HoloTech[tm]
Solar Hot Water System
Installation Manual

Ben Gravely, PhD
Holocene Technologies
1241 Wicker Drive
Raleigh, NC 27604

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1. Planning the Installation

This manual was written to provide straight forward procedures for the installation of HoloTech™ solar hot water systems manufactured by Holocene Technologies. As with any project, a few minutes of planning will save hours of fixing. The installer is responsible for knowing local regulatory codes and how they apply to the equipment. If in doubt, a visit with local code officials can prevent on-site inspection problems.

1.1 *Site Analysis*

Measure the angle of the collector mounting surface from south with a compass. This is called the South Azimuth. Correct for the magnetic compass error in your region. Note that "true south" and "solar noon" refer to the same direction, which does not match local noon during daylight savings time. It is preferable that the collector South Azimuth 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, including the routing for piping between the components.

Shading considerations can be included in the analysis by the use of sky imaging products.

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 (solar) 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.

Measure the roof slope and use Table 1.1 to select the leg length needed for the appropriate collector tilt.

Table 1.1 Collector Leg Length Selection

Roof Slope	**Angle**
Flat	0º
3/12	14º
6/12	26.5º
9/12	36.9º
12/12	45º

1.3 *Materials*

In addition to standard tools and plumbing parts, make sure to include hole saws, silicone sealant, and roof flashing boots. Collector piping should be 3/4" or greater for proper draining. Use only metal piping in the collector loop. Space heating and DHW circuits can use any code approved piping.

2. Tank Installation

The tank should be protected from rain, wind, and prolonged freezing temperatures in case of extended power failures. The preferred location is within the insulated area of a building, such as a garage, basement, or equipment room. If no space is available inside the building, a good alternative is an adjacent shed. See fig. 2.1 for examples.

Figure 2.1. Tank

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 residential 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
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 this manual. Additional 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 for.

It is very important to leak test and flush the collector lines before final connection to the tank. The tank is easily filled and maintained with the boiler drain valve at the bottom of the tank. A union can be installed in the collector return line as another fill point. An autofill system is offered as an option.

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

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 component 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 isolate the solar system from being accidentally cut off by other appliances tripping the breaker.

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.

Figure 2.1 80 Tank Face. Door is Removed

Fill the tank using the boiler drain valve at the bottom of the tank, or a union in the collector return line. See fig. 2.1. A hose with female fittings on both ends, such as a washing machine hose, is required for the boiler drain connection,.

Fill the tank until the water level is at the bottom of the site glass on the tank. Check for leaks in piping or weld seams. Then 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. For domestic hot water only systems, the tank may be filled to the top of the site glass. This leaves several inches of air gap at the top of the tank.

3. Collectors

3.1 *Frame and Collector Mounting*

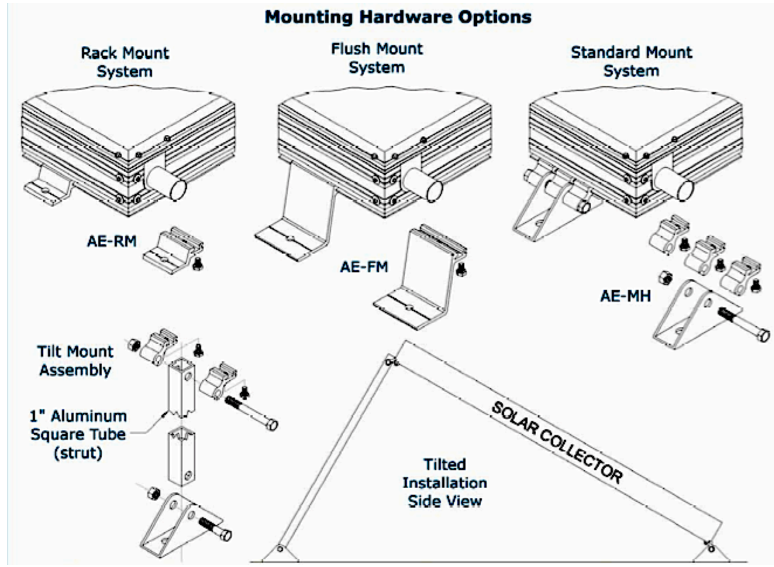

Figure 3.1 Typical solar collector frame and mounting hardware.

Typical flat plate collector mounting hardware is shown in fig. 3.1. Different collector brands have different hardware, but the essentials are the same.

There are three angles that must be considered when installing an array of solar collectors. The first is the south facing direction (south azimuth) 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 piping. If

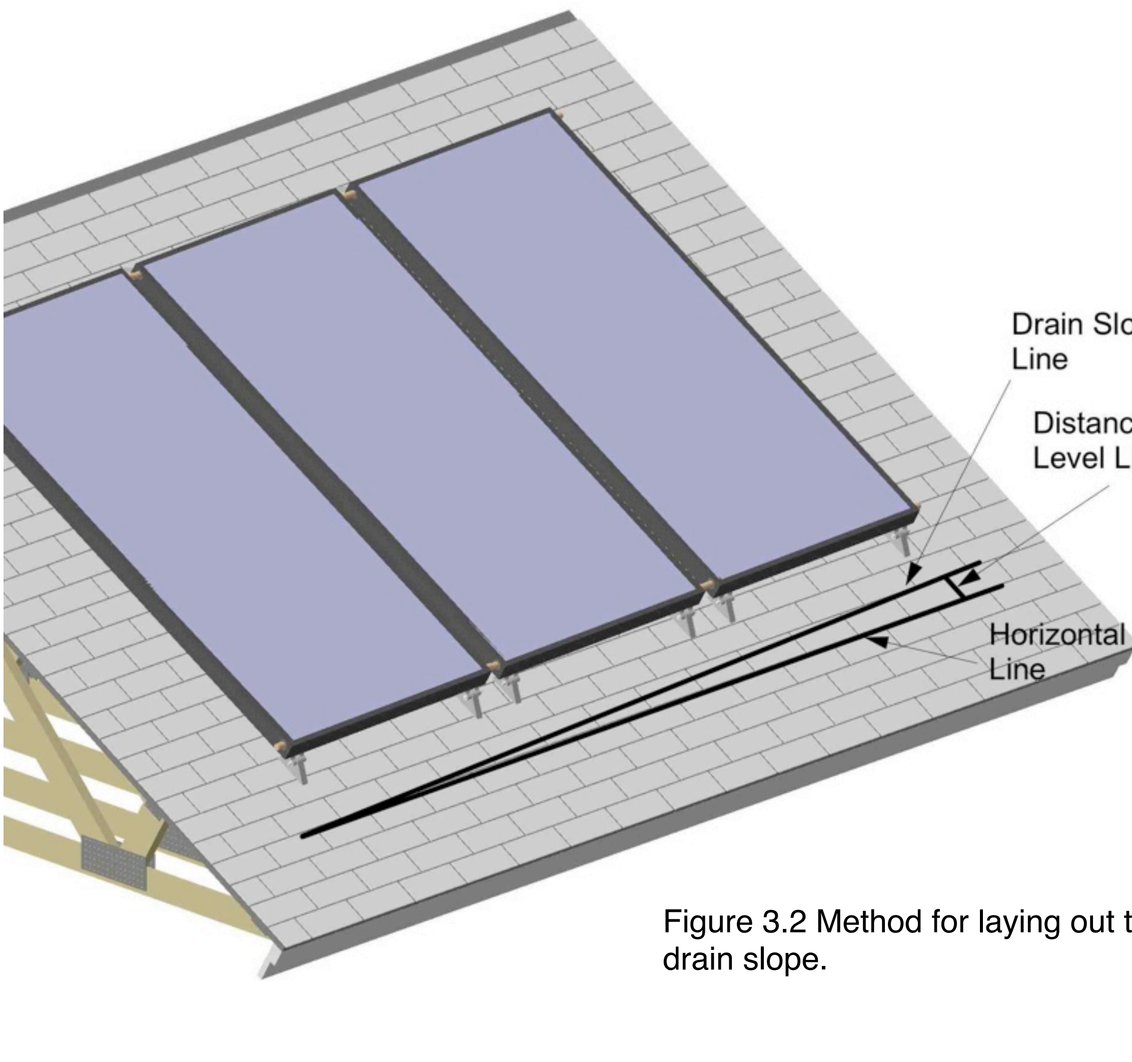

Figure 3.2 Method for laying out the drain slope.

there is insufficient drain slope, water standing in the supply header can freeze in the winter and burst the pipe. If the drain slope is too much, water can be trapped in the stub end of the return header and cause freezing problems in the winter. The drain slope should be 1 inch in 20 feet (approximately 1/4° slope) to assure proper draining. 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 or 20 feet long starting from the lowest corner of the collector array. On the opposite end mark the distance up the roof as shown in fig. 3.3. Another method is to hold a bubble level perpendicular to the level line and 1/2 or 1 inch above the end of the line. 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.

Collector Drain Slope Table			
Roof Pitch	Angle	h(in) for 20' Dist	h(in) for 10' Dist
2/12	9.5	6 1/16	3 1/16
3/12	14.0	4 1/8	2 1/16
4/12	18.4	3 3/16	1 9/16
5/12	22.6	2 5/8	1 5/16
6/12	26.6	2 1/4	1 1/8
7/12	30.3	2	1
8/12	33.7	1 13/16	7/8
9/12	36.9	1 11/16	13/16
10/12	39.8	1 9/16	3/4
11/12	42.5	1 1/2	3/4
12/12	45.0	1 7/16	11/16

Figure 3.3 Drain slope table for different roof slopes.

On a shingle roof, the collector mounting feet can be bolted to the roof through purlins nailed in place between the rafters. As shown in fig.3.4, it is usually not possible to have all mounting feet hit rafters. In most cases it is better to avoid the rafters.

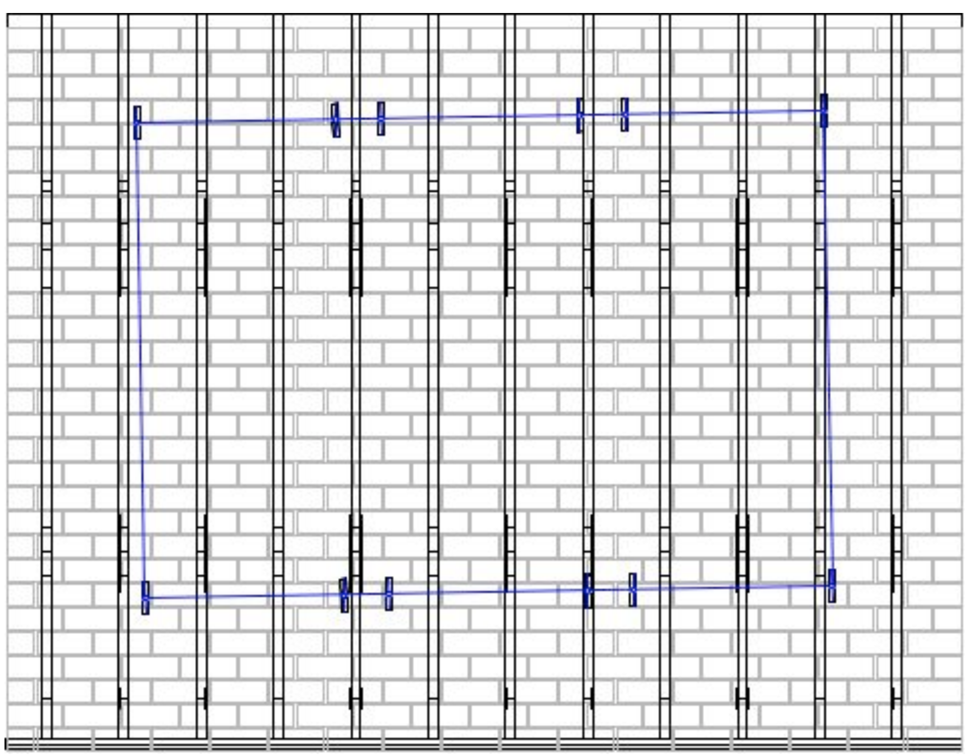

Figure 3.4. Typical shingle roof layout for mounting collectors.

After laying out the sloped chalk line, mark the position of the feet along the line. Drill a 1/4" pilot hole through the roof to locate the position of the purlin underneath. Secure the purlin underneath, then redrill through the hole for a 3/8 in. bolt. Figure 3.5 shows different options for the roof mounting structure.

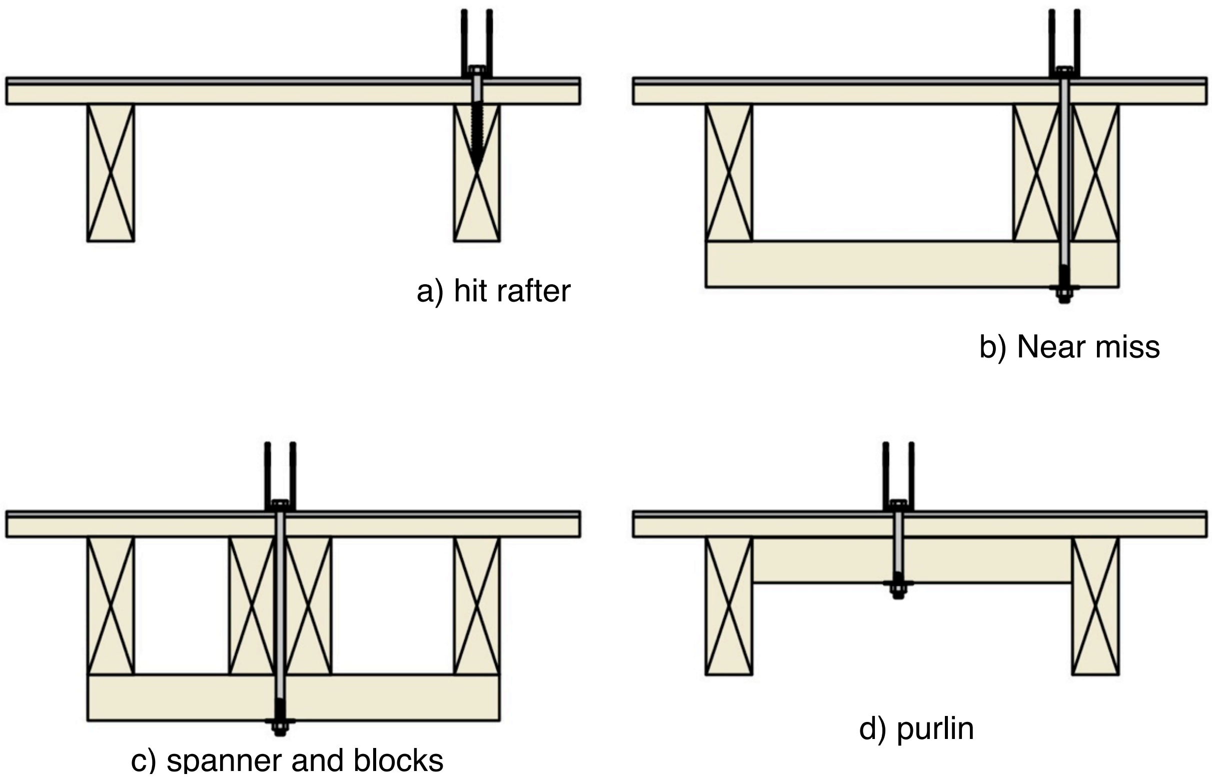

Figure 3.5. Different kinds of under roof fastening methods

Be sure to caulk under the bolt head and under the feet with silicone sealant to keep water out. Make sure to point the narrow dimension of the feet up and down the roof to prevent damming rain water and trapping leaves and debris. The collectors should be held at least 2 in. off the roof to clear debris and allow air flow.

Figure 3.6 shows the collector to tank piping concepts. The return line should be the shortest to conserve energy.

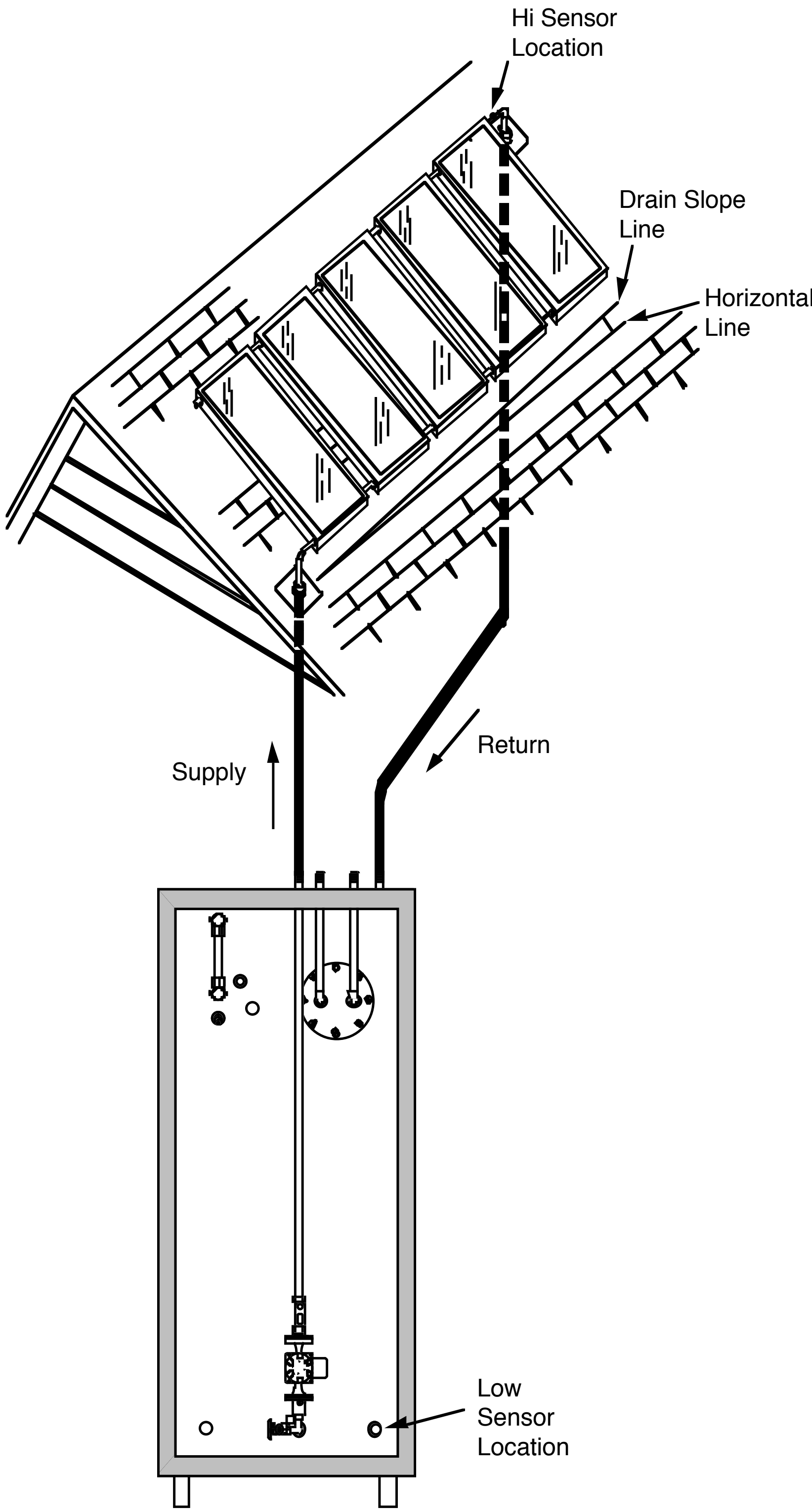

Figure 3.6. Collector to tank piping layout.

3.2 *Collector Piping*

The recommended flow rate for each collector is 0.025+/-.005 GPM/ft2. Consult the chart below to determine the proper pipe size for different collector areas. Use only metal pipe in the collector loop. Either type L or M copper is satisfactory, since the piping is operated only at atmospheric pressure. The supply and return pipes are the same size.

Table 3.2 Collector Circuit Pipe Sizing

Area of Collectors	Pipe Diameter
20-60 ft2	1/2 (3/4 in. recommended)
80-240 ft2	3/4 in.
240-400 ft2	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 made for vent pipes. The hole diameter should be the outside diameter of the pipe insulation, usually 2-1/2 - 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.
4. there can be no traps in the lines from the collectors to the tank.

The rules assure that all the collectors will fill completely before any one drains, and all the water from the collectors can drain completely to the tank. 95/5 solder is recommenced for all joints on the collectors.

A good technique for soldering the collector manifolds is to use a solder shield, or flame shield, to protect the grommet from excess heat. See fig. 3.7. The shield is a piece of sheet metal with a slot cut out to go over the pipe. Top and bottom collector headers are joined directly together to form a common manifold for all collectors in a bank.

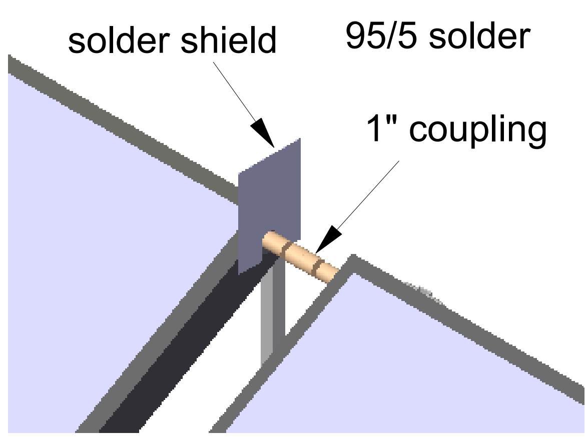

Figure 3.7 Solder shield for joining collectors.

> ***NOTE***
> *The collector header pipes must be completely cleaned of all black plating before soldering! Solder will not stick to black plating!*

Figure 3.8 shows piping routines for different numbers of collectors placed on a sloped roof. 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 four foot wide collectors be joined together in one bank as shown in fig. 3.8(a). However, six collectors may work if care is taken to assure there are no binding points in the piping. Symmetry is important in collector arrays to help balance the flow through each collector.

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. 3.8 show that the path lengths for every fluid circuit are the same, eliminating the need for balancing valves.

Figure 3.8(b) shows two banks of five collectors mounted in a single row on a common sloped line. This arrangement is called a "row tilt". A spacing of 5-6 inches between banks of collectors allows enough space to bring an insulated supply header between the collectors.

Figure 3.8(c) shows two rows of collectors arranged vertically over each other. Notice the return header connections. The water from the lower row must rise and join the higher row to guarantee all collectors are full before any water can return to the tank.

Figure 3.8(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.

Large arrays may have several rows of collectors on a flat roof. Figure 3.9 shows two banks of collectors piped as a single array and as separate arrays. In fig. 3.9(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. However, the long runs between rows require mechanical supports to prevent traps and to properly support the piping.

A more common arrangement is shown in fig. 3.9(b). In this case, there are separate return lines from each row that join below the collectors in a common return line. Individual balancing valves are required in the supply lines to set the flow rate in each row. 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 in the line.

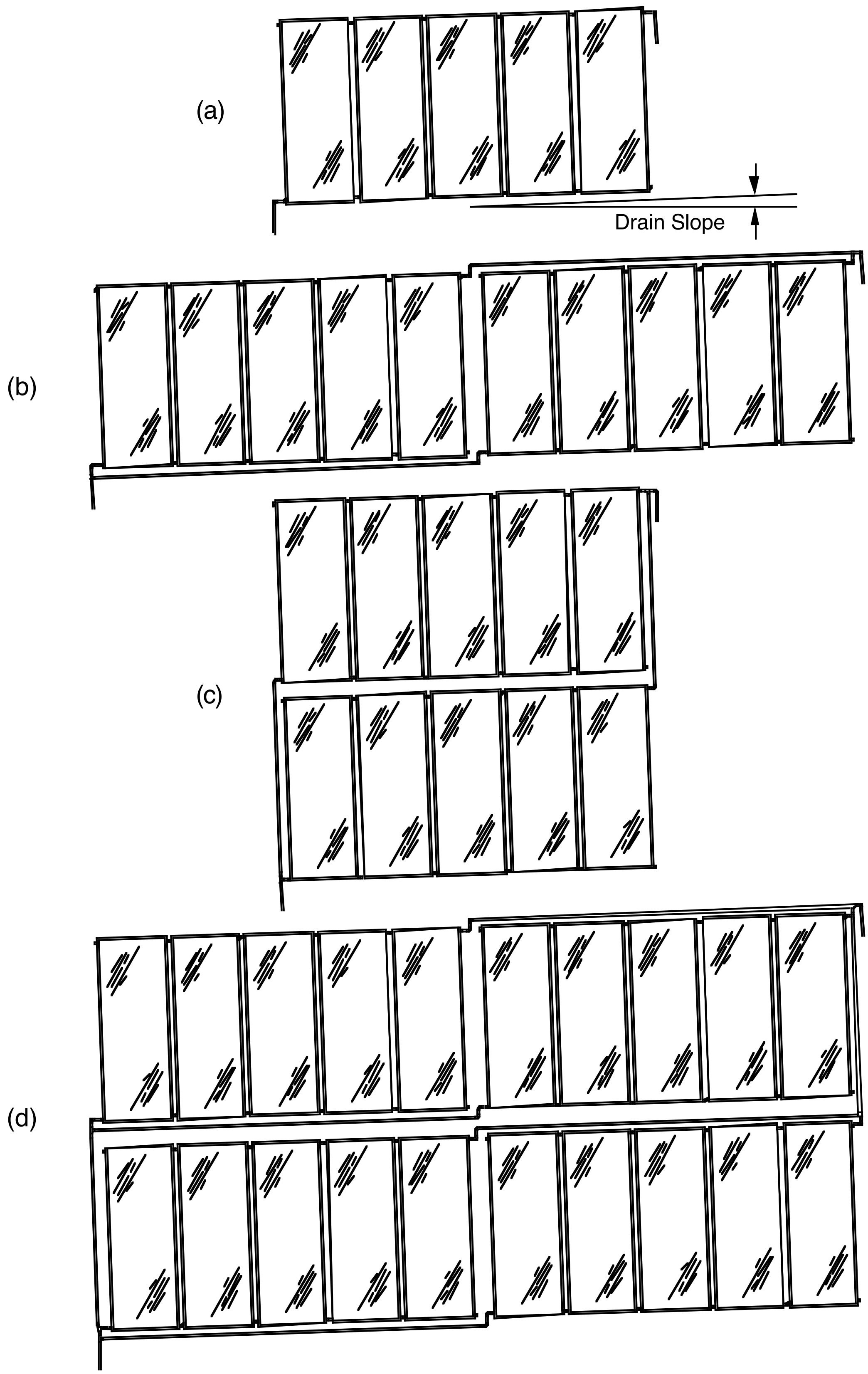

Figure 3.8 Collector piping for arrays in the same plane.

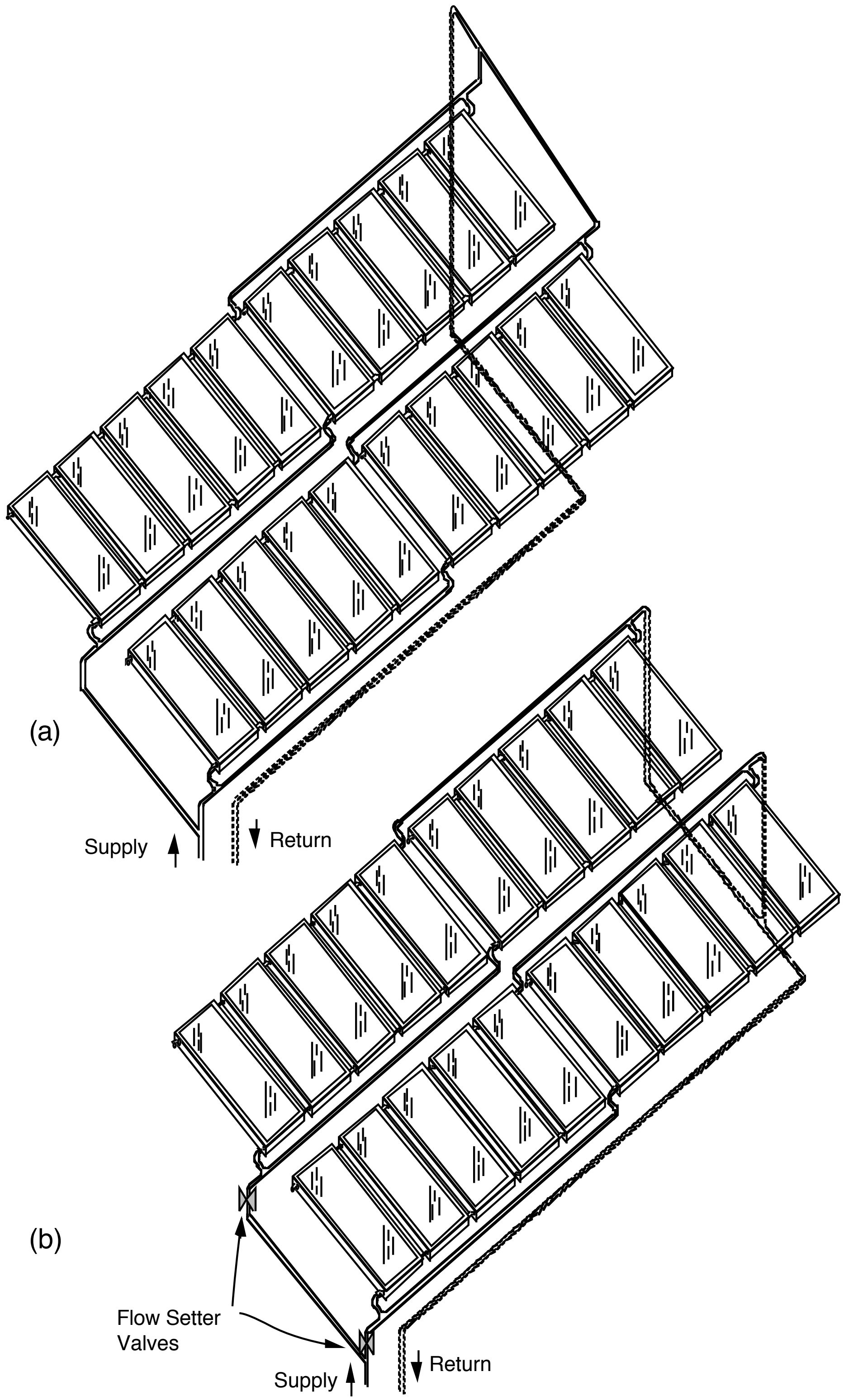

Figure 3.9 Collector piping for arrays on a flat roof.

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. Be careful that soft copper doesn't sag and cause traps.

When all the collector piping is finished, cap off the lines and leak test the collector array before final connection to the tank. Flush the lines with water, then connect to the tank. A removable union may be placed in the return line at the tank to add water and water treatment. The boiler drain at the bottom of the tank can also be used. Do not fill the tank until the startup procedure.

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 jacket. Elastic foam products are not recommended because they deteriorate badly in sunlight and at high collector temperatures. Fiberglass pipe insulation can be used as a second choice, but it has a lower R value than the rigid foam products. Use the next thickness up.

Note

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

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.

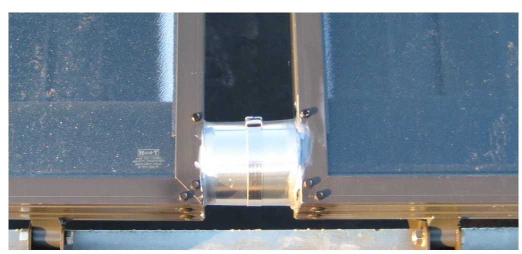

Figure 3.10. Insulation between collectors.

Leave the insulation off the return line from the last collector for installation of the collector temperature sensor. The insulation is installed over the sensor. It is recommended that the collector sensor wiring be run under the aluminum jacket to eliminate conduits and protect the collector sensor and wiring from lightening strikes. Inside the building isocyanurate foam or fiberglass insulation with either an aluminum or white craft paper covering (called All Service Jacket, ASJ) can be used.

3.4 *Solar Controls and Wiring*

Differential controllers (called "Delta-T" controllers) are used to operate the collectors, recirculator DHW option, and pools/spas. The temperature 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 HoloTech^{tm} solar systems 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 or a spa/pool heat exchanger. 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 feeds lower temperature water to the heat source. The low temperature sensor position is the bottom of the solar tank for collector 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 over temperature (OVT, for short) sensor on the heat receiver. Its function is to shut off the pump when the maximum temperature is reached in the tank or pool.

The control logic is as follows:
When the high temperature sensor (COL) is 18-20˚F warmer than the low sensor (STO), the controller turns the pump ON. This is called the CUT-ON DIFFERENTIAL temperature.

When the high temperature sensor (COL) falls to 4-5˚F warmer than the low sensor (STO), the controller turns the pump OFF. This is called the CUT-OFF DIFFERENTIAL temperature.

When the low/OVT sensor reaches its high limit set point, usually 160F, the controller turns the pump 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, 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.

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 of the last collector in the array as shown in fig. 3.11.

Push the flat end of the sensor under the grommet into the collector box. Fasten the sensor to the pipe 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.

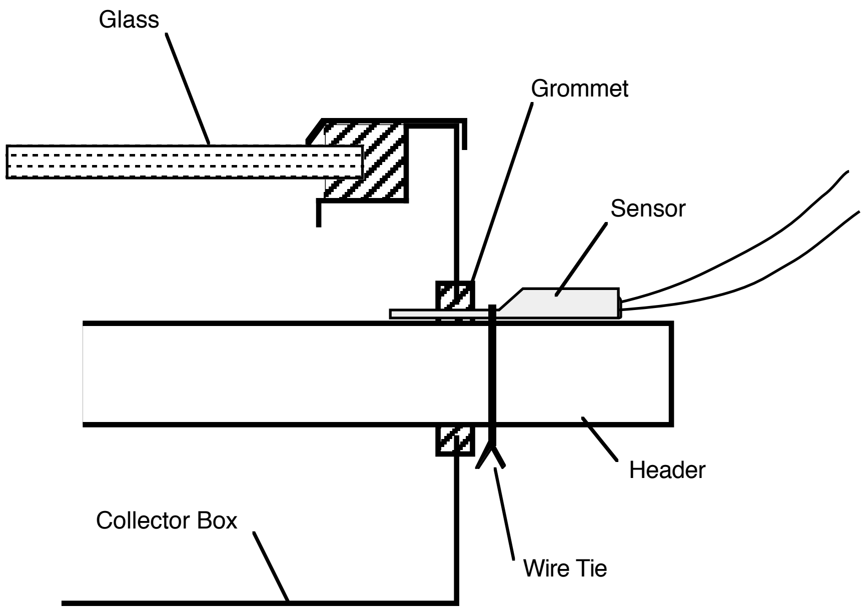

Figure 3.11 Collector sensor mounting.

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, it must be very carefully installed.

3.5 *System Startup*

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

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.

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 0.025 GPM per square foot of 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 the sensor wires installed, set the controller switch to the AUTO position. Refer to Table 3.3. Connect a low value resistor (low R = hot) across the COL terminals and observe the controller response. The system should turn on, since the COL terminals appear "hot". Note that a low value resistor corresponds to a hot sensor, and a high value resistor (hi R) corresponds to a cold sensor. The third row of the table tests the high limit control.

Table 3.3 Delta-T Controller Tests

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

OPEN (cold) = high R (~100kΩ)
SHORT (hot) = low R (~1κΩ)

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.

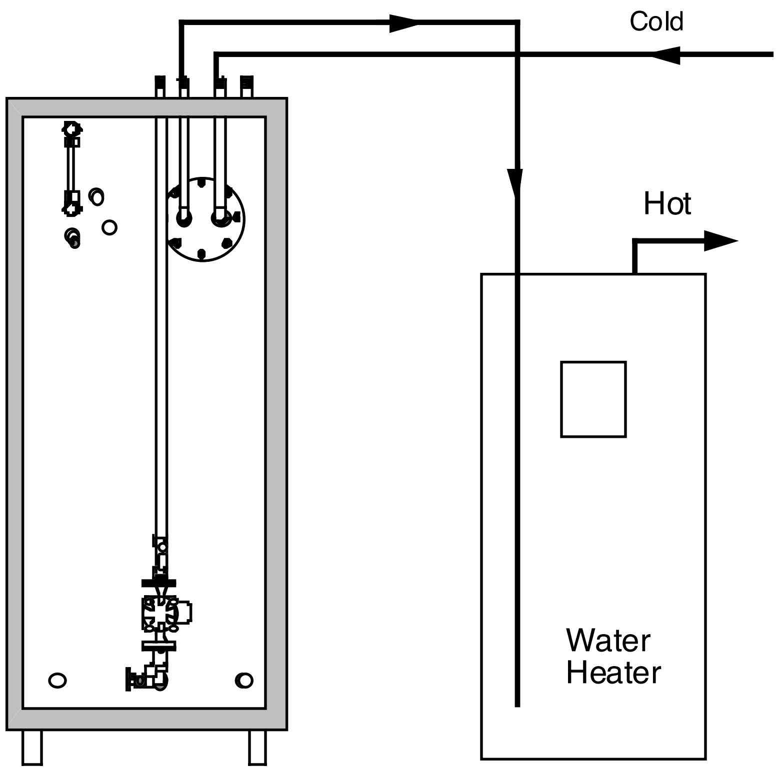

Figure 4.1 Single Pass DHW piping diagram.

4.2 *Recirculator Piping*

A second option is called a "recirculator" 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 recirculator 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 added expense of a recirc system is not usually warranted unless the solar tank and the conventional water heater are far apart.

4.3 *DHW System Startup*

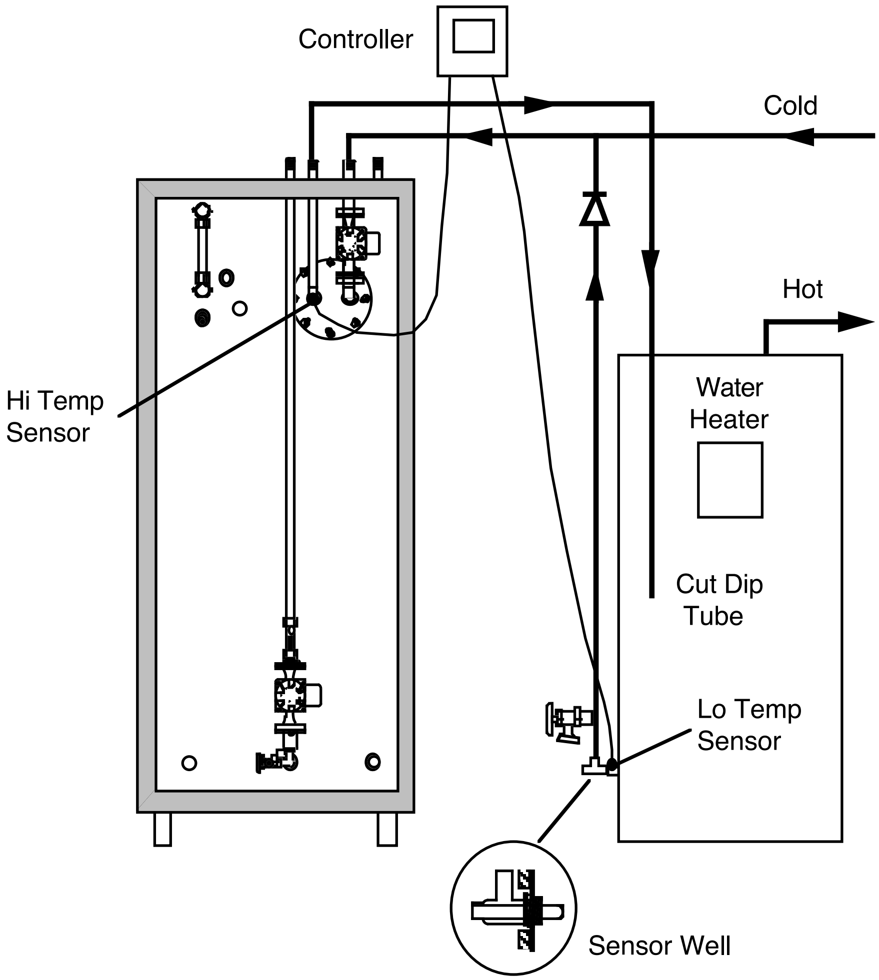

Figure 4.2 Recirculator DHW piping diagram.

Single Pass Startup:
Testing the DHW system requires the tank installation and wiring be complete, the tank full of water, and the pressurized lines leak tight and full of water. The collector loop should be in operating condition. If the tank is warm, 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.

Recirculator Startup:
Turn the recirculator Delta-T controller switch to the ON position. Observe that the recirculator pump runs and the water moves through the heat exchanger 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 in the Appendix for testing Delta-T controllers.

Appendix 1. 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 electrical circuits of a HoloTech™ solar system are all independent and can be treated separately. This simplifies the procedure considerably. The circuits are

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

A1.1 *Collector System*

Table A1.1 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 COL sensor 5. Shorted lead to tank STO sensor 6. Shorted lead to tank OVT sensor 7. High sensor not insulated 8. Bad collector pump(s) 9. Tank out of water
2. Pump runs at night	1. Outside temp is warmer than tank temp (Very rare -only on new system in summer) 2. Controller failure 3. Broken lead to tank STO sensor 4. Shorted lead to collector COL 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.

A1.2 *Differential (delta-T) Controllers*

Differential controllers, or delta-T controllers, are used in the collector, pool/spa, DHW recirculator, 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 on the tank.

1. Set the switch to the ON position. If the controller does not operate, remove the sensor wires and repeat the test. If it still does not operate it is bad and must be replaced. If it does operate, then there is a fault in the wiring or sensors.

2. To test the controller by itself, remove the sensor leads from the controller. A set of resistors is used to simulate the temperature values needed to cycle the controller through its modes. One simulates a cold STO tank sensor (25kΩ). One simulates a hot COL collector sensor (3kΩ), and the third simulates the very hot OVT condition (1kΩ). Set the controller switch to AUTO and connect the STO, COL, and OVT resistors to the terminals in the patterns indicated in Table A1.1. Note the operation of the controller.

Table A1.1 Delta-T Controller Tests

COL(Hi Temp) terminals	STO(Lo Temp) terminals	RESULT Collector Pump is
COLD	COLD	OFF (no solar)
HOT	HOT	ON (proper run)
HOT	OVT	OFF (Hi limit)

COLD = high R (25kΩ ~ 40ºF)
HOT = low R (3kΩ ~ 130ºF)
OVT = V low R (1kΩ ~ 189ºF)

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.

Table A1.2 Sensor Temperature vs Resistance

HoloTech™ solar controls use 10K thermistor temperature sensors. These devices change resistance with temperature. They are defined by having 10KΩ resistance at 25ºC (77ºF).

°F	Ohms Ω	°F	Ohms Ω	°F	Ohms Ω	°F	Ohms Ω	°F	Ohms Ω
-67.0	963,849	23.0	42,327	113.0	4,368	203.0	786.6	293.0	208.9
-65.2	895,332	24.8	40,159	114.8	4,201	204.8	763.5	294.8	204.1
-63.4	832,130	26.6	38,115	116.6	4,041	206.6	741.2	296.6	199.4
-61.6	773,799	28.4	36,187	118.4	3,888	208.4	719.6	298.4	194.8
-59.8	719,934	30.2	34,368	120.2	3,742	210.2	698.7	300.2	190.3
-58.0	670,166	32.0	32,650	122.0	3,602	212.0	678.6	302.0	186.1
-56.2	624,159	33.8	31,029	123.8	3,468	213.8	659.1	303.8	181.9
-54.4	581,605	35.6	29,498	125.6	3,340	215.6	640.3	305.6	177.7
-52.6	542,225	37.4	28,052	127.4	3,217	217.4	622.2	307.4	173.7
-50.8	505,763	39.2	26,685	129.2	3,099	219.2	604.6	309.2	169.8
-49.0	471,985	41.0	25,392	131.0	2,986	221.0	587.6	311.0	166.0
-47.2	440,674	42.8	24,170	132.8	2,878	222.8	571.2	312.8	162.3
-45.4	411,640	44.6	23,013	134.6	2,774	224.6	555.3	314.6	158.6
-43.6	384,703	46.4	21,918	136.4	2,675	226.4	539.9	316.4	155.1
-41.8	359,700	48.2	20,882	138.2	2,579	228.2	525.0	318.2	151.7
-40.0	336,479	50.0	19,901	140.0	2,488	230.0	510.6	320.0	148.4
-38.2	314,904	51.8	18,971	141.8	2,400	231.8	496.7	321.8	145.1
-36.4	294,848	53.6	18,090	143.6	2,316	233.6	483.2	323.6	142.0
-34.6	276,194	55.4	17,255	145.4	2,235	235.4	470.1	325.4	138.9
-32.8	258,838	57.2	16,463	147.2	2,157	237.2	457.5	327.2	135.9
-31.0	242,681	59.0	15,712	149.0	2,083	239.0	445.3	329.0	133.0
-29.2	227,632	60.8	14,999	150.8	2,011	240.8	433.4	330.8	130.1
-27.4	213,610	62.6	14,323	152.6	1,942	242.6	421.9	332.6	127.3
-25.6	200,539	64.4	13,681	154.4	1,876	244.4	410.8	334.4	124.6
-23.8	188,349	66.2	13,072	156.2	1,813	246.2	400.0	336.2	122.0
-22.0	176,974	68.0	12,493	158.0	1,752	248.0	389.6	338.0	119.4
-20.2	166,356	69.8	11,942	159.8	1,693	249.8	379.4	339.8	116.9
-18.4	156,441	71.6	11,419	161.6	1,637	251.6	369.6	341.6	114.5
-16.6	147,177	73.4	10,922	163.4	1,582	253.4	360.1	343.4	112.1
-14.8	138,518	75.2	10,450	165.2	1,530	255.2	350.9	345.2	109.8
-13.0	130,421	**77.0**	**10,000**	167.0	1,480	257.0	341.9	347.0	107.5
-11.2	122,847	78.8	9,572	168.8	1,432	258.8	333.2	348.8	105.3
-9.4	115,759	80.6	9,165	170.6	1,385	260.6	324.8	350.6	103.2
-7.6	109,122	82.4	8,777	172.4	1,340	262.4	316.6	352.4	101.1
-5.8	102,906	84.2	8,408	174.2	1,297	264.2	308.7	354.2	99.0
-4.0	97,081	86.0	8,057	176.0	1,255	266.0	301.0	356.0	97.0
-2.2	91,621	87.8	7,722	177.8	1,215	267.8	293.5		
-0.4	86,501	89.6	7,402	179.6	1,177	269.6	286.3		
1.4	81,698	91.4	7,098	181.4	1,140	271.4	279.2		
3.2	77,190	93.2	6,808	183.2	1,104	273.2	272.4		
5.0	72,957	95.0	6,531	185.0	1,070	275.0	265.8		
6.8	68,982	96.8	6,267	186.8	1,037	276.8	259.3		
8.6	65,246	98.6	6,015	188.6	1,005	278.6	253.1		
10.4	61,736	100.4	5,775	190.4	973.8	280.4	247.0		
12.2	58,434	102.2	5,545	192.2	944.1	282.2	241.1		
14.0	55,329	104.0	5,326	194.0	915.5	284.0	235.3		
15.8	52,407	105.8	5,117	195.8	887.8	285.8	229.7		
17.6	49,656	107.6	4,917	197.6	861.2	287.6	224.3		
19.4	47,066	109.4	4,725	199.4	835.4	289.4	219.0		
21.2	44,626	111.2	4,543	201.2	810.6	291.2	213.9		

A1.3 *Pumps*

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

Table A1.3 Pump Troubleshooting Table

1. Pump runs hot, pumps water	OK - Normal operation
2. Pump hums, does not pump water	Rotor frozen or jammed
	Capacitor or windings bad
3. Pump runs, pumps water, flow stops	Height greater than pump head
	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.

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 developed off-peak thermal storage equipment and 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 a 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.

In 2008 he cofounded Holocene, LLC and serves as Technical Director. The company is engaged in the design, manufacturing, 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.