INTERNATIONAL CODE COUNCIL®

SOLAR RATING & CERTIFICATION CORPORATION™

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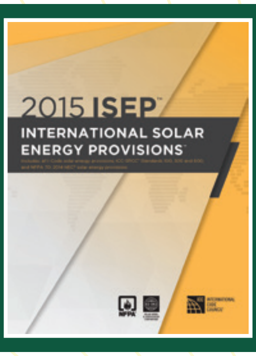
CodeNotes™

Solar Water Heating Systems

Based on the 2015 International Solar Energy Provisions™



Introduction

Solar water heating systems are an efficient way to meet some or all domestic hot water loads in most climates. Unlike photovoltaic energy systems that generate electricity, these systems pipe a fluid directly to a solar collector where it is heated through the "greenhouse effect." Solar energy has been used to heat water for centuries, but the modern solar water heater first appeared in the late 1800's and has been refined considerably since then. System designs range from the simple "tank in a box" to complex arrangements with multiple collectors and tanks. The application encountered most often by code officials is for residential domestic use. Residential domestic systems typically contain between one and four solar collectors mounted on the roof, one or two storage tanks (50 to 120 gallons), an electronically controlled pump, and insulated piping. Depending on the local climate, it may also include a heat exchanger that may be mounted either inside or outside of a tank. The collectors used in solar thermal systems are commonly 4'x8' or 4'x10', and unlike photovoltaic systems, usually only cover a portion of the roof. While this is the most common configuration, there are many different variations.

This edition of *CodeNotes* provides a description of the most common solar water heating systems used in residential and small commercial applications, and suggestions for inspecting them in accordance with the requirements found in 2015 International Codes®. It will cover:

1. System design types
2. Solar collector array installation
3. Storage tank and heat exchanger issues
4. Fluid transport system inspection

Code provisions for solar water heating systems are centered in Chapter 23 of the 2015 IRC® for residential systems and Chapter 14 of the 2015 IMC® for commercial systems. These chapters then reference other provisions elsewhere in the IRC and the IPC®, IBC®, IFC® and IECC®. The IRC also references and requires compliance with Standard 100 Solar Thermal Collectors and Standard 300 Solar Thermal Systems, from the Solar Rating & Certification Corporation (ICC-SRCC™) that provide other significant details.

For ease of access to these widespread provisions, the 2015 *International Solar Energy Provisions*™ (ISEP™) was created. The ISEP contains a complete listing of all provisions for solar thermal and photovoltaic system within the full family of 2015 I-Codes® along with SRCC Standards 100, 300 and 600.

Solar Water Heating System Designs

There are two basic types of solar water heating systems used for domestic water heating:

- Active: a pump circulates fluid through the collector array (Figure 1)
- Passive: natural convection (gravity and density) and city water pressure move the fluid and two typical configurations within each type (Figure 4) and two configurations (Figure 1):
- Direct: the potable water coming out of the faucet has traveled through and been heated directly in the solar collectors
- Indirect: water or antifreeze is heated in the collector and the heat is transferred to potable water through a heat exchanger

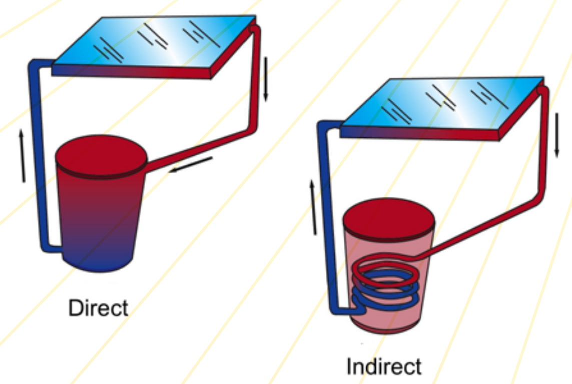


FIGURE 1. Direct vs Indirect System

The configuration chosen for each installation depends in large part on the potential for water to freeze in that climate. It is important for code officials to first determine the type of system in order to determine which code provisions are applicable and what to inspect. The single tank, active, direct system shown in Figure 2 is common in warm climates where the potential for freezing weather is minimal. A device called a freeze prevention valve prevents freezing in those occasional, short events where the temperature dips below freezing, by releasing a small amount of water to permit warmer water from the storage tank into the outdoor piping and collector. In the system shown, a backup element provides additional heat to the tank only when needed.

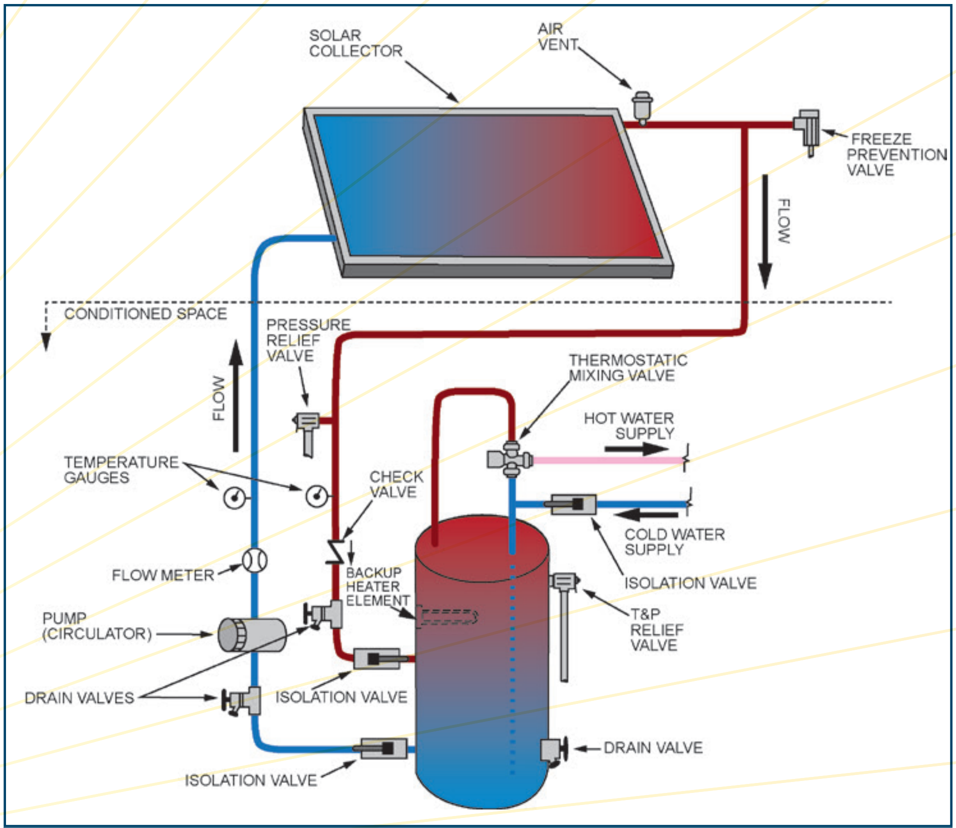


FIGURE 2. Active, Direct System

The double tank, active, indirect system shown in Figure 3 is common in most areas of North America where the air temperature falls below freezing for extended periods of time. Here, the collector is isolated from the domestic supply piping and is connected to separate piping known as the solar loop. This type uses a pump to circulate the fluid in the solar loop. The potable water is not sent the collector where it could be subject to freezing conditions. The system shown uses a solar tank with an immersed heat exchanger coil and a second backup water heater that only functions when needed. While a tank-type backup water heater is shown, a tankless water heater can also serve that function.

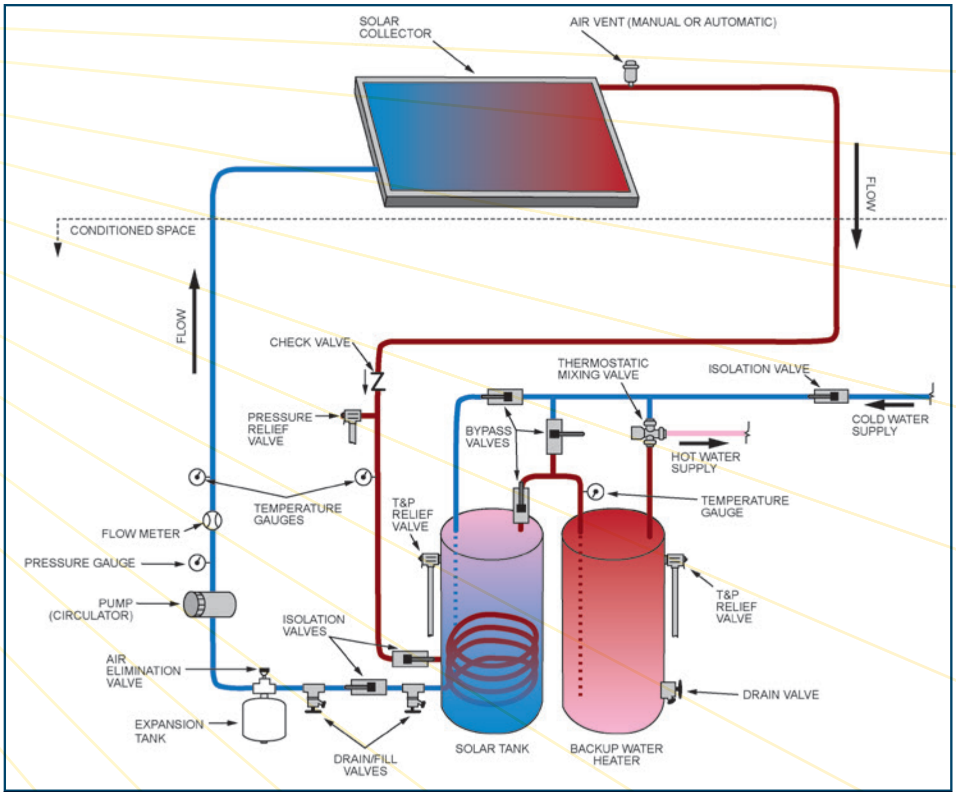


FIGURE 3. Active, Indirect System

Key Inspection Points

Solar thermal systems touch many building systems, including roofing, structural, plumbing, mechanical and electrical. They also involve unique components, elevation and outdoor exposures that make their inspection a challenge. This section lists some specific considerations when inspecting solar thermal systems. It is not exhaustive and users should consult the 2015 ISEP for all relevant I-Codes and standards.

Solar Collector Installation Location and Orientation

The solar collectors and arrays are usually mounted on the roof of the building (Figure 4), but can be mounted on a rack situated at ground level. While the code does not specify it, most systems are installed facing due south, at an angle approximately equal to the latitude of the site, to achieve the highest performance.

FIGURE 4. Roof-mounted solar collector

Listing

The collector component(s) shall be listed and labeled to relevant sections of SRCC 100 (see 6.1.2.1 of SRCC 300, IRC 902.1). Certified collectors are commonly marked as shown in Figure 5. Some collectors also seek additional certification to the U.S. EPA Energy Star program for Residential Water Heaters.

FIGURE 5. SRCC collector certification label

Shading of collector

Collector should not be shaded by external obstructions or each other more than the specified period allowed in the design. (See 6.5.13 of SRCC 300)

Structural Mounting

Collectors must be installed on a mount capable of maintaining the orientation to design conditions, and must be constructed of proper materials, approved for outdoor use. Structural mounts must be able to withstand wind, seismic and snow loads. Connection points to the roof must be flashed and sealed to prevent entry of water, rodents and insects. The roof structure must be capable of supporting all loads imposed by solar thermal systems, which may vary significantly by type.

Dissimilar metals that have galvanic action shall be isolated. (See 6.2.4 and 6.1.1.10 of SRCC 300, IFC 5703.6.5, IRC R908, 909, M2301.2.2.1, IBC 1607.12.5, 2606.12). The spanner mount (Figure 6) and lag bolt mounts (Figure 7) are frequently used to attach solar collectors to the roof, but manufacturer's mounting installations should be followed.

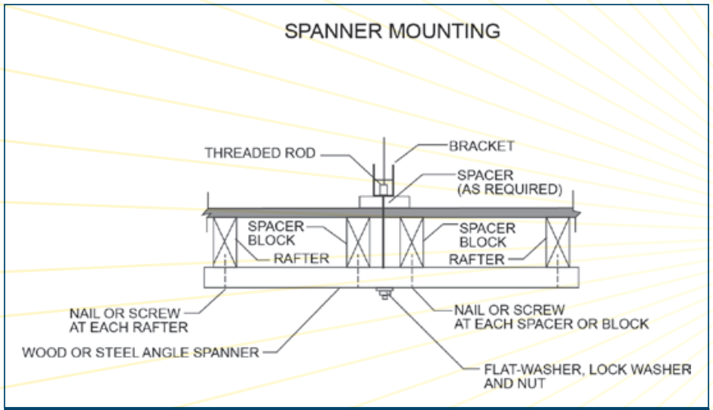


FIGURE 6. Spanner mounting technique
(Illustration Courtesy of the National Roofing Contractor Association)

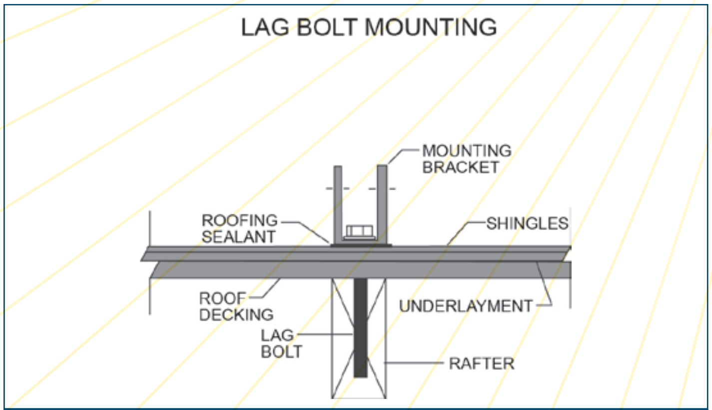


FIGURE 7. Lag bolt mounting technique
(Illustration courtesy of the National Roofing Contractor Association)

Access

The location of solar components must not impair accessibility needed to maintain the building or site. Roof access, pathways, and spacing requirements shall be provided. (See 6.5.4 of SRCC 300, IFC: 605.11.1-3, IRC R324.4-7, R902.4)

Penetrations

Penetrations of the building, through which piping or wiring is passed, shall not reduce nor impair the function of the enclosure, reduce any fire-resistance rating, nor allow intrusion by water, insects and/or vermin, in accordance with the plumbing code and mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code* and *International Mechanical Code*. (See 6.5.5, 6.5.10, 6.5.19, of SRCC 300, 703.1, 1105.4.5, 1105.6.4 IFP, IRC R909.3, G2427.7.5, M2301.2.9, 503.7.5) Figure 8 shows a typical "gooseneck" solar water heating system flashing that is commonly used for solar thermal installations to seal both piping and electrical penetrations.

Relief valves and discharge

Relief valve installation, and discharge, shall conform to the plumbing code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code*. Safety and relief valve discharge pipes shall be of rigid pipe, of the same diameter as the safety or relief valve outlet, approved for the temperature of the system, and shall not discharge so as to be a nuisance, hazard, nor cause damage. (See 6.3.1, 6.3.7, 6.4.4 of SRCC 300, IRC M2301.2.3, P2804.5-7)

Pipe insulation

Exterior piping insulation shall be rated for outdoor use and protected from ultraviolet radiation and moisture damage. The exterior of piping shall be properly supported and protected from corrosion and degradation. (See 6.1.6.3 of SRCC 300, IRC N1103.5.3, R403.5.3, 1204, M2301.2.5)

Storage Tank and Heat Exchanger

Storage tanks and backup heating equipment for solar water heating systems are typically installed in a garage or an equipment room situated to minimize the piping run to the solar collector array. There can be one (Figure 2) or two (Figures 3, 9) tanks in the system. In the two tank design, one of the tanks stores solar-heated water and the other one contains the backup heater. The system may also contain a small drain-back tank (Figures 9, 10) that holds the fluid from the solar loop when the pump is turned off. This system design uses water as the system fluid, but allows it to drain by gravity into conditioned space to prevent it from freezing when the pump is not operating.

Storage tanks shall be insulated. (See section 6.1.3.2 of SRCC 300)

Storage tanks and heating equipment installed in outdoor locations shall be designed for outdoor installation. (See section 6.1.3.1 of SRCC 300)

Non-pressurized tanks shall be vented. (See section 6.1.3.1 of SRCC 300)

FIGURE 8. Common "gooseneck" solar system flashing

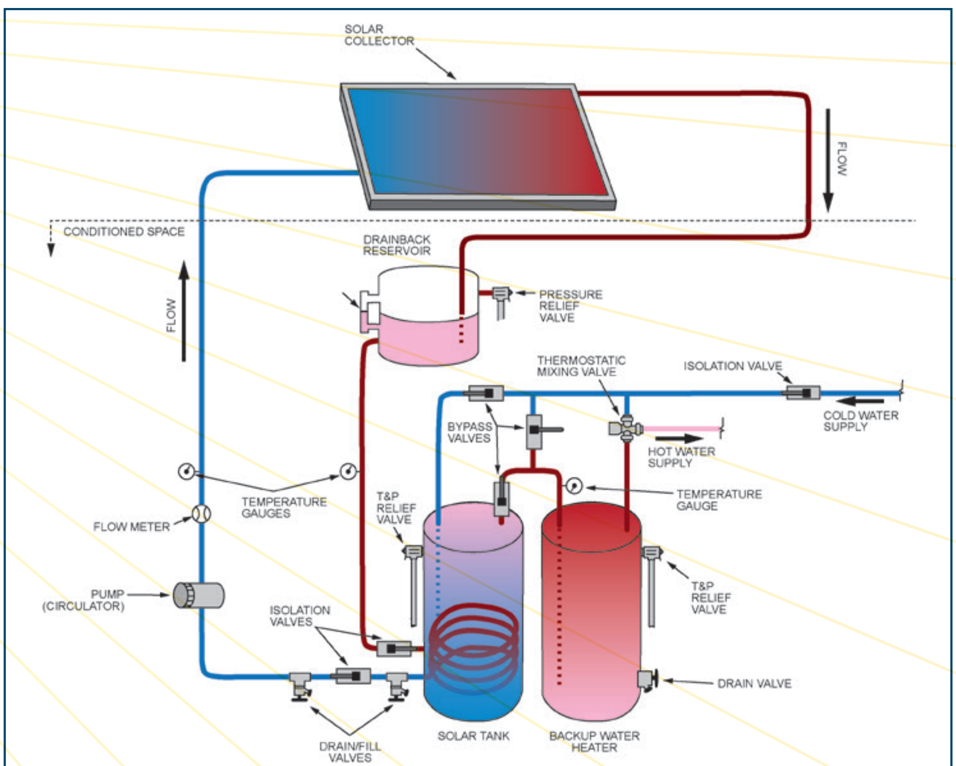


FIGURE 9. Two tank Active Indirect Drainback system

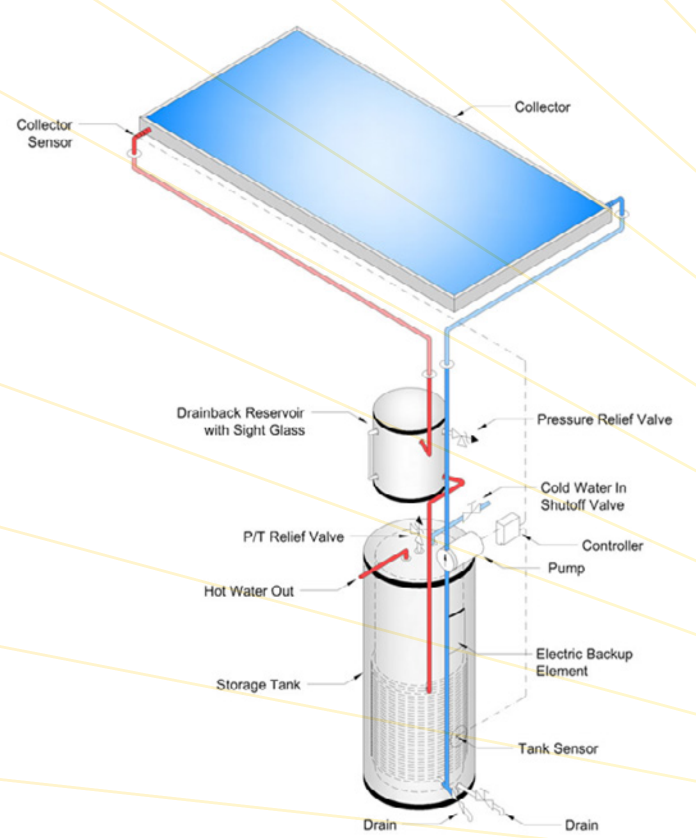


FIGURE 10. Single-Tank Drain-back system

Shutdown. A means for disconnecting the backup hot water supply system from its energy supply shall be provided.

Safety valves. Solar energy system components containing pressurized fluids shall be protected against pressures and temperatures. The solar collector loop requires a pressure-only relief valve. All components subject to heating with non-solar energy require a pressure and temperature relief valve. Each section of the system in which excessive pressures are capable of developing cannot be isolated from a relief device. Relief valves shall comply with the requirements of Section 6.3.5, 6.3.15, 6.5.6 of SRCC 300 and 504.4.1 IPC and discharge in accordance with Section 6.3.1 of SRCC 300 and 504.6 of IPC.

Safety and safety relief valves shall be listed and labeled, and shall have a minimum rated capacity for the equipment or appliances served (504.5 IPC).

Potable piping materials and standards. Water distribution pipe shall comply with Section 6.3.8 of SRCC 300. Hot water distribution pipe and tubing shall have a pressure rating of not less than 100 psi (690 kPa) at 180ºF (82ºC). Potable water pipe and fittings shall have appropriate approvals from recognized third party listing agencies.

Non-potable piping materials standards. Piping and pipe fittings for non-potable fluids shall conform to the standards required by the authority having jurisdiction.

Water shut-off. The solar thermal system shall have valves to provide for shut off from the service water supply without interrupting cold water service to the remaining portion of the water distribution system. (See section 6.1.6.5 of SRCC 300)

Service connections. Connections shall be provided with access for filling, draining and flushing liquid systems. (See section 6.1.6.6 of SRCC 300)

Piping system. The piping system shall be provided with isolation valves to bypass the solar system when the solar thermal system is inoperative or being serviced. (See section 6.1.1.2 of SRCC 300)

Pipe and component supports. Hangers shall support the weight of the filled pipe, provide and maintain slope of pipes (in the case of drainback systems), shall not cause galvanic corrosion and shall not compress or damage the insulation material. (See section 6.5.14 of SRCC 300)

Label. Auxiliary heating equipment shall be listed and labeled by a recognized third party listing agency. Auxiliary heating equipment shall be installed in accordance with the code requirements applicable to the type of fuel used. (See section 6.1.1.4 of SRCC 300)

Heat Exchangers. When the fluid in the solar collector array is not potable water, a heat exchanger is used to transfer heat from the collector loop to the potable water without permitting contact or mixing between the two fluids. The type of fluid used in the collector loop determines the type of heat exchanger that must be used. When the fluid is not food grade, the heat exchanger must have two walls with the space between them vented to the atmosphere and discharging in a visible location (See section 6.1.3.6 of SRCC 300). Every heat exchanger must be labeled to indicate its type. (See section 6.3.7 of SRCC 300)

FIGURE 11. Pump station

Fluid Transport System

Installation and operation of every solar water heating system is required to be fully described in manuals provided with the system (See section 6.6 of SRCC 300). These manuals should be consulted during the inspection to determine what type of system is installed.

The solar collectors and storage/backup tanks described above are interconnected with insulated piping (usually copper, see section 6.1.6 of SRCC 300) (insulation: see section 6.1.6.3 of SRCC 300, 720.7 IBC, N1103.5.3 (R403.5.3) IRC, 1204.1 IMC, R403.4, R403.5.3 IECC).

The system can contain none, one or two pumps. No pumps are required in a passive system where the fluid is circulated by natural convection. The pump(s) in an active system are low-head circulators except in a drain-back system where the solar loop fluid drains back into a freeze-protected tank when the pump is turned off by the controller (Figure 10). The system pumps are often contained, along with many of the other system components, in an integrated assembly known as a pump station (Figure 11).

Active system pumps are typically turned on and off by a differential controller (see section 6.1.5 of SRCC 300) using a temperature sensor at the collector array outlet and a temperature sensor near the bottom of the solar storage tank to compare the temperature of the fluid in the tank and collector (Figures 2 and 3). These sensors should be well insulated (see section 6.1.5.1 of SRCC 300) and thus are typically not visible during inspection. The wiring to and from the sensors is typically low voltage, but should be installed in accordance with the *National Electrical Code*® (NEC®) and protected from the environment.

A variety of valves is used in all system types to access and control the fluid (see section 6.4.7 of SRCC 300). Fill and drain valves should be located as shown in the system diagram in the manual and must be labeled (see section 6.3.7 of SRCC 300) to prevent accidental introduction of improper (toxic) fluids and to protect operators from spraying hot or highly pressurized fluids.

Check valves are used to keep fluid flowing the right direction. One is installed in most systems to keep fluid from reversing flow and dumping heat at night (see section 6.1.1.5 of SRCC 300).

All systems are required (see section 6.1.1.2 of SRCC 300) to have valves that permit isolation of the solar portion of the system so the backup system can continue to provide heated water during maintenance. Each valve must (see section 6.1.1.2 of SRCC 300) be labeled with its normal operating position. An expansion tank is required (see section 6.1.3.4 of SRCC 300) in all system designs except drain-back to absorb thermal expansion in the fluid.

The solar storage tank can be heated to well over 160°F, so a thermostatic mixing valve (see section 6.1.5.5 of SRCC 300) is required to prevent scalding.

All systems are required (See section 6.4.1 of SRCC 300) to have a way to determine whether the system is operating properly. This is usually accomplished with temperature gauges, flow meters and sight glasses. See the system operating manual for readings to expect on these devices. In general, when the sun is shining, the flow meter should indicate flow and the temperature of the fluid returning from the solar collector should be warmer than the fluid going to the collector. In a two-tank system, the temperature leaving the solar storage tank should be warmer than the city main's temperature when hot water is being drawn from the system.

Solar water heating systems certified by the Solar Rating & Certification Corporation will have a page in the owner's manual, and a label on the collector, listing the SRCC certification numbers for each certified system model. This certification assures that the system design and manuals have been reviewed by SRCC. With this assurance, the primary purpose of inspection is to verify that the system has been installed correctly and in accordance with the certified design and meets all local code requirements.