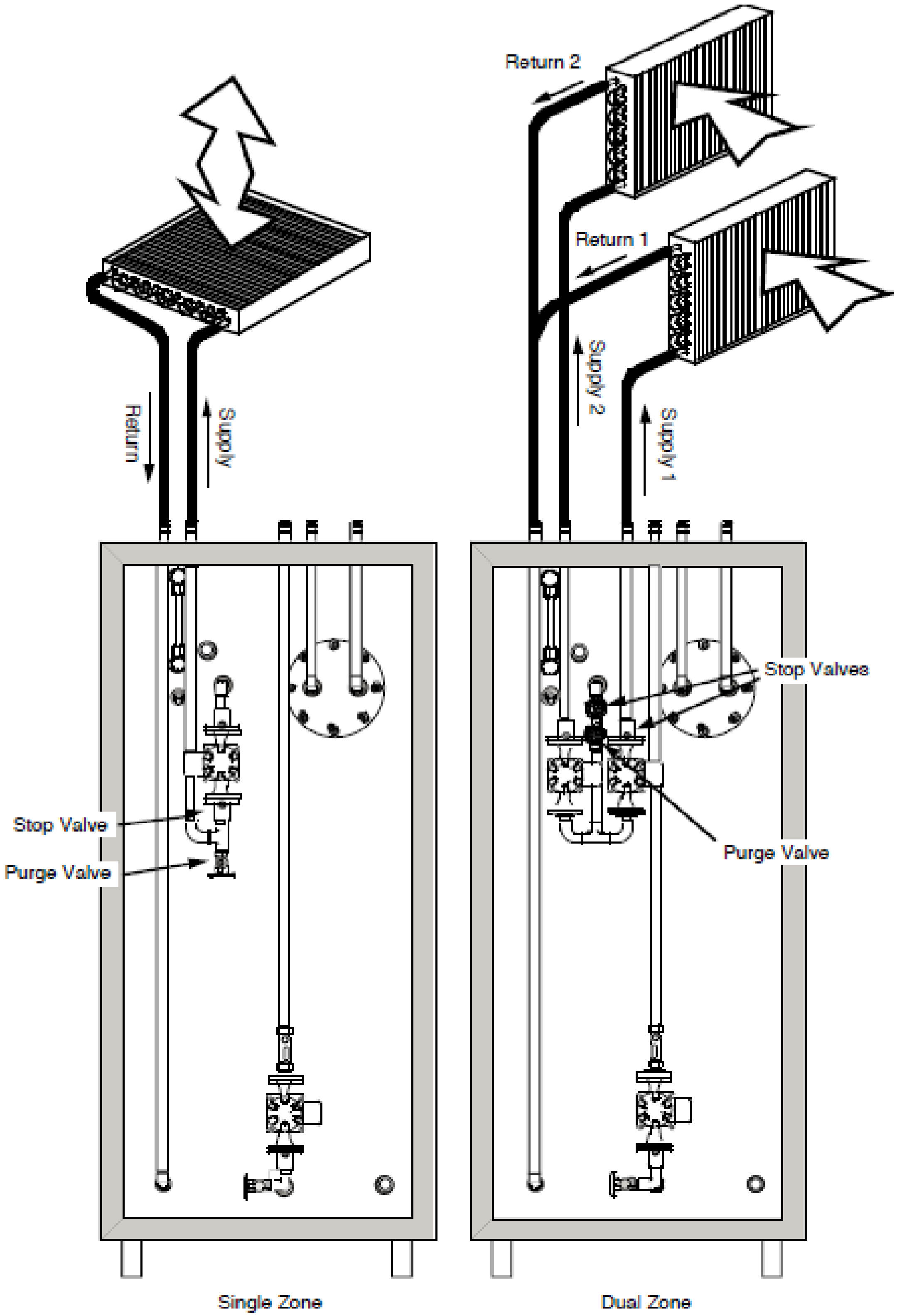


Figure 5.1 Space Heating Coil Installation

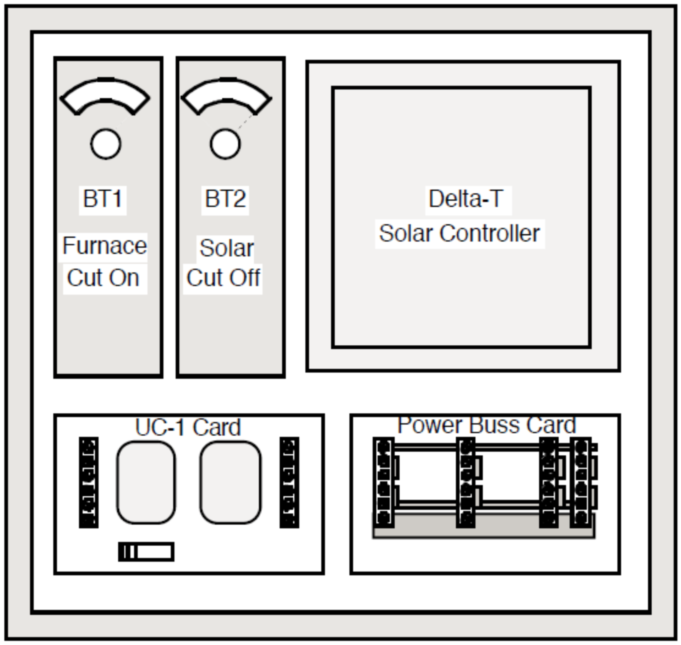


Figure 5.2 Single Zone Space Heating Controls

The normal setting is the return air temperature at the solar furnace, 65-75°F. *BT2* is called the *solar cut-off thermostat*.

> ***NOTE***
> *For an installation on an existing home, be sure the original HVAC system is in proper working condition by cycling the heating and cooling equipment through all modes of operation. Failure to do this can make the solar installer responsible for the condition of the existing equipment! Do not proceed with the solar installation until the conventional system is in proper working condition.*

Do not operate the solar controls until the tank is full of water and the pumps are wet as described in the startup section.

This manual refers to thermostat terminals by the popular names used in the Honeywell thermostat catalog. The designations are

R	24 VAC supply
G	fan terminal
C	common (return to power supply)
W	heat terminal (also H)
Y	compressor terminal
O	reversing valve terminal, powered for cooling
B	reversing valve terminal, powered for heating

These designations vary among manufacturers. Other terms are used for options which do not relate to solar, such as emergency heating and filter lights.

Several stages of heating may be labeled W1, W2, or H1, H2. The *solar control panel* controls only the first stage of heating. Any other stages operate according to the standard logic built in to the furnace and are not affected by solar operation.

First identify the control wiring from the house thermostat to the furnace. On a combustion furnace, identify the *heat, Fan, A/C,* and *24VAC* wires. On a heat pump identify the *compressor, reversing valve, fan,* and *24VAC wires.* Determine whether the *reversing valve* operates for heating or cooling.

On any system, a *common* or *return* to the 24VAC power supply must be established. This wire is necessary to operate the solar control relays. Figure 5.3 shows three typical heating system control circuits.

5.1.1 Solar Controls for Gas/Oil Furnaces

Figure 5.3a shows the control circuit of a typical gas or oil furnace. The 24V power comes into the thermostat on R and goes out W to the burner relay when the thermostat calls for heat. The wall thermostat does not turn on the fan directly in the heating mode. The fan is turned on by an internal thermal switch when the furnace gets hot.

In the cooling mode, 24V power goes out Y to the compressor relay. Y is also connected internally to G to turn on the fan relay.

> ***NOTE***
> *On some older two wire oil burners, there is no available RETURN to the 24V transformer, and no separate fan control. In cases like this, a new control circuit, such as shown in fig. 5.3b, must be installed to give the proper control modes listed below.*

The solar control circuit for a gas or oil furnace system is shown in fig. 5.4. When the wall thermostat calls for heat, 24V power goes from W in the thermostat to *heat in* on the UC-1 control card in the *solar control panel.*

Mode 1: Solar Tank Hot. (*BT1 = high*, *BT2 = high*)

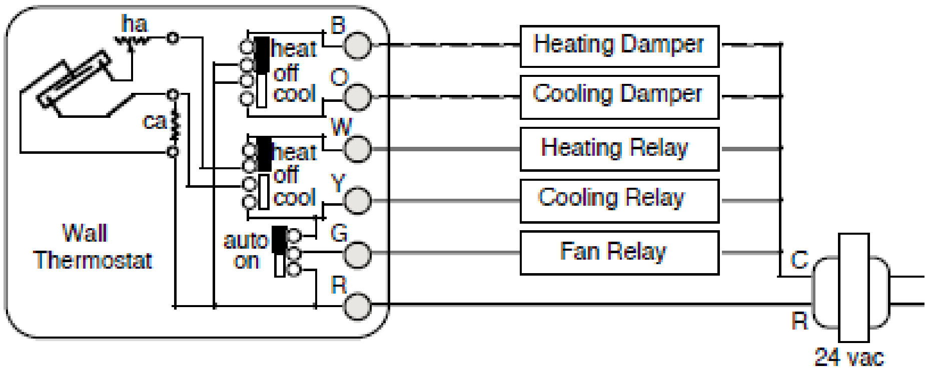
When the solar tank is hot, *BT1* interrupts the power to the burner relay so it cannot run. *BT2* sends power to the *solar pump* relay to turn on the circulating pump, and to the *fan out* terminal to turn on the fan. In this mode, the burner is off, the fan, and the solar pump are on. Note that the *fan out* is not connected to the *fan in* terminal. This would cause a back feed through G in the wall thermostat and turn on the compressor.

Mode 2: Solar Tank Warm. (*BT1 = low*, *BT2 = high*)

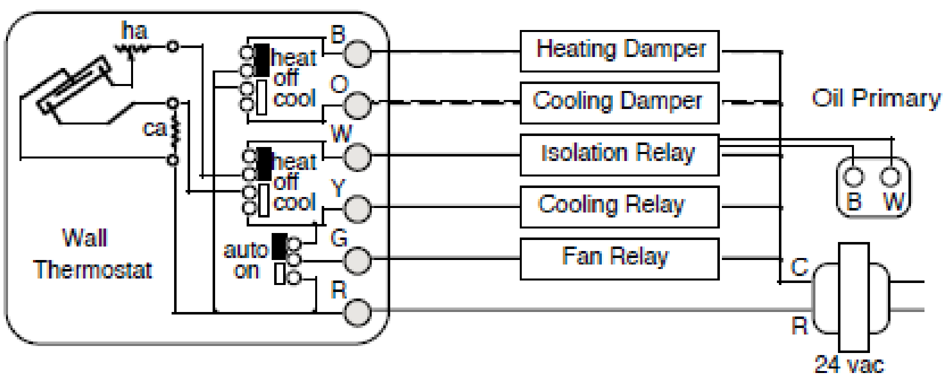
As the solar tank falls in temperature, *BT1* will switch from *high* to *low* at the preset temperature that indicates solar cannot carry the whole heating load. When *BT1* switches, power is sent to the *heat out* terminal to turn on the burner. In this mode, the burner, solar pump, and fan are all running. The solar coil preheats the air going into the furnace.

Mode 3: Solar Tank Cold. (*BT1 = low*, *BT2 = low*)

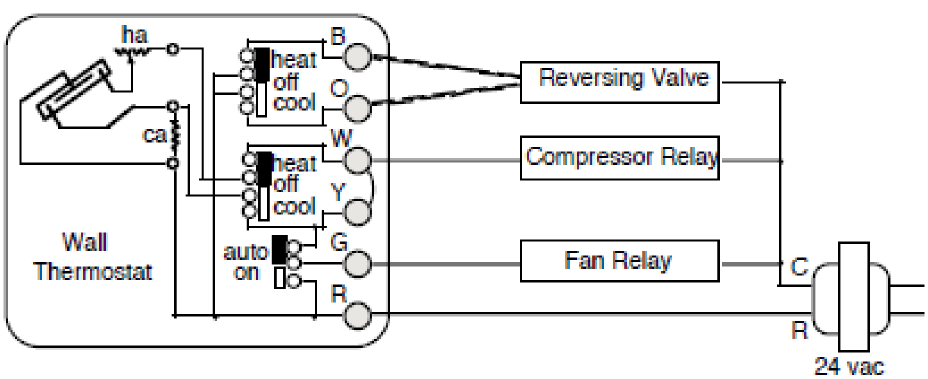
As the solar tank temperature continues to fall, *BT2* will switch from *high* to *low*, which indicates that solar cannot continue to preheat air going to the furnace. When *BT2* switches, the *solar pump relay* drops out. *Fan in* and *fan out* terminals are shorted in the unpowered mode, so the fan runs as requested from the thermostat. In this mode, the solar circuit does not control any functions of the standard furnace.



a) Typical Circuit for Gas or Oil Furnace With A/C



b) Upgrade Circuit for Older Oil Furnace with A/C



c) Typical First Stage Heating Circuit for Heat Pump

Figure 5.3 Conventional Space Heating Controls

Mode 4: Summer Cooling (*BT1 & BT2* settings do not matter)

In the summer, there is no power on the heating (W) wire from the thermostat to the solar control card, so the solar circuits do not operate. The two fan terminals, *fan in* and *fan out* are shorted in the unpowered mode so the fan runs as requested from the wall thermostat.

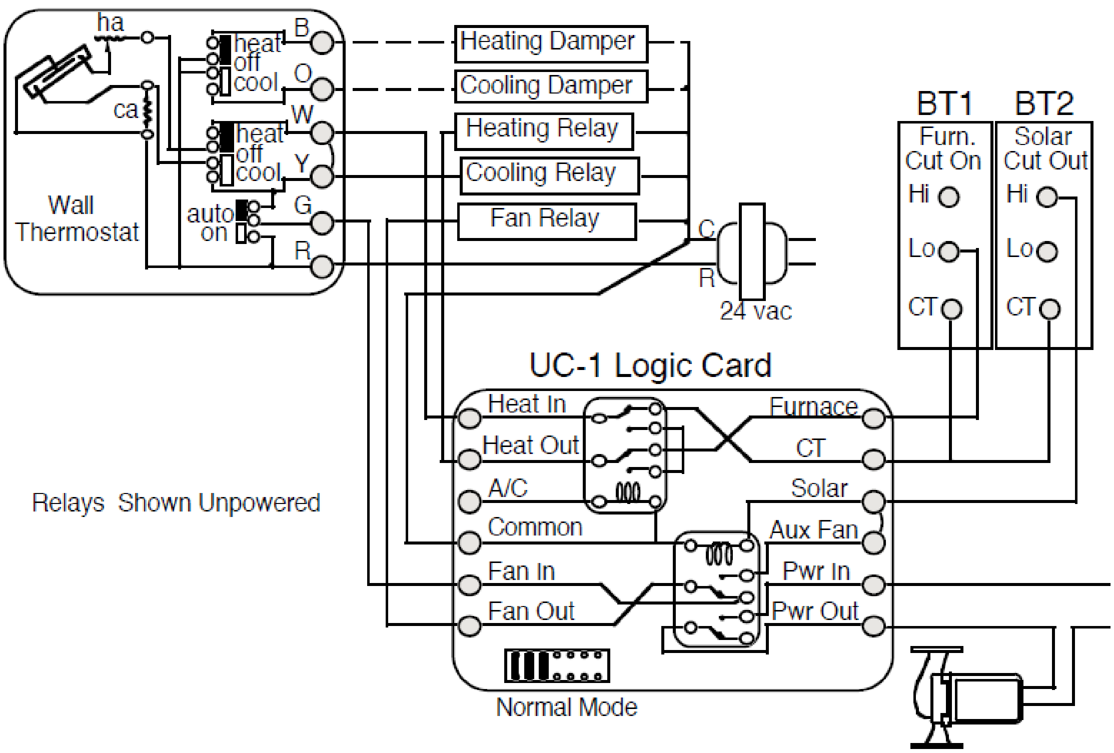


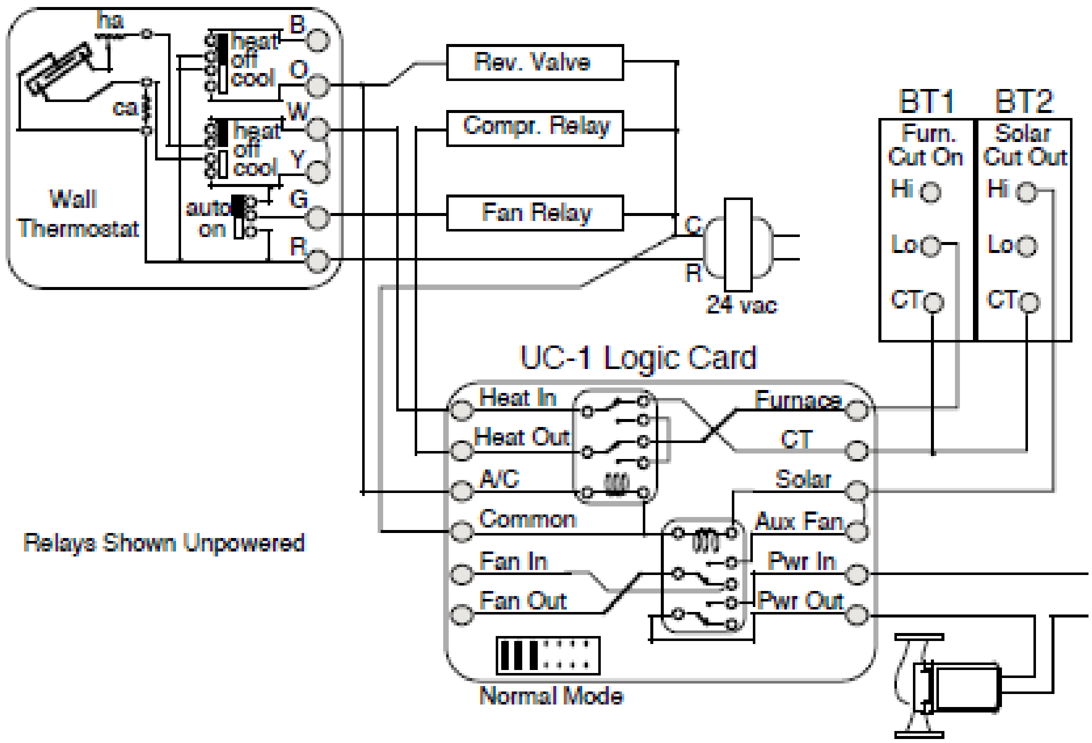
Figure 5.4 Solar Controls for Gas/Oil Heating Systems

5.1.2 Solar Controls for Heat Pumps (Reverse on Cooling)

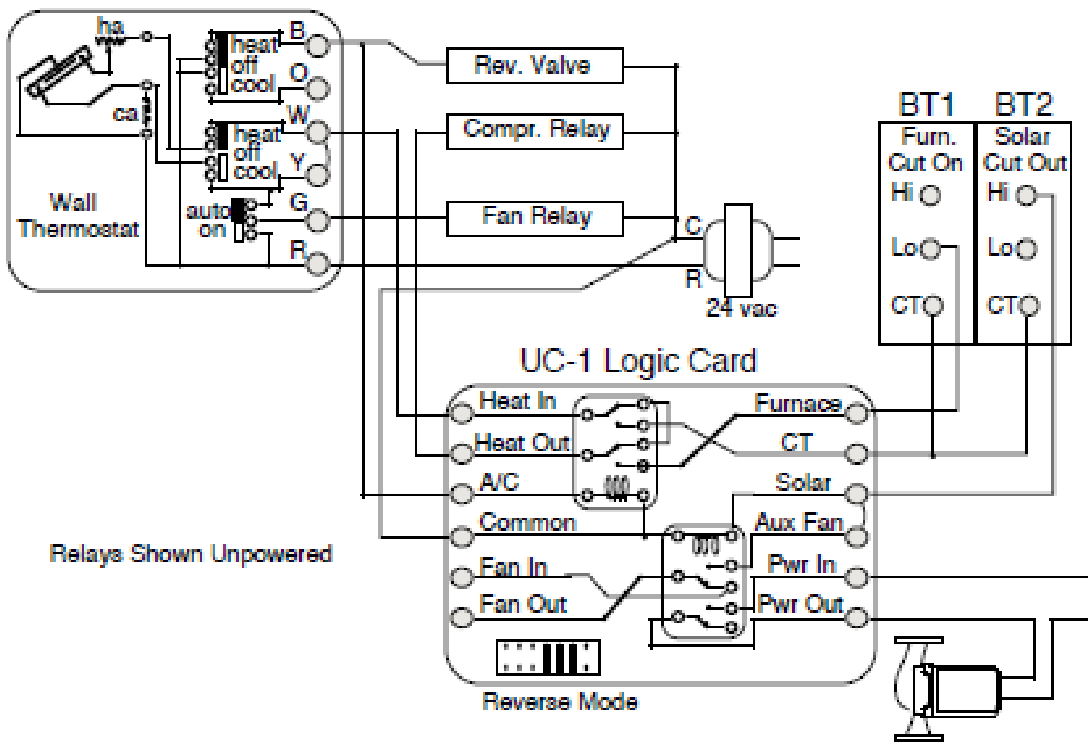
In some heat pump systems, the wall thermostat does not have separate heating (W) and cooling (Y) terminals, since the compressor runs for both heating and cooling. In other systems, both terminals are there, but are tied together. In some systems, the stage 2 electric strips are connected to W or H. Figure 5.3c shows a typical control circuit for this type of heat pump. The second stage strip heating circuits are not shown, since the solar controls do not affect them.

The 24V power comes in R and goes out Y when the thermostat calls for heat. Y goes to the *compressor* terminals in the A/C unit. Inside the wall thermostat, Y is connected directly to G, which sends power to the fan relay in the air handler. The *reversing valve* terminal 0 in the wall thermostat powers the reversing valve relay to activate the cooling mode.

The solar control circuit is shown in fig. 5.5a. When the wall thermostat calls for heat, 24V power goes from Y to *heat in* on the UC-1 logic card. The fan is operated directly from the wall thermostat and is not connected to the solar control panel. The solar system has nothing to do with the stage 2 heating.



a) Solar Control Circuit for Heat Pump - Reverse on Cool



b) Solar Control Circuit for Heat Pump - Reverse on Heat

Figure 5.5 Solar Controls for Heat Pumps

Mode 1: Solar Tank Hot (*BT1 = high*, *BT2 = high*)

When the solar tank is hot, BT1 interrupts the power to the compressor relay so it cannot run. *BT2* sends power to the *solar pump* relay to turn on the circulating pump. In this mode, the compressor is off, the fan and solar pump are on.

Mode 2: Solar Tank Warm (*BT1 = low*, *BT2 = high*)

As the solar tank falls in temperature, *BT1* will switch from *high* to *low* at the preset temperature that indicates solar cannot carry the whole load. When *BT1* switches, power is sent to the *heat out* terminal to turn on the compressor. In this mode, the compressor, solar pump, and fan are all running. The solar coil preheats the air going to the heat pump.

> ***CAUTION***
> *The inlet air temperature to an operating heat pump must not exceed 95°F or damage to the heat pump may occur.*

The *BT1* thermostat must never be set higher than about 100°F water temperature to make sure that the air coming out of the solar coil does not exceed 95°F. There is no problem if the heat pump compressor is not running as in mode 1. If the house cannot be heated with solar alone down to 100°F water temperature, then the optional *surge circuit* must be used. Check the heat loss rating of the home with the heat output rating of the coil for 100°F water temperature. The minimum water temperature which will heat the house under the "design load" conditions is called the **solar crossover** temperature. For a gas, electric or oil furnace, the *solar crossover* temperature is not as important, since these furnace types are not affected by high inlet temperatures.

Mode 2b: Surge Circuit

The *surge circuit* is a field-installed circuit consisting of the SG relay card and a duct thermostat, *BT3,* placed in the air stream between the solar coil and the heat pump inlet. The system is connected to the solar control circuit as shown in fig. 5.6. When the heat pump is operating, the 24V power on the *heat out* terminal also goes to *BT3*. If the temperature in the air stream exceeds the 95°F high limit, *BT3* switches to *high* and sends power to the *surge relay*, opening the circuit from *BT2* to the solar pump relay. The solar pump stops and the temperature in the solar coil drops until *BT3* trips to *low*, reconnecting the *solar pump* relay to send heat to the solar coil. This cycling continues until the solar tank temperature drops below the *BT3* high limit, leaving the solar pump running continuously. Without this circuit, the preheat mode would have to be eliminated, wasting a significant amount of solar energy.

Mode 3: Solar Tank Cold (*BT1 = low*, *BT2 = low*)

As the solar tank temperature continues to fall, *BT2* will switch from *high* to *low* indicating that solar cannot preheat the air going to the furnace. When *BT2* switches, the *solar pump* relay drops out. In this mode, the compressor and normal fan circuits run alone. *BT2* is the *solar cut-out* thermostat.

Mode 4: Summer Cooling (*BT1* & *BT2* settings not applicable)

In the cooling mode, 24v power goes from terminal O in the wall thermostat to *A/C* on the solar control card, causing the *lockout* relay to activate, and shorting *heat in* to *heat out*. The *lockout* relay is activated all the time the wall thermostat switch is set to cooling, regardless of whether the compressor is running.

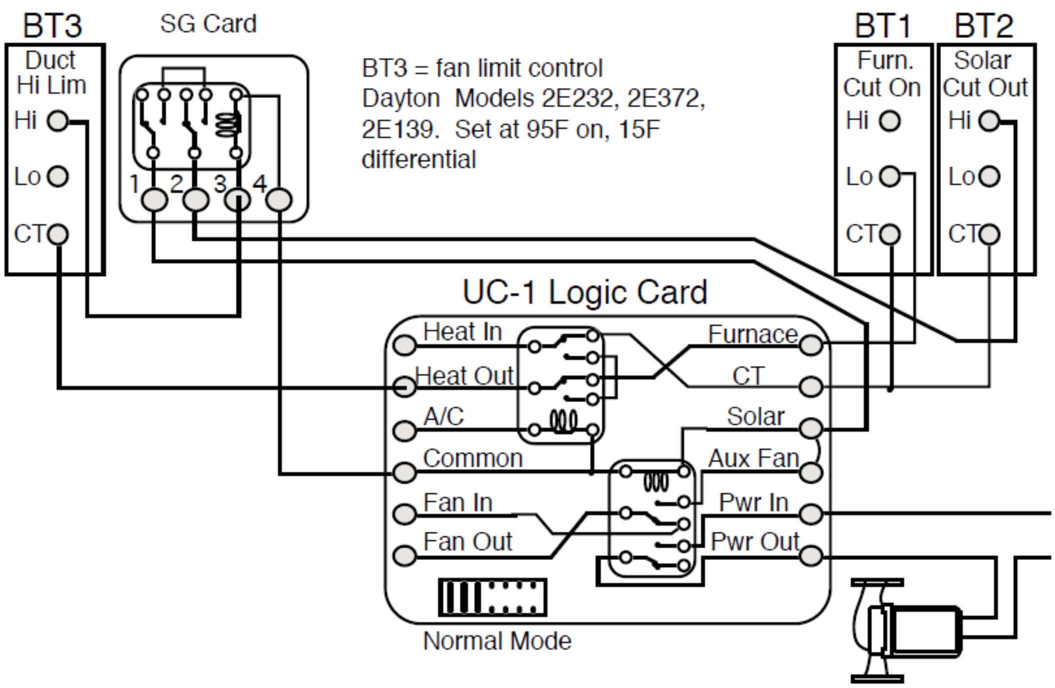


Figure 5.6 Surge Circuit for Heat Pumps

When the thermostat calls for cooling, power from Y goes through *heat in* and *heat out* directly to the compressor, bypassing the solar control circuit.

5.1.3 Solar Controls for Heat Pumps (Reverse on Heating)

In some heat pump systems, the reversing valve is activated in the heating cycle, exactly the opposite of case 5.1.2 above.

Figure 5.3c shows a typical control circuit for this type of heat pump. The 24v power comes in R and goes out Y when the thermostat calls for heat. Y goes to the *compressor* terminal in the *A/C* unit. Y is also connected internally to G, which sends power to the fan relay in the air handler. Terminal B in the wall thermostat powers the *reversing valve* relay to activate the heating mode.

The solar control circuit is shown in fig. 5.5b. The control card must be converted into the *reverse mode* by pulling the *pin block* on the UC-1 card straight out from the board and reinserting it to the right in holes 4, 5, and 6 in the socket.

The heating and cooling operations are identical with modes 1-4 listed in section 5.1.2. The only difference is that the *lockout* relay is powered for heating and unpowered for cooling.

5.1.4 Space Heating Startup and Test

The tank should be filled to the bottom of the site gauge before the space heating system is tested. Connect a hose to the drain/purge valve on the output side of the space heating pump. For a single space heating circuit, as shown in fig. 5.2, the purge valve is directly below the pump. In a dual space heating configuration, the purge valves are directly above the pumps. Close off the pump flange next to the purge valve and run water through the hose to flush out all the air in the supply and return lines. On dual space heating systems, repeat the procedure for each circuit.

After the tank has been filled with water and the space heating coil(s) purged of air, the control system may be tested as shown in table 5.1. Set the wall thermostat and solar tank thermostats, *BT1* & *BT2* as shown in each row in the table and note the operation of the solar space heating pump, the blower, and the burner or compressor. In the table, *MIN* means to turn the dial on *BT1* or *BT2* to the minimum setting. This corresponds to a *high* temperature condition where the temperature sensing bulb is warmer than the dial setting. Likewise, setting the dial to the *MAX* setting corresponds to a *low* temperature condition on the thermostat since the bulb will be cooler than the dial setting. At the completion of the tests, set *BT1* at 90°F and *BT2* at 70°F. During the heating season, adjustments to *BT1* or *BT2* may be necessary or desirable to optimize system performance.

If the building temperature falls too low in the winter before the auxiliary furnace cuts in, raise *BT1* by 5°F. The lowest setting that can be used comfortably will give the most efficient operation of the solar system and produce the most solar energy savings. Remember the caution about overheating heat pumps. Do not exceed a setting of 100°F on *BT1* without installing the surge option. On heat pump systems, the electric backup heat may cut in if the solar cross-over temperature is too low. The best way to avoid a mismatch between the solar coil output and the heating requirements is to compare the solar coil output specifications at 90°F against the heat loss calculation for the house at the design temperature.

BT2 controls the solar cut-off temperature. *BT2* should be set slightly above the temperature of the return air approaching the solar furnace coil. If in doubt, set *BT2* at the same setting as the building thermostat.

Table 5.1 Space Heating Controls Test

[--------------------------- Set Up			--------------------------]		[----------------- Observe		------------------]
Wall Thermostat			Tank Thermostats		Heating & A/C Operation			
Heat	Cool	Fan	BT1	BT2	Heat	Cool	Fan	Solar
ON	OFF	AUTO	MIN	MIN	OFF	OFF	ON	ON
ON	OFF	AUTO	MAX	MIN	ON	OFF	ON	ON
ON	OFF	AUTO	MAX	MAX	ON	OFF	ON	OFF
OFF	OFF	ON	NA	NA	OFF	OFF	ON	OFF
OFF	ON	AUTO	NA	NA	OFF	ON	ON	OFF

6. Pool/Spa Heating

6.1 Pool/Spa Piping

Connections to pools, spas, or hot tubs depend upon the fittings available on the unit. Pool pumps usually have too high a flow rate to circulate water through the solar heat exchanger. A separate pump installed on the solar package prevents flow rate mismatches and minimizes potential control headaches.

The flow rating of standard Holocene heat exchangers mounted internal to the solar tank is listed in table 6.1. For larger commercial applications, external heat exchangers are used.

Table 6.1 Maximum recommended heat exchanger flow rates

Model No.	Area (ft^2)	Maximum (GPM)
DX6	6.2	18
DX12	12.4	18

For existing pools, the only connections available may be to the pool circulation equipment. In this case, the supply and return lines to the solar heat exchanger are connected to two branch tees inserted side-by-side in the circulation loop between the pool pump and the chemical dispenser. Figure 6.1 shows the arrangement. It is important that the two tees be as close together as possible to prevent any pressure drop between them. Install a stop valve in the solar supply pipe with a boiler drain valve on the solar tank side. These valves are used to purge air out of the solar loop. The pool circuit is called the *primary* pumping loop and the solar circuit is called the *secondary* pumping loop.

> ***NOTE***
> *Never connect a pool exchanger into a circuit after a chemical dispenser. Fresh chemicals in high concentration going directly into a heat exchanger will shorten its life.*

If separate taps to the pool or spa are available, the solar circuit may be installed as a *primary* loop. The best arrangement is to connect a solar supply (cold) line to the bottom of the pool, and a solar return (hot) line near the top. Make sure that trash and debris cannot enter the solar supply pipe at the bottom of the pool. Install a stop valve in the solar supply line with a boiler drain valve on the solar tank side. These valves are used to purge air out of the solar loop. Air bubbles from whirlpool jets can enter the solar supply line and air lock the pump. An effective air separator may be required to prevent this problem.

The pool/spa heat exchanger on the solar tank contains the circulator pump and temperature sensor well in the return (hot) line.

6.2 Pool/Spa Controls

The *high* temperature sensor is already installed in the heat exchanger well in the tank and wired to the controller. It reads the output temperature of the heat exchanger. It is directly analogous to the sensor on the collector return line which reads the high temperature output of the collectors.

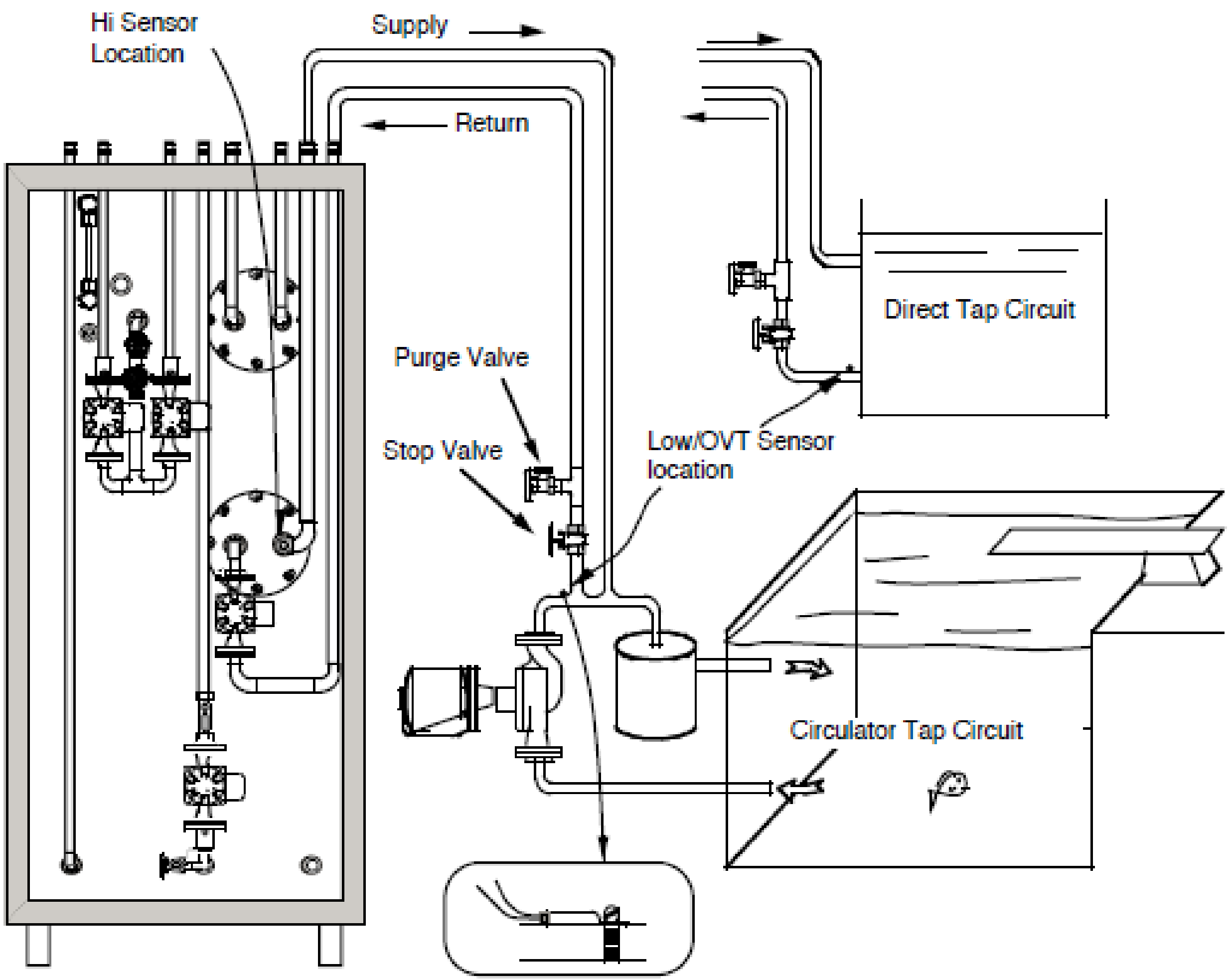


Figure 6.1 Solar Circuits for Pools or Spas

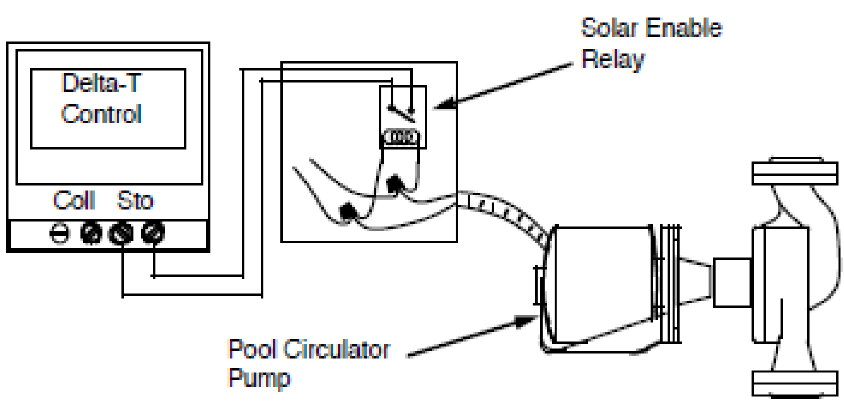


Figure 6.2 Lockout Relay Control Circuit

Circulator Tap Systems

On systems that tap into the existing circulator loop, the *low/ovt* sensor is installed on the (cold) line just before the branch to the solar heat exchanger. See fig. 6.1. The function of the *low* temperature sensor is to read the (cold) input to the solar heat exchanger. The overtemperature (*ovt*) or high limit function turns off the solar heat input when the proper temperature is reached. Strap the *low/ovt* sensor to the pipe with a band clamp over the flat end. Insulate over the sensor so it reads only the pipe temperature, not the surrounding air temperature.

Connect the hook-up wire to the sensor leads with crimp connectors or wire nuts. Seal the connections with silicone sealant to keep moisture out. On the pool controller, connect the *low* sensor wires to the terminals marked storage (STO). Set the controller high limit adjustment to the desired high limit setting, usually 85-90°F. This setting must be calibrated against the actual pool temperature.

NOTE
The solar pool heating pump is allowed to run only if the pool circulator pump is running.

A lockout relay is used to short the *low* sensor leads and stop the solar pump when the pool circulator pump is not running. The relay is field installed according to fig. 6.2 and connected to the storage, or STO terminals on the controller in addition to the leads from the *low* temperature sensor. When the pool pump is off, the relay is off, and the *low/ovt* terminals are shorted. The relay is wired in the *normally closed* mode.

Direct Connection Systems

On systems which can connect directly into the wall of the pool/spa without using the circulator pump circuit, the *low* sensor should be fastened to the wall of the pool next to the solar supply line and insulated to read only the pool temperature and not the air temperature. If this is not possible, the *low* sensor can be fastened to the solar supply (cold) line as close to the pool as possible. Fasten the sensor to the pipe with a band clamp over the flat end. Insulate over the sensor so it reads only the pipe temperature. The solar circuit runs anytime heat can be added, regardless of other circulator pumps.

Connect the hook-up wire to the sensor leads with crimp connectors or wire nuts. Seal the connections with silicone sealant to keep moisture out. On the pool controller, connect the *low* sensor wires to the terminals marked for storage (STO). Set the controller high limit adjustment to the desired high limit setting, usually 85-90°F. This setting must be calibrated against the actual pool temperature.

6.3 Pool Startup

After finishing the solar installation and filling the tank with water, use a hose to purge all the air out of the solar heat exchanger lines with the boiler drain purge valve and stop valve. On circulator tap systems, make sure the pool circulator pump is running and the solar lockout relay is functioning. Switch the solar pool controller to the *ON* position and note the circulation if water through the solar heat exchanger loop. If the solar tank is 15°F hotter than the pool supply line, switch the controller to *AUTO* and note the operation of the solar pump. The solar controller may be tested independently according to the checkout procedure in Section 3.

7.0 Auxiliary Heat Input Systems

7.1 Manually Fired Wood/Coal Boilers

Auxiliary heat from manually fired wood/coal stoves, boilers, or fireplace heat exchangers can be stored in a solar tank and distributed to space heating, domestic hot water, and pool heating. It is not recommended that *automatic* gas or oil boilers be used to heat solar storage tanks. The reasons are based on efficiency and control. Automatic boilers can be turned on and off as desired. Manually fired units are basically uncontrolled heat sources which cannot be turned on and off as desired (similar to solar collectors). Storing energy from an uncontrolled heat source allows the energy to be saved for future use and then directed in precise amounts to different applications. Automatic boilers should be hooked directly to the load - the energy is already stored in the fuel and does not need to be re-stored in the solar tank. The Holocene boiler option is inherently safe because it uses a patented atmospheric tank and circuit design that prevents dangerous pressure buildup.

Manually fired boilers should be installed in a location meeting all safety codes. A position near the solar tank in the basement, garage, or utility area is preferred. For boilers installed in or adjacent to a living area, the units must meet all the safety certifications and code requirements for boiler systems.

7.2 Piping

The supply (cold) line from the solar tank to the boiler should attach to the lowest fitting on the boiler heat exchanger. This allows air to be purged out of the boiler heat exchanger on startup. Figure 7.1 shows a boiler piping circuit.

> ***NOTE***
> *Do not put any valves in the hot return line. If the boiler overheats and boils the water in the exchanger, the return line will blow into the non-pressurized solar tank and be vented harmlessly to the atmosphere.*

A flow control valve is already installed in the (cold) supply line above the boiler pump on the solar tank. It is very important that the return (hot) line not have any valves in it. On a power failure, the pump will stop and the water in the boiler heat exchanger will boil. A valve in the return line could create a serious hazard. In a properly piped system, no pressure relief valve is required, since the tank has an atmospheric vent that relieves any pressure.

7.3 Controls

Manual boilers are operated by differential controllers in the same manner as collectors. The *low* sensor is factory installed on the solar tank near the supply line. The *ovt* or high limit function is not used and should be disabled inside the controller. It is not desired to turn off the pump under any conditions except a cold boiler.

The *high* sensor is fastened to the hot return line from the boiler to the solar tank. The sensor must be placed as close to the boiler as possible to sense the heat buildup and turn the pump on. It is best to place the sensor in a well inserted into a pipe fitting as close as possible to the boiler exchanger, preferably inserted into the exchanger at the outlet. The sensor may also be strapped to the pipe with a band clamp. Insulate over the sensor so it reads only the pipe temperature and not the surrounding air temperature.

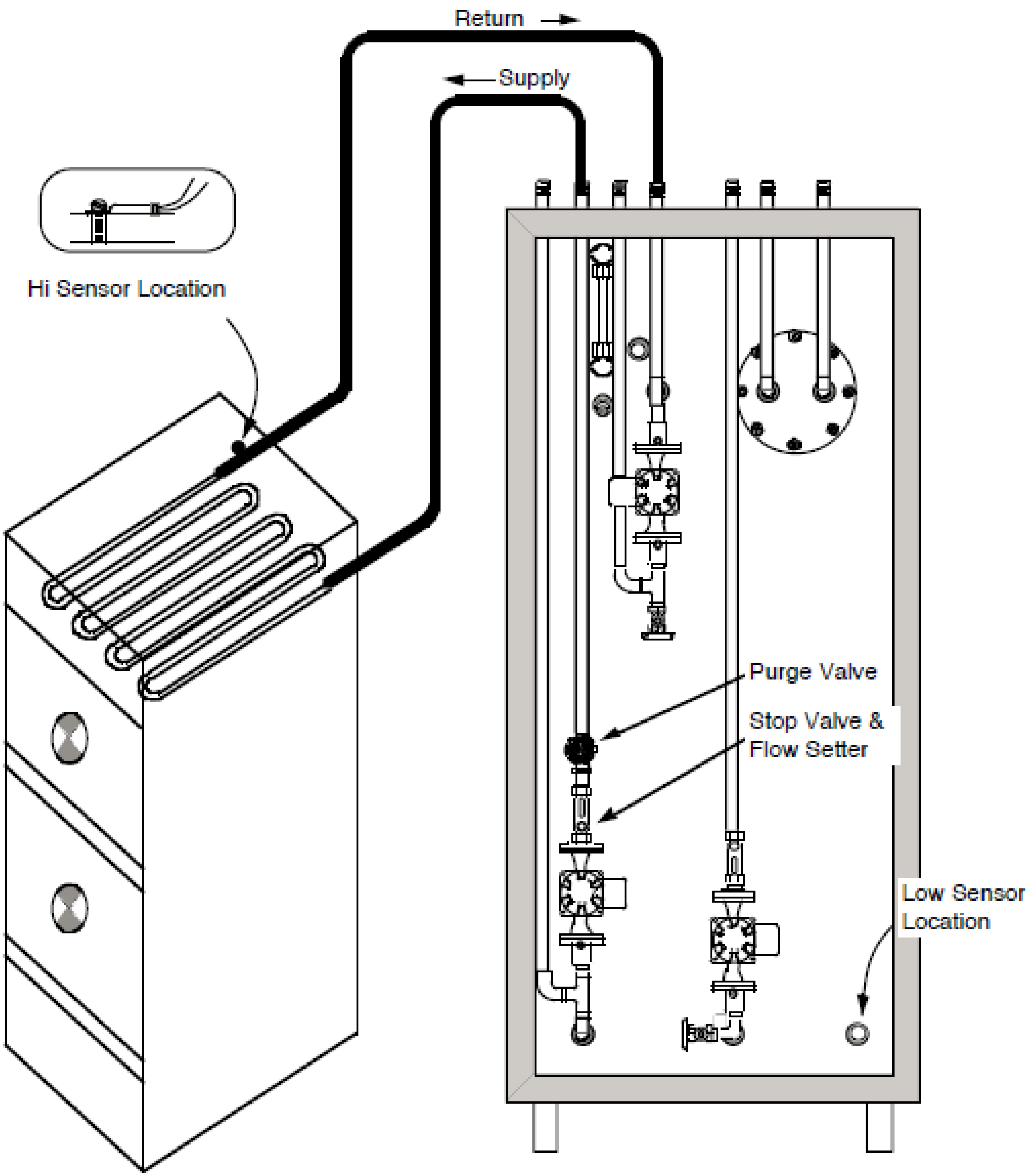


Figure 7.1 Boiler Piping Diagram

Connect hook-up wires to the sensor leads with crimp connectors or wire nuts. Caulk the connections with silicone sealant to keep moisture out. On the controller, fasten the *high* sensor wires to the collector, or COL terminals.

7.4 Boiler Startup

> ***NOTE***
> *Purging the boiler loop adds water to the tank. Be sure the tank is not completely full before starting this process.*

On an *almost* full tank, connect a hose to the boiler drain purge valve above the boiler pump. Refer to fig. 7.1. Close the adjacent flow setter valve to act as a stop valve. Run water through the hose and flush out all the air in the solar supply and return lines. Disconnect the hose and open the pump flow setter valve. It is important to know the BTU output expected from the boiler in order to set the flow rate. The rating of interest is the *output* rating, not the *input* rating. For every 10,000 BTU/hr of estimated energy output, the flow rate should be set in the range of 0.5 - 1.0 GPM. Turn the boiler differential controller *on* with the manual switch. Set the flow rate on the flow setter above the boiler pump according to the energy rating described above. Automatic operation of the controller can be determined only if the boiler output temperature is 15°F hotter than the bottom of the solar tank. For a cold system test refer to Section 3.

8.0 Troubleshooting

Before troubleshooting the system, make sure there really is a problem. Sometimes circuits do not work because a temperature limit is satisfied or the circuit control is off. Make sure all circuits have power. In many cases, tracing the steps in the installation section will reveal an error.

Proper trouble shooting requires the right tools. In addition to hand tools, a digital voltmeter and temperature sensor resistance chart are needed for electrical testing.

Asking the right questions is very important in pinpointing a problem quickly. The different circuits of a Holocene solar system are all independent and can be treated separately. This simplifies the procedure considerably. The circuits are

- Collectors
- Domestic Hot Water
- Space Heating
- Boiler
- Pool/Spa

8.1 Collector System

Table 8.1 Collector System Troubleshooting

Problem	Cause
1. Sunny Day - System not operating	1. Solar control *ovt* sensor satisfied 2. Power off / controller off 3. Controller failure 4. Broken lead to collector *high* temp. sensor 5. Shorted lead to tank *low* sensor 6. *High* sensor not insulated 7. Bad sensors 8. Bad collector pump(s) 9. Tank out of water
2. Pump runs at night	1. Outside temp is warmer than tank temp (only in summer -very rare) 2. Controller failure 3. Broken lead to tank *low* sensor 4. Shorted lead to collector *high* sensor

Check all sensor lead wires for short circuits due to staples driven into the wire, or for cut wires, or for wire connections which have become corroded or loose.

8.2 Differential (delta-T) Controllers

Differential controllers, or delta-T controllers, are used in the collector, pool/spa, DHW re-circulator, and boiler options. They all have a *high* temperature sensor, and a *low* temperature sensor. The over temperature (*ovt)* or high limit function comes from the *low* sensor.

1. Set the switch to the *on* position. If the controller does not operate, it is bad and must be replaced.

2. Remove the sensor leads from the delta-T controller. Set the switch to *auto* and short the terminals as shown in table 8.2 below. Note the operation of the controller. In the table, *open* means no connection is made to the terminals and *short* means to short circuit the terminals.

Table 8.2 Delta-T Controller Tests

HIGH / COL	LOW / STO	Pump is…
OPEN (cold)	OPEN (cold)	OFF (no solar)
SHORT (hot)	OPEN (cold)	ON (proper run)
SHORT (hot)	SHORT (hot)	OFF (Hi limit)

If no fault is found, test the sensor wiring by reading the resistance of each circuit with a digital ohmmeter. The leads must be disconnected from the controller for these measurements. Determine the temperature reading from the temperature vs. resistance chart of the sensor. If the circuit is *open* (infinite resistance) or *shorted* (zero resistance), the wiring is probably at fault. If the resistance is out of the range of the values on the chart, the sensor is probably at fault or the wiring has too much resistance.

> ***NOTE***
> *A **short circuit** is the same thing as a **hot sensor**. An **open circuit** is the same thing as a **cold sensor**.*

8.3 Space Heating

A good way to start troubleshooting the space heating system is to repeat the steps in the installation procedure as a checkout. Defining the standard operation of the existing furnace is essential to finding problem areas. The most frequent problems center around not having a good *common* connection and having the reversing valve operation backwards on heat pumps.

Other problems center around back-feed through the wall thermostat on the fan wire which turns on the air conditioning mode at the wrong time. In this case, the fan terminal G from the wall thermostat can be run through the *fan in* and *fan out* terminals on the control card. When connected this way, no signal goes to the G terminal when the solar relay puts power on the *fan out* terminal.

Air conditioners added to old oil furnaces frequently result in a system with two transformers. The fan operates off the air conditioner power supply, and the burner off the other. The solution usually involves bringing the control circuits up to modern specifications, as shown in the space heating control diagrams in Section 5, and then adding the solar controls.

Bad wall thermostats, relays, and limit controls can cause intermittent operation and are very difficult to discover. When all other efforts fail, reconnect the standard heating circuit without the solar in it and check the standard operation. Occasionally, the solar circuit will use contacts in the wall thermostat which have never been used, and are defective through corrosion and age. Changing the wall thermostat on an old system may well fix the problem.

There are many non-standard control circuits on heat pump systems. The universal Holocene control system will work with almost any furnace or heat pump unit. The logic pattern must be understood before proper solar control is possible. Getting a circuit diagram is an important step in determining how the solar controls can be installed. The circuit diagrams are usually pasted on the panels on the air handler and furnace cabinet.

8.4 Pumps

TACO brand pumps are used extensively on Holocene systems. On the smaller pumps, the bodies can be disassembled and the rotor cartridge replaced without taking the pump from the line. For detailed drawings of the components, check the pump literature. Replacement parts are available from Holocene. Many of the pumps have shut-off flanges which allow the lines to be closed off and the pump removed without draining the system.

Table 8.3 Pump Troubleshooting Table

1. Pump runs hot, pumps water OK	1. Normal operation
2. Pump hums, does not pump water	1. Rotor frozen or jammed
	2. Capacitor or windings bad
3. Pump runs, pumps water, flow stops	1. Height greater than pump head
	2. Air locked lines (traps in lines)

If a pump does not pump water, the first test should be to swap out the capacitor. If this does not work, remove the cartridge to see if the impeller is frozen. Sometimes a frozen impeller can be freed by turning the shaft with the hand. However, in most cases, once a pump impeller freezes, it does not last long after that. Changing out the impeller cartridge is recommended. If the impeller is free, a short live test will determine if the impeller will spin. Do not run the pump long with the impeller in the air. With no cooling, heat will damage the bearings. If the impeller is free and the live test does not work, the field coil windings may be bad and the motor must be replaced.

8.4 Collector Fogging

Fogging is caused by water condensation on the underside of the glass in the collector. There are several reasons for the condensation.

1. Some condensation is normal. Solar collectors expand and contract from a daily temperature swing that can exceed 300°F, causing the copper headers to slide in and out through the grommets and the glass frame to expand and contract. Proper collector design *sheds* water and provides *ventilation* for the moisture that does get inside. The ventilation system is a compromise between clearing moisture and causing excessive heat loss. As the collector cools down in the evening, the air volume inside contracts, drawing in humid outside air. When the temperature of the glass drops below the dew point, water condenses on the inside of the glass causing fogging. This type of fogging occurs only at certain times of the year when weather conditions are right. The fog is thin and burns off easily when the collector heats up again.
2. A leaking absorber plate can introduce water into the collectors. Usually, this kind of leak will show up as fluid running down the roof and will deplete the water in the solar tank. A telltale sign is the pink or purple color of the leaking water, indicating tank water with corrosion inhibitor in it. One kind of leak that may be difficult to find is a poorly soldered coupling between two collectors. A leak in the coupling can squirt water into the collector box through the grommet and imitate a leaking manifold. If the leak appears to be tank water, check the couplings to determine if they are leaking.
3. The water in a collector can come from rain. Holocene collectors are made to shed rain water. The top glass frame piece laps over the side pieces to shed water. At the bottom, a bead of silicone rubber caulking is run horizontally across the top edge of the bottom glass frame piece so that water cannot get under the upturned edge of the glass frame metal. The collector has a top and a bottom. On older models, two 1/4 inch vent holes were put at the bottom corners of the collector. If the collector was installed upside down, the water could enter the vent holes and through the uncaulked part of the glass frame at the bottom of the collector. Newer collectors have no exposed vent holes, but do have top and bottom end caps on the box which indicate the top (outside lap) and bottom (inside lap).
4. Poor sealing of the pipe insulation against the side of the collector can allow rain water to enter the collector. The insulation must be very carefully installed and caulked with silicone caulking to prevent rain water from entering through the grommets. Over time, the insulation may pull away from the box and require recaulking or repair. Refer to the insulation section of this manual for description of proper techniques.

About the Author

In 1977, Dr. Ben Gravely established Gravely Research Corporation (GRC) to pursue various optical and thermal inventions for solar energy systems, for which two patents were granted. Other inventions include a range of thermal energy products including thermal storage systems, heat exchangers, a thermal engine, and a high sensitivity, low cost, flow sensing device. He founded Astron Technologies, Inc. in 1980 to manufacture and distribute solar and other energy products developed by GRC.

Dr. Gravely also created a universal logic control system to interface thermal energy systems to different heating applications, and off-peak thermal storage units for utility load leveling. He has written a 35 page manual on off-peak thermal storage methodologies, including computer programs to simulate hour-by-hour performance. The methodologies and equipment were adopted by several utilities for thermal storage field testing programs.

GRC solar systems have been installed on hundreds of private residences, federal post offices, state park visitor centers, highway rest stations, military barracks, US Air Force bases, VA hospitals, police headquarters, jails, public pools, public health facilities, schools, public housing projects, motels, car washes, and many more.

Dr. Gravely has written computer programs to analyze energy requirements, solar performance, and economic benefit that were recognized as authorized analytical methods by HUD, the NC Energy Division, and the US Army Corp of Engineers. He has presented numerous papers in this field, and was appointed by the governor of North Carolina to be a founding director of the NC Advanced Energy Corp. His work in this area has been recognized by commendation from the governor, ASME, TVA, and the NC Sustainable Energy Association, of which he is co-founder.

Through his website, http://www.solarhotwater-systems.com, Dr. Gravely hopes to share the valuable knowledge he has accumulated over three decades with solar thermal designers, installers, and project owners in order to strengthen the growth of the industry.

Dr. Gravely cofounded Holocene, LLC in 2008 as Technical Director. The company is engaged in the design, installation, and financing of commercial solar thermal systems. For more information, go to http://www.holocene-energy.com.

Dr. Gravely has a broad background in many scientific disciplines. His experience includes research, invention, design, and development in Plasma Physics, Ophthalmology Diagnostic Imaging, Laser Physics, Automatic Stages, Nuclear Magnetic Resonance, Robotic Vision Systems, Electron Optics, Electro-Optical Microscopy, Image Analysis, Cystic Fibrosis Therapy Devices, Electrical Power Connectors, Medical Hyperthermia Instruments, Microscale Thermal Storage and Heat Transfer, and Solar Energy.