

**Section 4: Solar Water Heating System Troubleshooting** presents structured methods to follow in diagnosing and correcting system problems.

- **Module: Problem Assessment and System Checkout** provides guidelines for assessing installed system problems.
- **Module: Troubleshooting Checklist** provides a comprehensive checklist for determining probable causes and the appropriate corrective actions.

## **Section 4**

### **Module: Problem Assessment and System Checkout**

#### **I. PROBLEM ASSESSMENT**

To diagnose system problems, you must not only understand the system type and its components and how they work, but you must also know what questions to ask to determine the problem and find out when and why it occurred. The more experience you have servicing solar systems, the more you will learn what questions to ask the customer.

##### **The Initial Service Call**

When you first receive a service call, record the caller's name, address and telephone number and be sure to get directions to the service location. Also, verify the caller is the system owner and is authorized to have you service the system.

Determine what kind of service the caller is requesting. Is it a routine service call or is the system not working properly? If the system is not working, what exactly is wrong? Is there no hot water? Is the system leaking? If it is leaking, where is the leak – on the roof or at the storage tank? The more you know about the system, the better prepared you will be when you arrive at the site. For example, if the system has an expansion tank and the system is over two years old, you will want to take new glycol with you to replace the old glycol. If the system has a drainback tank, you will want to have distilled water with you.

Avoid any misunderstanding by making your payment policy clear at the outset. For example, if the caller is renting the home, clarify whether or not you expect to be paid at the time service is rendered.

Find out the type of system, who installed it, how old it is and what previous service has been performed. Also, find out if the caller has a manual, a schematic, and a parts list for the system and what, if any, service contracts, warranties and insurance policies cover the system or its components.

##### **System Records**

All collectors and systems sold or manufactured in the state of Florida must be certified by the Florida Solar Energy Center (FSEC) in Cape Canaveral. As part of the certification requirements, each system must include a homeowner's manual that lists system components and describes the system design, operation and maintenance requirements. In addition to the manual, each system should have a freeze protection information label displayed at a prominent location on the system – on the storage tank, heat exchanger or controller. This label describes the system's freeze protection mechanism and any actions the homeowner must take when freezing occurs.

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Information pertaining to a specific FSEC certified system can be obtained by contacting FSEC at <http://www.fsec.ucf.edu>.

The Solar Rating and Certification Corporation (SRCC), a national solar collector and system certification agency certifies many systems sold throughout the United States. Information pertaining to a specific SRCC certified system can be obtained by contacting SRCC at <http://www.solar-rating.org/>.

### **Warranty Coverage**

Find out if the system or its components are covered by warranties. Typically, the term of the collector warranty will be from 5 to 20 years, with other components varying from 90 days to 5 years. It is also important to know whether the warranties are full or limited. This designation is required to appear on the warranty document. A full warranty is required by law to provide the following:

- A defective product will be fixed (or replaced) free, including removal and reinstallation if necessary.
- The product will be fixed within a reasonable time after the customer complains.
- The customer will not have to do anything unreasonable to get warranty service (such as shipping components back to the factory).
- The warranty is good for anyone who owns the product during the warranty period.
- If the product cannot be fixed (or has not been after a reasonable effort to do so), the customer may choose to receive a new product or a refund.

Limited warranties provide less protection than the full warranty. For example, a limited warranty may:

- Cover only parts, not labor
- Allow only a prorated refund on credit
- Require the customer to return the product to the manufacturer for service
- Cover only the original buyer
- Charge for handling the service order

Be aware, too, that some companies include a provision that unauthorized service may void their warranties. In these cases, be sure to contact the manufacturer for approval. If you provide unauthorized service, you may be held liable and be forced to take over that warranty.

Typically, a solar water heating system has a system or installation warranty separate from the individual component manufacturer warranties. Be prepared to explain this to the customer if necessary. Some service problems that arise during the warranty period may not be covered by the warranty for the item in need of repair or replacement. For example, if a component fails because of faulty installation rather than a product defect, the manufacturer of the product may not be required to repair the component. In this case,

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the contractor's system warranty, if still in force, should cover the cost to repair the problem.

Another potential gap in warranty coverage falls in the area of freeze damage. Some collector warranties will specifically exclude damage as a result of freezing. In addition, the freeze protection component will typically exclude coverage of incidental damages. If the freeze protection device fails, causing damage to the collector, this exclusion normally relieves the manufacturer of the component of liability for repair or replacement of the collector. The customer can usually seek recourse from the homeowner's policy to recover these costs.

If the customer has warranties that appear to be in force, but the company is no longer in business, all hope is not necessarily lost. If the system was financed, the finance company may be liable for all warranty claims as a "holder in due course." A review of the installment sales contract will usually specify what rights the customer may have in this regard.

Even when the warranty is no longer in force, some contractors replace components at no cost as a goodwill gesture toward the customer. But they are not obligated to absorb this expense. Ask about warranties at the outset so neither you nor the customer is surprised when you prepare the repair estimate.

### **Service History**

Many contractors offer service contracts to their customers, providing either the labor or materials for free, depending on the type of contract. So it is important to determine whether or not you are doing something you do not need to do because the customer has a service contract with another company.

Find out about past service and repairs on the system. If you know a system is five years old, you may think the controller is no longer under warranty. But if the controller was replaced just 90 days ago and is under a one-year warranty, you can take the controller back to the supplier for exchange. The customer will appreciate not having to pay for another controller and will call you back the next time service is needed.

### **Contractor Liability**

Some contractors give customers advice over the telephone about how to correct a problem. If you do this, be aware of potential liability. For example, pushing the reset button on the storage tank is a very simple procedure, and you may suggest that your customers do this themselves. It saves you time and saves them the cost of a service call. But tell them first to turn off the circuit breaker. Emphasize that they should never remove the front plate on the tank until they have turned off the power.

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You might rather not give any instructions over the telephone. Even if you only need to reset the heater you can make the visit worthwhile for the customer and for yourself by performing a routine service check while you are there.

### **Overall Checkout**

You should always check the entire system while you are on a service call because many times more than one problem exists. For example, you may replace a defective pump. Later, when this new pump also fails, you find that a defective valve was preventing water from getting to the pump, causing the pump failure. Keep in mind that a “system” requires proper performance of all the components working together.

While you check the system, consider ways you can improve its performance. For example, open-loop systems can include an air vent, a vacuum breaker, a pressure relief valve and a freeze valve. You will find many direct systems do not have all of these components, even though each one has a definite function. You can give the customer a better working system by adding these useful components.

At the same time, do not change the system for change’s sake. Some contractors do not like or do not understand controllers or PV systems. So rather than make repairs, they change the whole system. If you do not want to work on one type of system, refer the job to someone else.

When you first look at a system, prepare an estimate for the customer including the cost, the results and the benefits of the repairs. After you complete the repairs, test the system completely once again. Be sure that it is right. If you have to go back on a second or third call, you lose whatever money you made on your first call. And finally, point out your work so the customer knows what you have done.

### **Investigating Consumer Complaints – An Example**

Suppose a collector loop pipe has burst, but the customer manually drained the system to prevent freeze damage. The collectors were drained using the proper isolation and drain valves; yet the next morning water was trickling from the collector and a pipe was ruptured. Somehow water had gathered in the collector. You should check several possible causes.

First, is the homeowner sure all the water was drained from the collector? Is the system installed to prevent water being trapped when the collectors are drained? Investigation reveals the system contains a vacuum breaker at the collectors and the drain valves are installed in such a manner that one is at a higher level than the other. You determine the amount of water the homeowner says was drained represents what would have been in the collectors and piping – unless, of course, there is a small water trap in the collector or collector piping. If the collector is large and mounted in a horizontal position, are the flow tubes bending in the midsection (creating a water trap)? Investigation reveals no trap.

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There could be another culprit – the isolation valve. Although the valve was closed by the homeowner, sedimentation build-up or a malfunction could have caused the valve to leak, allowing water to slowly seep to the collectors, freeze and rupture the pipe.

### **Lifestyle Analysis**

Some people think when they acquire a solar DHW system, they have an unlimited supply of hot water. Be sure they understand the DHW system storage can provide the hottest water during the late afternoon and early evening hours. Keeping this in mind, they should use hot water during these periods to achieve the best results from the system. To minimize their back-up heating expense, they could, for example, take showers and use the dishwasher during the evening and use only small amounts of hot water in the morning. Here are some questions that you may want to ask if the complaint is “not enough hot water” or “high electric use”:

1. How many people are using the hot water?
2. Have recent guests added to the water use? How many guests?
3. Have extra washing (clothes or dishes) demands recently been put on the system?
4. When is the family’s major use of hot water?
5. Has the weather been clear, allowing the maximum solar heating? Or has it been overcast, especially around the middle of the day?
6. Are water bills higher than usual (perhaps indicating a leak in the system – perhaps a leak under the slab)?

**Note:** Remember, this is only a sample of the questions service personnel might ask.

## **II. COMMON PROBLEMS**

Some common problems are easy to identify and correct. Other problems, such as “not getting enough hot water” require investigating numerous components, the system design and location, as well as the homeowners’ lifestyle. This section first discusses problems that are easy to identify and then describes problems that demand more investigation. A detailed and concise listing of these problems, the components to check, the possible causes, and the corrective actions are listed in Section 4, Module: Troubleshooting Checklist.

The simplest way to find out if the system is working is by turning off or disconnecting the electric back-up element (or other source of back-up heat). Some installers provide a switch near the storage tank for this purpose. In most cases it is necessary to turn off the appropriate circuit breaker at the electrical load center.

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Certain symptoms are obvious, but you may find more than one problem. Therefore, once you identify the initial symptoms, continue the diagnostic procedure.

Before you begin the diagnostic procedure, ask the owners to describe any symptoms they have noticed (for example, insufficient hot water, pump running at night, noisy pump or leaking collectors). Use this information and the Troubleshooting Checklist Module to quickly identify the causes. Then follow this procedure to identify other, less obvious problems.

The most common problems are related to the following:

- Controls and sensors
- Pumps and flow rates
- Thermosiphoning and check valves
- Freeze damage
- Collector shading
- System sizing and consumer lifestyle

### **Controls and Sensors**

If the pump operates constantly or does not operate at all, the problem may be in the control system.

The controller itself, a sensor or the wiring might have been damaged by lightning strikes, line voltage surges or short circuiting from water, rust or abrasion. Each of these components should be examined. But if the pump does not operate, the problem could also be in the pump itself or the piping.

### **Pumps and Flow Rate**

If the system controls are working correctly, an inoperative pump may be due to a stuck impeller, a burned-out motor or a broken shaft. These types of problems may be expected over the lifetime of any component subjected to the temperature and cycling stresses of a solar system pump.

Even though a solar pump is operating and is being controlled correctly, there still may be problems with the actual flow rate in the collector loop. If the pump has been sized to just barely overcome the pressure head of the collector loop, an unexpected added resistance can stop all flow through the collector. For example, air in the fluid may, over a period of time, collect in a section of piping, especially if it cannot escape through a vent to the atmosphere. This "air lock" can prevent any flow if the pump does not have the capacity to compress the air completely and force it through the system.

In an indirect system, loss of collector fluid pressure can also prevent flow in the collector loop. The pump is generally not sized to overcome the static head or pressure

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due to the difference in height between the top and bottom of the collector loop. It is usually sized to maintain the desired flow against the dynamic head or pressure due to the resistance to flow in the pipes, fittings and valves. If the fluid pressure to overcome the static head is lost, then the pump may not be able to maintain flow against the combined static and dynamic head of the system.

### **Thermosiphoning and Check Valves**

As the liquid in the active system collector loop becomes cooler in the evening or in colder weather, it becomes denser and heavier, flowing down into the storage tank. In turn, it forces less dense, heated liquid up into the collector where this heated liquid cools. This action, if not stemmed with a properly operating check valve, can result in excessive loss of heat. In addition, this action often deceives the collector sensor and controller into believing the collector is hot and thereby activating the pump intermittently during the evening and colder nights.

The most common check valve utilized in active solar systems is the vertical ring check valve. Unfortunately, scale and sedimentation build up over time may prevent this valve from seating completely. Defective valves must be cleaned of all sedimentation and corrosion or replaced. A simple and relatively accurate method of determining if the check valve is defective is to check the operation of the pump at night. If the pump is turning on and off (on differential controlled systems), leaking through the check valve and thermosiphon heat loss is indicated.

### **Freeze Damage**

Burst collector tubes and piping are a result of an improperly functioning freeze protection system. In a differential controlled system, the fault may lie in the freeze sensor operation, in the sensor's location or in the controller itself. If the system has a freeze sensor but no freeze protection valve, a power failure during a freeze could result in pipe rupture. It is not uncommon to have a power failure during a freeze.

In a system using an automatic freeze prevention valve, the valve or its location may be at fault. This type of valve often fails to reseal properly after opening. Extreme temperatures during summer conditions can affect the calibration and internal components of the valve, which in time may lead to failure or leakage. A leaking valve should be removed, serviced and recalibrated per manufacturer's recommendations or replaced to ensure proper operation during the winter season.

Freeze damage can also occur when the collector is "drained." (Some systems have "traps" in the piping that prevent complete drainage.)

### **Other Potential Problems**

The common problems discussed above are fairly easy to diagnose. The following problems require more investigation because they cannot readily be seen.

### **Shading the Collector**

Collector shading may not be a problem in the summer months, but during winter months, the sun is at a lower position in the sky and shading from adjacent trees or man-made structures may occur. Relocation of the collector or trimming vegetation causing the shade are the only solutions. In both cases, use the *Crome-Dome Collector Siting Aid* provided in the Appendix or an appropriate site selection device to make sure that shading of the collector does not occur.

### **Pipe Insulation Degradation**

Ultraviolet (UV) rays and extreme system temperatures accelerate degradation of many materials, especially exterior pipe insulation. Although many manufacturers claim their pipe insulation contains ultraviolet inhibitors and does not require a protective coating, sustained exposure appears to degrade almost every unprotected material.

Therefore, all insulation should be inspected for degradation and be replaced as necessary. Exterior insulation should be coated with UV resistant material. Several insulation manufacturers offer a coating for this purpose. Latex paint that matches the roof color and has pigments that inhibit UV degradation is also available.

Insulation that has degraded due to high temperatures must be replaced with a brand that can withstand such temperatures. This is critical for insulation that is used on the collector return line directly adjacent to the collector. When replacing exterior insulation on the roof area valves, take care not to restrict the operational parts of these valves.

### **Equipment Sizing**

If solar system equipment is sized improperly, the homeowner might not have enough hot water or might have excessive utility costs. Use the *FSEC Simplified Sizing Procedure for Solar Domestic Hot Water Systems* provided in the Appendix to determine proper system sizing.

## **III. SYSTEM CHECKOUT**

Use the following procedures to diagnose system problems and can also be used to verify that new systems are installed correctly and working properly.

The simplest way to find out if the system is working is by turning off or disconnecting the electric back-up element (or other source of back-up heat). Some installers provide a switch near the storage tank for this purpose. In most cases it is necessary to turn off the appropriate circuit breaker at the electrical load center.

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With the electric back-up element off, the system – if it has been properly sized to the owner's demand – should provide ample hot water on bright, sunny days and even on days with a modest amount of cloud cover. If the system fails to provide enough hot water, or if the water is not hot enough (lower than 115°F), something may be wrong with the system operation. Use the following procedure to identify the problem and its cause.

Certain symptoms are obvious, but you may find more than one problem. Therefore, once you identify the initial symptoms, continue the diagnostic procedure.

Before you begin the diagnostic procedure, ask the owners to describe any symptoms they have noticed (for example, insufficient hot water, pump running at night, noisy pump, or leaking collectors). Use this information and the *Troubleshooting Checklist Module*, to quickly identify the causes. Then follow this procedure to identify other, less obvious problems.

- 1. Collectors.** Standing on the ground outside and looking at the collectors, verify these details:
  - a. They receive very little shading, if any, from three hours before solar noon to three hours after, for all seasons of the year. (*Appendix: Crome-Dome Collector Siting Aid* gives a method for estimating the sun's location in relation to the collector for all seasons of the year.)
  - b. They face approximately south (within 45° east or west of south). If they are oriented outside of this range, collector surface area should be increased above normal sizing requirements.
  - c. They have a reasonable tilt. To maximize solar system performance in the winter, proper tilt is latitude plus 10°-15° from horizontal. For example, in Orlando, Florida, optimum tilt is 43° ( $28^\circ + 15^\circ = 43^\circ$ ).
  - d. They are not leaking. Water running off the roof or collector fluid stains from the collector area indicates an obvious leak.
  - e. For systems utilizing PV modules as the control method, the PV module is not shaded or covered with dirt.

Any of these problems reduces the performance of the system. However, avoid climbing on the roof at this stage unless you have determined the exact problem and need to perform repairs or service.

- 2. Back-up heating element.** At the storage tank, check to see if the electric back-up element is on or off. Solar tanks usually have only one element, located in the upper area of the tank. The element may be wired to a separate switch, but by code, it must also be controlled by a 230 VAC breaker at the house load center.

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If it has been off for some time and the area has just experienced a period of cloudy weather, the storage tank won't contain much hot water. If it is on and it is also a bright sunny day, turn the element off so only the solar system operates for the rest of the procedure. For your own *safety*, make sure that it stays off for the remainder of the procedure.

If the symptoms warrant it, remove the element cover plate and check the setting on the tank thermostat. Set it to the lowest necessary temperature (usually about 120-125°F). Finally, make sure the bottom element, if any, is properly disabled or if a conventional tank is used, set to a low temperature. Sometimes, the over-temperature breaker above the thermostat has deactivated the element. To reset this breaker, simply press the reset button. (See *Appendix: Electric Water Heater Circuitry* for a description of the operation of an electric water heater.)

**3. Plumbing attached to the tank.** Inspect the plumbing attached to the tank(s). Identify and verify the proper connection of each of the following elements according to the system manual or the plumbing schematics in this publication. (In some cases, the tank may be different from the one diagrammed in the manual and have different plumbing connections. Note these variations.)

a. *Hot and cold water service connections.* If there is a tempering valve, is it connected properly? Generally, the hot, cold and mixed ports of the valve are marked, as are the connections to the tank.

The mixing valve should also be located below the top of the tank so it is not continuously exposed to the hottest water of the system. Check the temperature setting of the valve. (Keep in mind that some anti-scald valves can be installed above the top of the tank.)

b. *Collector supply and return connections.* Does the supply line run from the bottom of the tank and the return line from the collector deliver water below the thermostat of the back-up heating element? Systems that utilize a timer as the pump control method can have collector supply and return lines located at the bottom of the storage tank.

Finally, note where the pipes penetrate the ceiling/roof so the lines may be traced for proper connection at the collectors).

c. *Control valves and their settings.* A serious problem can sometimes be traced to a valve being incorrectly open or closed or having been installed in the wrong location.

d. *Pump and check valve.* Generally an arrow or some other symbol on the pump and the check valve indicates the direction of water flow. Be sure these devices have

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been installed so flow is in the right direction. (The check valve may be covered by insulation. You can usually find it by feeling the pipes through the insulation.)

- e. *Piping insulation.* Check the insulation around the tank. Ensure there are no uninsulated pipes or valves. At least two feet of the “cold-in” and “hot-out” lines should be insulated. If convenient, check for pipe insulation in the attic. Note deficiencies for later service.

### **Pressurized Indirect Systems Only:**

- f. *Expansion tank.* Check the expansion tank location. The commonly used diaphragm type tank may be installed anywhere in the collector loop and in any position. However, for the most efficient pump operation, it should be located on the suction side of the pump with the distance between the pump and expansion tank as short as possible.

An expansion tank may also be used in the water side of an indirect solar system if a back-flow preventer is installed on the cold-water supply line. The tank must be sized to accommodate any expansion in the total storage capacity of the hot water system.

- g. *Pressure gauge.* The system fluid is generally charged to a static pressure (pump not running) of 10-30 psig. If the collectors are located more than one story above the pump, system pressure will be increased. On the discharge side of the pump, the pressure gauge normally registers additional pressure (about 3-5 psig) when the pump is running. The pressure also fluctuates depending on the temperature of the collector fluid.

### **4. Control system.** Locate the control sensors, temperature sensors and the electronic controller box (if one is present). Determine which type of control system is used:

- a. *Thermosiphon and integral collector storage (ICS) systems.* Controls and sensors are not needed.
- b. *Snap-switch (absolute).* These sensors are attached to the pipes with #14 to #18 gauge wire connected to the 115 VAC supply to the pump motor. Although usually this type of control system does not have a control box, occasionally a control box houses a step-down transformer to supply low voltage to the collector snap-switch.
- c. *Timer.* The pump is connected to a simple clock timer plugged into an electrical outlet. Check the time and on/off settings and that the timer functions properly.
- d. *Differential temperature.* Sensors are attached to a controller by two small wires. The controller is plugged into a 115 VAC electrical outlet. Once you have located everything in the control system, consult the manufacturer’s information or controller labels to ensure everything is connected properly.

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e. *Photovoltaic (PV)*. The PV module is generally wired directly to a DC motor pump with from #14 to #18 gauge wire. Sometimes an electronic pump starter is connected in between the PV module and the pump to facilitate current matching. There may also be an on/off switch. Check the switch position and all connections.

**5. Pump operation.** Check the operation of the pump. Confirm that it is plugged in or wired correctly and power is available. Some controllers have an on/off automatic switch and you can manually place the switch “on.” You can usually hear a slight hum when the pump is running. You might also be able to see the motor fan moving or feel a slight vibration.

**WARNING!** Many pump motors are very hot after operating continuously for some time.

In some systems, an indicator lamp on the controller signals when power is supplied to the pump. When this indicator is on, the pump should run.

a. *Sunny day*. On a sunny day, the pump should run most of the time. If the system has a differential temperature controller or PV module, passing clouds may cause the pump to cycle on and off occasionally.

If the system has a snap-switch control, the pump tends to turn on and off more often.

b. *Cloudy day*. On a heavily overcast day or at night, the pump should not run. To see if an AC-powered pump is defective, unplug it from the controller and plug it directly into a wall outlet. If the pump does not have its own plug, direct wire the pump to power (bypassing the controller and/or switches).

**CAUTION:** Do not attempt this procedure if *you* are not familiar with safe electrical practice.

It is generally easier and safer to “fool” the controller into turning on the pump. See item 7a., *Differential controller test*.

**6. Flow in the collector loop.** If there is a flow meter or indicator in the collector loop, determine if the fluid is actually moving. If there is no flow indicator, use the following methods:

a. *Sunny day*. If it is a sunny day and the pump is running, pull back a portion of the insulation on both the collector supply and return pipes (at points a few feet from the tank). Carefully feel (or measure with a thermometer) the pipes to make sure that the return line from the collector is hotter than the supply line going to the collector. On a sunny day, such a temperature difference (usually 5-15°F) indicates fluid is flowing in the collector loop.

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If you cannot detect a temperature difference, turn the pump off by disconnecting its power supply. Leave the pump off for a few minutes; long enough for the fluid in the collector to heat up. Then restart the pump and feel the pipes again.

Within several seconds, you should feel the hotter fluid from the collector pass through the collector return line into the tank. If you do not feel this surge of hot fluid on a sunny day, there is probably some blockage in the collector, the pump, the valves or the pipes.

- b. *Cloudy day or at night.* On a very cloudy day or at night, you can still use the above procedure to check for flow in the collector loop. However, make sure the pump has been off for a long time, so that the fluid in the collector is relatively cool.

Then, when you turn on the pump again, you should feel a surge of cool fluid pass from the collector into the tank. Of course, this method works best on colder nights.

To determine the actual flow rate through the solar collectors, use a flowmeter or one of the methods discussed in *Appendix: Solar System Flow Rates*. Check the controller operation before determining the exact flow rate.

### **7. Control system operation.** Conduct the following tests to check the control system.

**WARNING:** For any procedure involving electrical equipment, always turn off or disconnect the unit from the power supply before making any adjustments or resistance measurements.

- a. *Differential controller test.* You may need to follow the manufacturer's checkout procedures to not void the warranty. If their procedure is unavailable, you can follow these steps to check most differential controllers with thermistor sensors.
- i. Disconnect and separate all sensor inputs. Identify the sensor wires for proper reconnection.
  - ii. On drain-down controls that use normally closed freeze sensors, short the freeze sensor input wires or terminals at the control.
  - iii. With the controller in its normal operation or automatic switch position, short the collector sensor input wires or terminals together. The control should turn on (indicated by lights and/or pump operation).
  - iv. Remove the short and the control should turn off. (Some older-model controllers may utilize a time delay circuit to keep the pump from cycling on and off too often.)

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v. The controller is probably in good condition if it responds correctly to these steps. Test the temperature sensors next before proceeding to a more detailed test of the controller.

For the differential controller that uses resistance/temperature devices (RTDs) – positive temperature coefficient sensors – the tank sensor input should be shorted in Steps iii and iv. Shorting the collector sensor indicates a low temperature and the pump should stay off. Shorting the tank sensor should turn the pump on. If freeze protection and the collector sensor functions are combined, shorting the collector terminals simulates a freeze condition. The pump should turn on if recirculation freeze protection is used.

b. *Sensor test.* To check the temperature sensors of a differential controller, measure their resistance. Disconnect the sensors from the controller terminals or lead wires and use a volt-ohmmeter to measure the resistance across the sensor wires.

For thermistors and metal film sensors, compare their resistance to the manufacturer's temperature versus resistance specifications. Also, see *Appendix: Volt-ohmmeter (VOM) or Multimeter Operation.*)

Generally there are two types of thermistor sensors: a 3,000 ohm sensor and a 10,000 ohm sensor. Sensor resistance should match the measured temperature as closely as possible. (See Table 1 in *Appendix: Volt-ohmmeter (VOM) or Multimeter Operation.*

For example, when the environment temperature is 77°F, the 3,000 ohm sensor should read 3,000 ohms, and the 10,000-ohm sensor should read 10,000 ohms. As the temperature increases, the resistance decreases. At 90°F, a 3,000 ohm sensor reads 2,200 ohms; a 10,000 ohm sensor reads 7,333 ohms.

The general range of solar system temperatures is 70-140°F for the tank sensor and 100-150°F for the collector sensor depending on the time and conditions of day. If an "open" or "short" condition is indicated, check the wiring between the controller and sensor.

A common cause for an "open" condition is a broken connection between the wiring and the sensor. A "short" may be caused by a piece of metal pinching the sensor wire and conducting it to ground or causing it to short across the wires.

For temperature-actuated switches (freeze sensors, upper limit sensors, and snap-switch controls), you can also check the switch position with a volt-ohmmeter. The switch is either normally open or normally closed, and changes position at a particular temperature. You can check the freeze sensor by placing it in ice water and measuring with the VOM to see that the switch changes position.

c. *Detailed controller test.* A complete method of checking the controller involves the use of a differential controller test set. Containing fixed and/or variable resistances, the test set is generally calibrated for a specific manufacturer's line of controllers, though it

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can be adapted to test other brands of controllers. Instructions for its use are usually supplied with the tester.

The test set enables you to determine the exact “turn-on” and “turn-off” temperatures of the controller. Compare these differential temperatures to the manufacturer’s specifications. If the measured temperatures do not match the specifications, and if the setting is adjustable, you can change the setting to match the manufacturer’s recommendations.

- d. *Photovoltaic (PV) module controller test.* Use the following procedure to check the voltage and current output of the photovoltaic module on a sunny day:
- i. Disconnect the pump from the wires coming from the PV module or pump starter box.
  - ii. With a volt-ohm-meter, check the voltage between the positive and negative terminals of the PV module. This open-circuit voltage should be between 14 and 22 volts, in almost any amount of sunlight.

You should also check the PV module's short-circuit current with a volt-ohm-meter (with milliamp measurement capability). Under sunny conditions, the short-circuit current should be between 200 and 1000 milliamps, depending on the voltage rating of the PV module. If there is no amperage at good sun conditions, the PV module or the connecting wiring may be defective. (Do not exceed the amperage measurement capacity of your meter.)

If there is no amperage at the pump, check the amperage of the module at its roof location to determine if there is a break in the connecting wiring.

- iii. To check the DC-powered pump, use two 6-volt lantern batteries connected in series (12V). Disconnect the PV panel from the pump and connect the pump to the proper terminals of the batteries. If the pump does not operate off the batteries, the pump is defective. If the pump does run off the batteries, the PV module or connective wiring is defective.

- 8. Heat-transfer fluids and the collector loop.** For indirect systems, inspect the heat transfer fluids; for direct systems, inspect the collector loop.

Perform item 8a for pressurized indirect systems only:

- a. *Evaluate heat-transfer fluids.* All heat-transfer fluids must be inspected and evaluated periodically. Most fluid manufacturers and system vendors recommend periodic inspections. To check the fluid, remove a few ounces from a fill or drain point. (Be careful not to spill any fluid and do not allow air to enter the system.)

To determine the average condition of the fluid, take the sample from a point above the bottom of the collector loop, during a period when the system is operating.

## **Problem Assessment and System Checkout**

Examine the sample for rust, scale, water deposits, sludge and gummy materials. Rust or scale accumulation is probably the result of degradation of iron in the system. If you find water in the sample, look for system or heat exchanger leaks.

Sludge in the sample indicates heat transfer fluid degradation, which in time can lead to clogs in the collector and heat exchanger loop. Fluids can deteriorate some plastic seals and gaskets. Gummy materials in the sample usually indicate this deterioration is occurring.

Test the various fluids using the specific manufacturer's recommended procedures. Be sure to obtain the fluid manufacturer's recommendations for filling, flushing and refilling of various heat-transfer fluids. Some fluids must be completely drained and the system recharged with new fluid. Other fluids may not need to be drained, only more fluid added. In addition, systems using one type of fluid can be flushed with water while other systems must be flushed with specified fluids.

Perform items 8b-f for direct systems only:

- b. *Drain the collector loop.* Disconnect the pump and controller from the power supply.

**CAUTION:** The PV module can be disconnected from the pump only for short periods of time (4-5 hours).

Isolate and drain the collector loop, if drains are available.

**CAUTION:** If you drain the collector loop on a sunny day, direct the hot water to a safe point of discharge.

A loop that drains easily indicates properly pitched (or tilted) pipes and a path for air to enter the system. A vacuum breaker valve or a system air vent at the top of the collector loop may supply this path. Sometimes air enters during draining only through a second drain valve at the bottom of the loop.

- c. *Flush the collector loop.* Isolate and flush the collector loop, preferably in the reverse direction of normal flow. If the check valve is located on the collector supply, use the cold-water service pressure to back flush the collector return. If the check valve is located below the collector return hose bib drain, use a garden hose with a double female adaptor connected to both an outside faucet and the collector return drain.

In both cases, force water out the collector supply drain and through an attached hose leading to a point of safe hot-water discharge. Check this water for dirt, scale and other signs of blockage. Stop when the discharge no longer contains any debris.

### ***Problem Assessment and System Checkout***

If sedimentation build-up in the tank is a problem, isolate the tank and drain several gallons of water to remove any sedimentation. Advise the owner this draining should be performed at least once per year and preferably every six months.

- d. *Test the check valve.* Use the hose bib drains and service water pressure to check these two valves: a horizontal swing check valve or a vertical in-line ring check valve.

Send water against the normal flow direction. Water flowing past the valve indicates a faulty seat or stuck hinge that will not seal under the low backflow of unwanted thermosiphoning.

Check a solenoid-actuated or motorized ball valve by using the manual lever (if it is present) to open and close the valve while checking for flow. Some motorized valves are not designed to close off against normal city water pressure. Verify the normal operation of these valves by listening to and watching the valve open and close as the pump is turned on and off. Since check valves are very prone to problems from sedimentation build-up, they should be inspected periodically.

If the check valve cannot be tested by the above backflow procedure and it is suspected of being the cause of nighttime thermosiphoning, you need to examine the system at night. When the fluid in the collector has cooled to a temperature sufficiently below the fluid in the tank, feel the collector supply and return pipes a few feet from the heat of the tank. If one pipe is warm, the check valve might not be sealing.

Sometimes a leaking check valve can cause a differential control to cycle the pump at night. To confirm this speculation, unplug the pump from the differential controller and plug a clock into the controller instead. Note the clock's time. Note the time again the next morning before the solar system would normally start. If the clock has advanced because the controller supplied power to it, the check valve is not sealing and needs to be replaced.

To check a mixing valve, feel or measure the temperature of the service hot water at the closest house hot water faucet. As you measure, adjust the mixing valve over its range of motion, leaving it at the desired temperature setting. Sometimes these valves stick open or closed after prolonged use and must be repaired, replaced or eliminated.

- e. *Purge air from the system.* With the collector supply isolation valve open, close the collector return isolation valve. Force water out of the collector return line drain (and hose). Close the return line drain when air no longer bubbles out the drain hose. Open the collector return isolation valve.
- f. *Plug the pump and controller back in.* Check for proper operation and return the electric heating element switch (if provided) to its original on/off position.

## ***Problem Assessment and System Checkout***

### **9. Inspect the collectors up close.**

**Caution:** Some roofs can be damaged by a person's weight.

Walk slowly and make sure the roof can support you wherever you move. Be careful that you do not break concrete tiles or brittle asphalt shingles.

Look for the following items:

a. *Dirty glazing.* Rain generally does a good job of keeping collectors clean, but occasionally in very dry and dusty weather they will gather a visible layer of dirt and dust. If so, they should be cleaned with mild soap and water. Clean the collectors only when they are not hot to the touch, in the early morning or late evening. Spraying the collectors with a garden hose during early morning or late evening hours is also effective.

b. *Condensation or outgassing on the inside of the glazing.* A major part of the solar energy striking the collector may be blocked by moisture or chemical deposits from outgassing of the collector insulation on the inside of the collector box.

To remove extreme and lasting condensation, take off the glazing, wipe it dry and dry the box. To minimize future water collection, drill small holes (weep holes) in the frame – a few in the bottom of the frame for drainage and two at the top corners to allow warm moist air to escape. Screen the holes to keep out insects.

To clean off inner outgassing deposits, the glazing will have to be removed and the glazing cleaned with a detergent or a solvent such as alcohol. (Depending on the amount of time they have been on the glazing, these deposits may be difficult to remove.)

c. *Leaking connections.* Repair small leaks around fittings and pipes to minimize heat loss from the system. Freeze damage causes many leaks. Generally, leaks appear in the collector flow tubes.

d. *Temperature-pressure relief valve.* Look for stains on the roof around this valve, indicating repeated discharge of collector fluid from over-temperature conditions. This symptom generally indicates a lack of flow in the collector loop even though solar heat is available. (Note that most installations now use pressure relief valves in the collector loop.)

Overtemperature of the collector may be due to a low use of hot water, a faulty upper limit sensor, or air in the collector loop that prevents the pump from maintaining flow. An air vent at the highest point should discharge this air from the system.

## ***Problem Assessment and System Checkout***

**WARNING:** Lifting the test lever of the temperature pressure relief valve may cause the valve to fail. Be prepared to replace the valve before manipulating the test lever.

- e. *Air vent.* When you fill the system, you might hear and even feel a stream of air leaving a properly operating air vent. Most air vent caps must be loose (to permit the air to escape).

**NOTE:** The cap should be in place to prevent dirt from entering the valve or insects from plugging it, but it should not be completely tightened.

When water reaches the air vent, the vent should close fast, without leaking. Many valves have a stem that can be depressed to allow fluid to escape, flushing the valve seat clean.

**CAUTION:** When filling a system that has been solar heated, the escaping air may be extremely hot and contain steam until the system reaches normal operation.

- f. *Vacuum breaker.* When draining the collector loop, you should be able to hear air entering the valve, permitting water drain-down.

**NOTE:** In reference to air vents and vacuum breakers, the interior valve seats and float pivots may collect deposits and become inoperative. Disassemble the valve, if possible, and clean it thoroughly to ensure proper operation and to eliminate air pockets and drainage problems.

- g. *Pipe insulation.* Look for cracks or splits, opened joints or deteriorating insulation. Most closed cell foam insulation should be wrapped or covered with a protective paint to shield it from ultraviolet radiation. Plasticized vinyl lacquer and exterior latex with a white pigment both protect well and may be found at air conditioning supply stores.

- h. *Sensor location.* Sensors placed on the collector outlet need to be in good thermal contact with the pipe and insulated from the surrounding air. Sensors placed inside the collector box generally do not require the same intimate contact and may even have to be separated from the absorber plate. Refer to the manufacturer's recommendations.

Check the wire leads to these interior sensors to ensure they are not crimped or exposed to the metal of the box. Sensor wires that cross over the metal edges of the box will wear through and short due to weather induced movement of the box and wires.

Also, if a freeze sensor is used, check that it is indeed a freeze-actuated switch, different from the actual collector sensor, and is either wired separately or according to the controller manufacturer's recommendations. The freeze sensor also needs to be in

### ***Problem Assessment and System Checkout***

good thermal contact with the pipe or collector plate and to be insulated from the surrounding air.

- i. *Collector anchoring.* While not directly affecting the efficient operation of the solar system, improper mounting of the collectors can cause serious problems, such as roof leaks or building damage from high winds.

Supports should be durable, materials tightly fastened, and mountings strong enough to resist the near-hurricane force winds to be expected in Florida. Roof penetrations should be well sealed with a durable roofing sealant to prevent leaks and interior water damage.

- j. *Collector piping.* When the system has two or more collectors, they should be plumbed in a parallel configuration, unless the manufacturer suggests otherwise. The pipes and interior collector tubes should all have a continuous slope (1/4 inch per foot).

They should not contain any low pockets that do not drain or high pockets that capture air. Use a builder's level to correctly determine proper pipe slope, as the roof or shingle line may not be level.

- k. *Photovoltaic (PV) module.* Ensure the PV module is securely mounted and properly oriented for the geographical area and collector mounting. Check that all electrical connections are secure and wiring is protected from environmental degradation.

**Troubleshooting Checklist**

**Section 4**  
**Module: Troubleshooting Checklist**

**Introduction**

When the symptoms for problems have been identified, the following checklist can be used to determine the probable causes and the appropriate corrective actions. During system evaluation, the complete system should be checked to identify any other situations that might lead to more problems. A well-maintained system is the best insurance against future problems.

Solar system problems are difficult to organize because no problem is more important than another – to the solar system owner, any problem is important.

The checklist begins with problems relating to water temperature. It continues with general system problems and problems relating specifically to the controller, and then system leaks and drainage.

PROBLEM	CHECK THIS	POSSIBLE CAUSE	CORRECTIVE ACTION
No hot water	Auxiliary Heater (electric)	No power to auxiliary back-up heating element	Check high temperature protection and push reset button above thermostat. (Use caution when dealing with electricity.)
	Auxiliary heater (gas)	Failure to ignite	Check pilot light mechanism
		Safety switch malfunctioning	Check and replace
		Defective automatic pilot valve	Check and replace
		Pilot wont stay lit:	
		Too much primary air	Adjust pilot shutter
		Dirt in pilot orifice	Clean and open orifice
		Pilot valve defective	Replace
		Loose thermocouple connection	Tighten
		Defective thermocouple	Replace
	Improper pilot gas adjustment	Adjust	
	Auxiliary heater thermostat	Thermostat defective	Replace
	Mixing and/or anti-scald valve	Improper adjustment	Check water temperature at house faucet and adjust valve setting
Valve defective		Replace or remove from system plumbing	
Distribution piping	Leak (under slab or in walls)	Locate leak and correct	
Not enough hot water	Auxiliary heater	Undersized for hot water demand load	Replace
		Storage tank losses	Insulate tank
		Thermostat set too low	Increase set point temperature

### Troubleshooting Checklist

Not enough hot water (Cont.)		Element failure	Replace element
		Thermostat failure	Replace thermostat
		Lower element disconnected in conventional rank system	Reconnect element and set thermostat to low temperature
	Check valve	Heat loss due to defective or improperly installed check valve	Inspect valve and repair or replace
	Solar return dip tube	Missing, wrong location, defective	Replace dip tube
	Cold water supply dip tube	Missing or wrong location	Install in proper location
	Collector(s)	Absorber coating degradation	Recoat or replace absorber (Contact manufacturer)
		Area undersized	Increase collector area (See FSEC Sizing Guide)
		Excessive condensation	Inspect and repair glazing seal, pipe gaskets and weep holes and vents at bottom
		Glazing dirty	Clean as required
		Leaks	Repair
		Orientation	Check orientation. Face collector " 45° east or west of south
		Outgassing inside collector glazing	Clean surface and contact manufacturer
		Plastic glazing deteriorating	Replace
		Reduction of glazing transmission	Replace glazing
		Shaded by tree(s) or building(s)	Remove obstacle and shading or relocate collectors(s)
		Improper tilt	Check tilt for geographic area. Set " 15° of latitude
	Improperly plumbed	Compare with system schematic in installation manual	
	Differential controller	Improper operation (cycling, late turn on)	Check sensor placement and insulation from ambient conditions
		Faulty sensors or controller	Conduct resistance measurement or check by placing sensors against hot and cold-water glasses and watching pump function. Replace defective units.
Improper wiring or loose connections		Compare with system schematic. Check for proper connections. Seal all splices against moisture.	
Shorted sensor wiring		Check wiring for breaks, metal contact, water exposure and corrosion.	

### Troubleshooting Checklist

Not enough hot water (Cont.)	Heat exchanger	Sized too small	Replace with properly sized heat exchanger. Insulate.
		Scaling, clogging	Back flush, clean
	Isolation valves	Closed	Open
	Mixing/Anti-scald valve	Improperly adjusted	Reset temperature indicator
	Owner	High water usage	Check system size and discuss solar system and owner's lifestyle
	Piping	Clogged with corrosion or sediment	Replace excessively corroded components
		Insufficient insulation	Add insulation where required
		High heat losses	Check insulation for splits, deterioration, absence
		Nighttime thermosiphoning	Check for pump operation at night.
		Improperly plumed	Compare with system schematic. Check flow direction.
		Isolation valves closed	Open valves
		Isolation valve failure after closing	Replace valve
		Flow blockage	Flush system. Check effluent for dirt/scaling.
		Low system pressure	Check pressure gauge. Refer to owner's manual for correct pressure.
	Pump	No power	Check breaker, pump, and controller. Repair or replace.
		Flow rate too high or too low	Adjust flow rate
		Defective	Check and replace
		Activation switch off	Check for switch on PV to pump wiring
		No power	Check breaker, pump cord, controller fuse, if any. Replace if necessary.
		Faulty pump	Listen for irregular noises in pump operation. Feel collector feed and return pipes for temperature difference.
		Runs continuously	Check control system for breaks and shorts
	Improperly installed	Compare with system schematic	
	Sensors	Improper wiring, cuts, or loose connections	Check and correct
	Sensor wiring	Shorted wiring	Check and repair
	Storage tank	Too small	Install larger tank
		Storage losses	Insulate tank with insulation blanket

### Troubleshooting Checklist

PROBLEM	CHECK THIS	POSSIBLE CAUSE	CORRECTIVE ACTION
No hot water in morning	Check valve	Stuck open or does not seat	Replace check valve
	Controller	Sensor wires reversed	Check wiring and reconnect
	Water heater circuit breaker	Water heater circuit breaker shutoff	Turn breaker back on
	Freezing conditions at night	Recirculation freeze protection (with back-up power off)	Turn back-up power back on (circuit breaker)
	Occupants	Excessive consumption	Discuss hot water usage. Check system size and auxiliary heater status.
Water too hot	Auxiliary heater	Thermostat set point too high	Reduce set point temperature
	High limit sensor	Improper calibration	Check, recalibrate and replace
	Occupants	No hot water use (vacation, etc.)	Run hot water to reduce tank temperature
	Mixing or anti-scald valve	Temperature set too high	Adjust
	Mixing/anti-scald valve	Valve failure	Replace valve
No water	Cold-water supply valve	Valve closed	Open valve
High electric use	Piping, hot water distribution	Leak	Repair leak
	Tank	In dual element tank, lower heating element	Turn to low setting or disconnect
	Tank thermostat	Thermostat set too high	Check setting and adjust to desired temperature
		Inaccurate temperature dial	Recalibrate or replace
	Tank dip tubes	Collector return above tank thermostat	Increase length of dip tube
Piping	Collector return above tank	Check tank plumbing. Contact installer, if necessary.	
Pump does not start	Differential controller	Controller switch in "off" position	Turn to "automatic" or normal operating position.
		Unplugged	Return power to controller
		On and/or off temperature differential set points too high	Reset according to specifications
		Loose contacts	Clean contacts and tighten connections or replace
		Defective components	Replace components or controller
	Controller circuitry	Sensors connected to wrong terminal	Correct per manufacturer's recommendations
	DC pump	Loss of circuit continuity	Check and repair or replace
	Electrical power supply	On/off switch is "off"	Turn to "on"
		Blown fuse or breaker tripped on overload	Determine cause and replace fuse or reset breaker
		Brownout	Await resumption of utility power
Photovoltaic module	Shaded	Relocate or eliminate shade	

### Troubleshooting Checklist

Pump does not start (Cont.)		Defective	Check and replace, if required	
	Photovoltaic wiring	Improper wiring, cuts or loose connection	Check and repair	
	Pump	Motor failure		Check brush holders and other mechanical components that may be loose, worn, dirty or corroded. Replace as appropriate and reasonable. Check for thermal overload.
		Pump motor runs when started by hand. Capacitor failure.		Replace capacitor
		No power		Check breaker, cord and controller
		Stuck shaft, impeller, or coupling		Replace
		Frozen bearings		Replace
	Sensors	Defective sensor(s)		Replace
		Improper installation		Clean and reinstall properly
		Sensors out of calibration		Recalibrate or replace
	Sensor wiring	Defective sensor wiring		Repair or replace
		Open collector sensor wiring		Check wiring continuity. Repair or replace.
		Shorted tank sensor wiring		Check wiring for continuity. Repair or replace.
	Timer	Defective		Replace
		Wrong on and/or off time		Reset, check battery.
	Pump starts, but cycles continuously	Differential controller	On and off temperature differential set points are too close together	Reset according to specifications
			Freeze protection setting too high	Reset according to specifications
Faulty controller			Use controller test set to perform operation check. Repair or replace.	
Piping		Reversed connections to collector	Reconnect properly	
Sensors		Improper location		Relocate sensors as per system design or manufacturer's requirements
		Not properly secured		Secure properly and insulate from air
	Faulty		Test sensors. Replace if necessary.	
Pump cycles after dark	Sensor wiring	Interference from radio or garage door opener, etc.	Use shielded sensor wire	
		Radio frequency interference from close proximity to antenna.	Use shielded sensor wire	
	Check valve	Does not seat	Replace	

### Troubleshooting Checklist

PROBLEM	CHECK THIS	POSSIBLE CAUSE	CORRECTIVE ACTION
Pump runs continuously	Controller	Off temperature differential set point too low	Reset according to specifications
		Lightning damage	Replace controller
		Controller in "on" position	Turn to "automatic" or normal run position
	Sensor(s)	Sensor(s) out of calibration	Recalibrate
		Defective sensor	Replace
		Improper installation	Reinstall
	Sensor wiring	Interference from radio/garage door opener, etc.	Shielded cable may be necessary
		Shorted collector sensor wiring	Check wiring for continuity. Check wiring connections for weather tightness. Repair or replace.
		Open tank sensor wiring	Check wiring for continuity. Check wiring connections for weather tightness. Repair or replace.
Pump operates but no fluid flows from collector	Air vent	System air-locked. Air vents closed.	Disassemble and clean seat and seal. Replace if necessary.
		Improper location	Install at the highest point. Install at all high points if possible air trap locations exist. Install in true vertical position.
		Air vent cap tight	Loosen ¼ turn
	Check valve	Installed improperly	Check flow arrow on valve to ensure direction is per system design
	Collector	Flow tubes clogged	Flush collector tubing
	Drain-down valve	Drain-down valve stuck in drain position	Clean cause of sticking. Check power to valve.
	Fluid	No fluid in direct system	Open cold-water supply valve
		Loss of fluid in indirect system	Locate leak and refill
		Loss of fluid in drain-back system	Cool system, locate leak, refill properly
	Isolation valves	Valves in closed position	Open valves
	Piping	Clogged or damaged piping	Unblock piping or repair damaged piping
	Pump	Broken impeller shaft	Replace shaft
		Impeller broken or separated from shaft	Replace impeller and/or shaft or replace pump
		Improperly installed	Install to ensure correct flow
		Not vented properly	Install in correct orientation
Undersized		Check pump specifications. Change pump if required.	
Valves	Valves closed	Open valves	

### Troubleshooting Checklist

PROBLEM	CHECK THIS	POSSIBLE CAUSE	CORRECTIVE ACTION
Pump cycles on and off after dark	Check valve	Corroded or defective check valve	Repair or replace
Pump runs after dark, but eventually shuts off	Sensors	Defective	Change sensor
		Improper location	Relocate
		Sensor not insulated	Insulate
No power to pump with switch on	Sensor (freeze)	Open circuits	Check sensor and wiring. Repair or replace.
	Controller output relay	Weak or failed relay	Replace relay or controller
Noisy pump	Air vents	Air trapped in system	Open automatic air vent
	Pump bearings	Dry or excessive wear	Lubricate or replace
	Pump impeller	Loose impeller	Tighten or replace impeller
	Pump location	Pump enclosed in small room (closet)	None
		Pump attached to wall – wall acts as amplifier	Relocate pump if noise is unacceptable
	Pump volute	Corrosion or particles in volute	Clean volute and impeller. Replace if required.
	Vent port on pump (if applicable)	Air trapped in pump	Open vent port and/or vent valve and bleed air
Noisy system	Pump	Bearings need lubrication (if applicable)	Oil per manufacturer's recommendation
		Air locked	Bleed air
	Piping	Entrapped air (direct systems only)	Purge system by running water up supply pipe and out drain on return line (isolation valves closed)
		Pipe vibration	Isolate piping from walls
Controller does not turn on or off in the "automatic" mode but operates in the "manual" mode	Controller	Defective	Conduct function check and repair or replace
	Sensors	Defective sensors; resistance problem; sensors off scale	Check with multimeter (ohm). Correct or replace sensors.
		Improper contact or insulation	Ensure proper contact is made. Insulate sensors.
		Improper location	Relocate
Wiring	Short or open	Replace or splice wire	
System shuts off at wrong high limit or continues to run	Controller	Defective	Repair or replace
	Sensors	Defective sensor	Check with multimeter (ohm) and replace
		Improper location	Relocate
System leaks  System leaks (Cont.)	Collector(s)	Pipe burst due to freeze or defective joint	Repair or replace. Check freeze-protection mechanisms.
	Freeze-protection valve	Did not reseal after opening	Recalibrate, if required, or replace.
		Valve out of calibration	Recalibrate per manufacturer's instructions or replace

### Troubleshooting Checklist

		Normal operation (most open at 42°F)	No action
	Hose connection	Clamps not tightly secured	Tighten clamps. Replace clamp or hose.
	Pipe joints	Thermal expansion and contraction.	Replace and provide for flexibility
		Joint improperly made	Reassemble
		Improper seal in system using glycol solution	Make a good seal. Use recommended sealer. Note: glycol will leak through joints where water would not.
	Pressure-temperature relief valve	Did not reseal after opening	Replace
		Defective	Replace
		Improper pressure or temperature setting	Reset, if possible, or replace
	Valves	Valve gland nuts loose	Tighten nuts. Replace seal or packing if necessary.
		Seats deteriorating	Replace seat washers. Redress seat. Replace valve if necessary.
Water comes off the roof	Pressure-temperature relief valve	Defective seal	Replace
		Activates due to no circulation through collector(s)	Check flow in collector loop. (See “Pump does not start” and “Pump operational but no flow to collector.”)
	Freeze-prevention valve	Out of calibration	Calibrate, if possible, or replace.
		Defective seal	Repair or replace
		Normal operation (most open at 42°F)	No action
	Collector piping	Ruptured piping due to freeze	Repair or replace
		Defective piping	Repair or replace
Low-pressure valve installed on collector supply line	Power loss. Pressure loss from well.	No action required.	
System does not drain	Collector (parallel)	Fins and tubes are horizontal and are sagging, preventing drainage from occurring	Straighten fins and tubes. Realign collector so it will drain completely
	Collector (serpentine)	Serpentine design prevents drainage	Blow water out of tubes with air compressor
	Piping	Insufficient slope for drainage	Check and ensure piping slopes ¼" per foot of piping
	Vacuum breaker	Does not open. Defective due to internal mechanism or corrosion.	Clean or replace