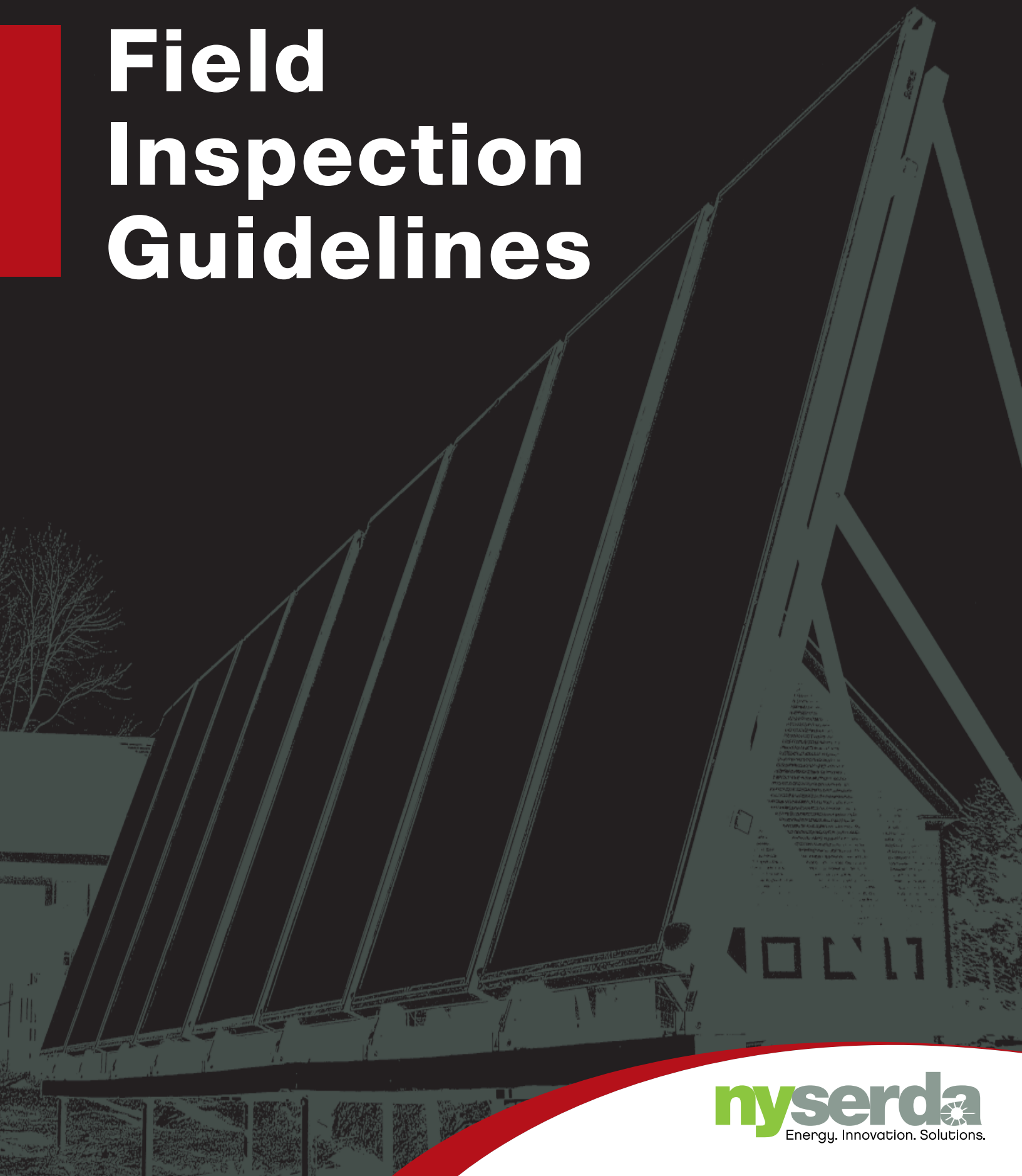
SOLAR HEATING SYSTEMS

Field Inspection Guidelines



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FIELD INSPECTION GUIDELINES FOR SOLAR HEATING SYSTEMS
STATE OF NEW YORK

INTRODUCTION

The field of solar water heating (SWH) has a long history in the United States. During times when nonrenewable fuel sources have been scarce and/or expensive, the SWH industry has gone through periods of significant growth. These periods have been marked by development in the various technologies involved in the trade – collectors, controls, heat exchangers, etc. - and the need for quality assurance to ensure that systems are designed and installed properly.

This manual serves as an educational tool for Code Enforcement Officials (CEOs) and solar heating installers in New York. Though SWH has been used in the United States for over a century, it hasn't yet achieved enough of a market share to be considered as a "conventional" heating source. It is our hope that this guide will help with the development of uniform standards for residential SWH systems in New York.

It is easy to wistfully promote "uniform standards," but such a concept is difficult in practice. While there are State Codes in New York, local jurisdictions (such as New York City) may have their own codes, and codes are only consistent across jurisdictions if there is consistency in enforcement. This situation is not unique to New York. There are two dominant codes relating to SWH in the United States – the International Codes and the Uniform Codes. Figure 1 illustrates the state-by-state adoption of plumbing codes across the U.S.

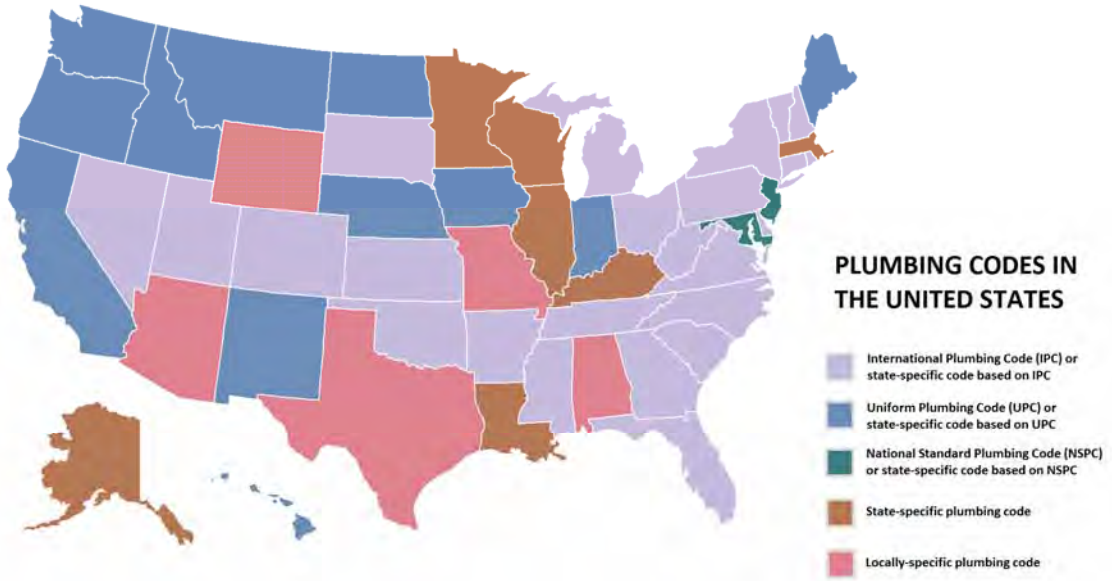


Figure 1 - Map illustrating state plumbing codes (based on Reed's Construction Data and author's research)

Because there is a lack of widespread access to comprehensive details on code compliance of SWH systems in the United States, this guide may eventually be read by individuals outside of New York State. It is critical for readers to recognize how codes differ by jurisdiction. For example, a contractor from California that installs a SWH system in compliance with the information in this manual might not satisfy codes in California, where the Uniform Plumbing Code has been adopted.

Whether in New York or elsewhere in the U.S., it is critical to compare the contents of this guide with the rules adopted by the Authority Having Jurisdiction (AHJ) to ensure code-compliance of an installation.

This manual is built upon the ***Inspection Checklist for Solar Heating Systems*** (pages iv-vii). This checklist includes requirements from the following sources:

- 2010 Plumbing Code of New York State (NYSPC)
- 2010 Mechanical Code of New York State (NYSMC)
- 2010 Building Code of New York State (NYSBC)
- 2010 Energy Conservation Construction Code of New York State (NYSECC)

These codes are all based on the 2009 International Codes. The ***Inspection Checklist*** cites the section of code that relates to each installation requirement. These items are discussed in further detail in the manual.

It is possible for a system to be code-compliant without functioning properly or adhering to industry "best practices." The Solar Rating and Certification Corporation (SRCC) Operating Guidelines 300 (OG-300) have been included in this manual to address these deficiencies. OG-300 details the minimum standards for systems that are certified by the SRCC. While OG-300 *Certification* is not necessary to qualify for local incentives in New York, it is necessary for installers to comply with OG-300 *practices*.

For ease of navigation and to assist the Inspector with his/her assessment, the manual has been organized as illustrated in Figure 2 and described below:

Section 1: Collector Array focuses on the collector array and other major equipment that is installed outdoors. On many systems this portion of the inspection will take place upon the roof, though some systems may be wall-mounted or ground-mounted. Much of this section is regulated by the NYSMC, NYSBC, and OG-300 Guidelines.

Section 2: Solar Loop includes all of the piping and components between the collector array and the heat exchanger. This portion of the installation is primarily regulated by the NYSMC and OG-300 Guidelines.

Section 3: Solar Storage & Potable Tie-In focuses on storage tanks and domestic water supply. This section is guided primarily by the NYSPC with some inclusion of the OG-300 Guidelines.

Section 4: Controls covers the electrical requirements of a properly-installed system. The National Electrical Code (NEC) provides guidance for this section.

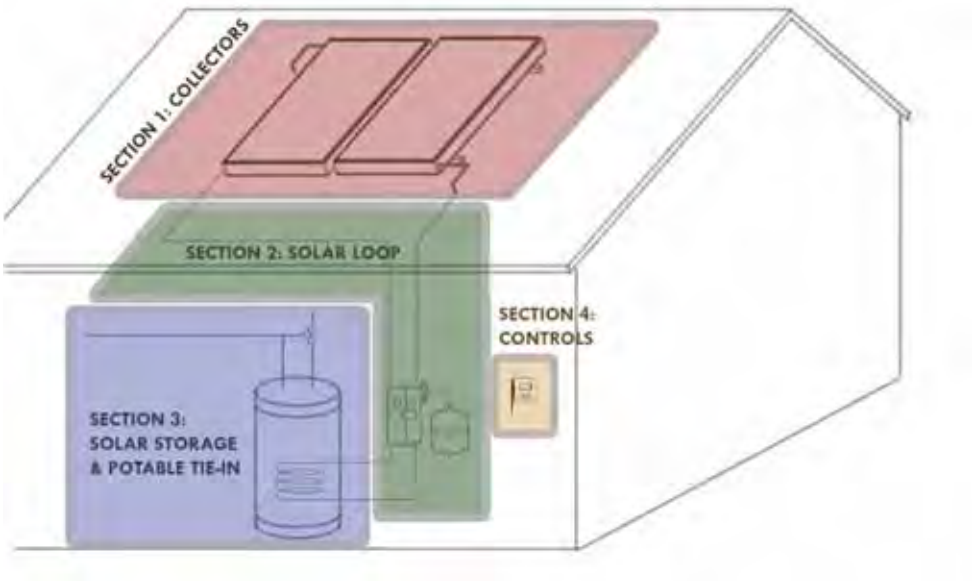


Figure 2 - Organizational structure of the Inspection Manual

As SWH becomes a conventional energy source, the understanding of proper code-compliance and best practices will continue to develop. Consequently, we understand that this will be a dynamic document – one that responds to the needs of inspectors and the market. If you believe that an error has been made in this document, please contact Vicki Colello at: vac@nyserda.ny.gov.

This document was authored by Vaughan Woodruff, Solar Thermal Instructor at Kennebec Valley Community College (KVCC). KVCC is part of the U.S. Department of Energy's Solar Instructor Training Network. KVCC's Northeast Solar Heating and Cooling Instructor Training Project is a "train the trainers" project to increase access to instructor training and create pathways for the highly-skilled, technical workforce. Vaughan would like to thank Mark Thornbloom of Kelelo Engineering, Darren Vaux of Camosun College, Mark Sevier of Cadmus Group, and Todd Hoitsma of Liquid Solar Systems for reviewing and adding their expertise to this document. He would also like to express his appreciation to Kennebec Valley Community College and the Interstate Renewable Energy Council for their support.

Production of this document was funded by the New York State Energy Research and Development Authority (NYSERDA) under contract agreement 9991 with the Interstate Renewable Energy Council (IREC). The purpose of this manual is to provide a detailed resource manual to support growth and development of the Solar Thermal industry in the State of New York. The guide might also be used by local code enforcement officials as a reference. Those interested in participating in the RPS funded Solar Thermal incentive programs should refer to PON 2149 for the specific details of that program and its processes.

SOLAR HEATING INSPECTION CHECKLIST

Customer Name _____ Customer Phone No. _____

Installation Address _____ City _____ State _____ Zip _____

Eligible Installer _____ Eligible Installer E-mail _____

Company _____ Installer No. _____ Phone No. _____

SECTION 1: COLLECTOR ARRAY

Yes	No	N/A	Requirement	Source of Requirement	Page #
			(A) COLLECTORS		
			(i) Shading analysis accurate	Program requirement	1
			(ii) Tilt and azimuth consistent with application	Program requirement	3
			(iii) Collector manufacturer, model, and quantity matches program application	Program requirement	5
			(iv) Collector certified by SRCC OG-100	NYSMC 1404.1, OG-300 6.1.2.1, Federal Tax Credit	5
			(v) Inlet and outlet piping plumbed correctly	NYSMC 1401.4, OG-300 6.1.2.4	5
			(vi) Multiple-collector banks plumbed and balanced properly	NYSMC 1401.4, OG-300 6.1.2.4	6
			(vii) Multiple banks plumbed and balanced properly	NYSMC 1401.4, OG-300 6.1.2.4	8
			(viii) Collector sensor(s) securely attached in appropriate location	OG-300 6.5.18	9
			(ix) Sensor wire properly protected from UV degradation and excessive heat	OG-300 6.1.2.2	10
			(x) Collectors sloped ¼" per foot (min.) towards the collector inlet *for drainback systems*	OG-300 6.2.5	11
			(xi) Manual or automatic air vent installed at high point of system –or- alternate OG-300 design for air elimination *for pressurized glycol systems*	OG-300 6.3.9	11
			(B) COLLECTOR RACKING		
			(i)(a) Collector racking installed per manufacturer's specifications	NYSMC 1401.4	12
			–OR- (i)(b) Custom rack engineered and installed per design specifications	NYSMC 301.12	12
			(ii) Attachment between collector(s) and rack fastened properly	NYSMC 1401.4	13
			(iii) Dissimilar metals galvanically isolated between collector rack and metal roofing	OG-300 6.2.4	13
			(iv)(a) Collector rack connected to structure in accordance with building permit	NYSMC 302.1	13
			–OR- (iv)(b) Collector rack connected to structure in accordance with collector manufacturer specifications	NYSMC 1401.4	13
			-OR- (iv)(c) Collector rack connected to structure in accordance with engineered design	NYSMC 302.1	13
			(v) Attachment points sealed properly	NYSBC 1503.2, NYSMC 1402.6, OG-300 6.5.5	15

SECTION 1: COLLECTOR ARRAY	Yes	No	N/A	Requirement	Source of Requirement	Page #
				(vi) Foundation installed per specifications detailed in building permit *for ground-mounted systems*	NYSBC Ch. 18	16
				(C) EXTERIOR PIPING		
				(i) Exterior piping supported properly	NYSMC 305.2, 305.4	16
				(ii) Exterior piping insulated properly	NYSECC 403.3, 503.2.8	17
				(iii) Pipe insulation protected from UV degradation	OG-300 6.1.2.2	18
				(iv) Pipe penetrations flashed and sealed properly	NYSPC 305.7, NYSMC 1402.6, OG-300 6.5.5	19
				(v) Piping sloped ¼" per foot, minimum, *for drainback systems*	OG-300 6.2.5	20
				(vi) Dissimilar materials isolated properly, if required	NYSMC 1203.1.1; OG-300 6.2.4	20
				(vii) Polymer materials are not used in the collector loop unless approved by the SRCC in a specific OG-300 certified system	Design requirement	20

SECTION 2: SOLAR LOOP						
				(A) PIPING CONSIDERATIONS		
				(i) Piping supported by appropriately-spaced hangers	NYSMC 305.4	21
				(ii)(a) Hanger material compatible with piping material -OR- (ii)(b) Hangers isolated properly from piping	NYSMC 305.2	22
					OG-300 6.2.4	22
				(iii) Piping insulated properly	NYSECC 403.3, 503.2.8	22
				(iv) Dissimilar materials isolated properly, if required	NYSMC 1203.1.1; OG-300 6.2.4	23
				(v) Penetrations through structural members consistent with code	NYSMC 302.3, 302.4, 302.5	23
				(vi) Piping backfilled properly *for ground-mounted systems*	NYSPC 306.1, 306.3	24
				(vii) Piping installed to allow system draining	NYSMC 1206.2, OG-300 6.5.15	24
				(B) HEAT TRANSFER FLUID		
				(i)(a) System utilizes water as heat transfer fluid –OR- (i)(b) System utilizes propylene glycol solution as its heat transfer fluid	NYSPC 608.16.3	25
					NYSPC 608.16.3; OG-300 6.3.12	25
				(ii) Heat transfer fluid is rated for solar applications	NYSMC 1403.1, OG-300 6.2.1, 6.2.8, 6.3.14	25
				(iii) Propylene glycol concentration is appropriate for application	OG-300 6.2.5	25
				(C) PRESSURE CONSIDERATIONS		
				(i) Pressure relief valve and relief drain installed properly	NYSMC 1402.5.1; OG-300 6.1.1.1, 6.2.3, 6.3.5	26
				(ii) Pressure relief valve cannot be isolated from collector array	NYSMC 1402.5.1, OG-300 6.3.16	26

SECTION 2 : SOLAR LOOP	Yes	No	N/A	Requirement	Source of Requirement	Page #
				(iii) All system components rated higher than pressure relief rating	NYSMC 1202.3, 1402.5.1; OG-300 6.2.3	27
				(iv) Expansion tank sized and installed properly *for pressurized glycol systems*	NYSMC 1009.2, 1402.5.4; OG-300 6.1.3.4	27
				(v) System tested to 100psi for at least 15 minutes, *for pressurized glycol systems*	NYSMC 1208.1	28
				(vi) System pressure is within standard limits	Design requirement	29
	(D) OTHER CONSIDERATIONS					
				(i) Penetrations between conditioned and unconditioned space airsealed	NYSECC 402.4.1, OG-300 6.5.5	29
				(ii) Check valve installed to prevent passive cooling *for pressurized glycol systems*	OG-300 6.1.1.5	30
				(iii) Expansion tank located between check valve and collector array *for pressurized glycol systems*	Best practice	31
				(iv) System drains correctly *for drainback systems*	OG-300 6.2.5	31
				(v) Piping labels show type of fluid and direction of flow	NYSPC 608.8.1	32
				(vi) Drain and fill valves labeled	OG-300 6.3.7	33

SECTION 3: SOLAR STORAGE AND POTABLE TIE-IN						
	(A) STORAGE TANK					
				(i) Tank manufacturer, model, and capacity matches application	NYSERDA	34
				(ii) Tank labeled with pressure rating *for pressurized storage*	NYSPC 501.7, OG-300 6.4.3	34
				(iii) Temperature and pressure relief valve installed properly *for pressurized storage*	NYSPC 504.4, 504.5; NYSMC 1006.3	34
				(iv) Relief drain plumbed properly *for pressurized storage*	NYSPC 504.6, NYSMC 1006.3	34
				(v) Tank drain installed *for pressurized storage*	NYSPC 501.3	35
				(vi) Tank vented to atmosphere *for atmospheric tank*	Design requirement	35
				(vii) Tank water adjusted to proper pH level *for atmospheric tank*	Design requirement	35
				(vii) Galvanized steel pan and installed below tank and drained, as appropriate	NYSPC 504.7	35
				(ix) Tank installed on level surface	NYSMC 304.9	36
				(x) Tank supported for seismic loads, if applicable	NYSPC 502.6, NYSMC 301.15	36
				(xi) Tank meets requirements for installation in attic or garage, if applicable	NYSPC 502.2, 502.5; NYSMC 304.7	36
				(xii) Storage tank sensor(s) installed properly	OG-300 6.5.18	36
	(B) POTABLE PIPING					
				(i) Mixing valve installed properly	OG-300 6.1.5.6	38
				(ii) Mixing valve set to appropriate temperature	NYSPC 501.2, NYSECC 504.3, OG-300 6.1.5.6	38
				(iii) Isolation valve installed on cold water feed to water heater	NYSPC 503.1; OG-300 6.1.1.2, OG-300 6.1.6.5	39

SECTION 3: SOLAR STORAGE	Yes	No	N/A	Requirement	Source of Requirement	Page #
				(iv) Isolation valves installed to allow bypass of solar storage tank	OG-300 6.1.1.2, OG-300 6.1.6.11	39
				(v) Heat traps properly installed	NYSECC 504.4	40
				(vi) Antisiphon device installed properly	NYSPC 504.1	40
				(vii) Dissimilar materials isolated properly, if required	NYSPC 605.25	40
				(viii) Thermal expansion tank installed and sized properly *for cold water supply with check valve or backflow prevention*	NYSPC 607.3.2	41
				(ix) Interconnecting piping insulated properly	OG-300 6.1.6.3	41
				(x) All valves and fittings are rated for potable systems	NYSPC 605.2	42
				(xi) Isolation valves labeled with normal operating position	OG-300 6.1.1.2	42

SECTION 4: CONTROLS				CONTROLS		
				(i) Wiring between controller and outputs (pumps, motorized valves, etc.) installed properly	NEC 430.21(G), 110.14(B)	43
				(ii)(a) Controller relay(s) rated higher than each output -OR- (ii)(b) Appropriately rated intermediate relay(s) installed between controller and output(s)	Design requirement	43
					Design requirement	43
				(iii) Wiring between controller and power source (line voltage) installed properly	NEC 110.14(B), 310.104, Ch. 9	44
				(iv) wiring to PV module installed and sized appropriately *for PV-controlled systems*	NEC 310.10(D), Article 690(IV)	44
				(v) PV module sized appropriately for DC pump *for PV-controlled systems*	Design requirement	44

SECTION 1: COLLECTOR ARRAY

The collector array is the major energy source for any SWH system and represents some unique challenges for the Installer. Because it is located outdoors, the array is subject to unique live loads (wind and snow). Additionally, materials used in and around the array must be resistant to degradation from ultraviolet (UV) light.

Inspection of the collector array provides its own difficulties. Because many arrays are located on the roof, access may be difficult and provide significant risk for the Inspector. OSHA does not *require* fall protection for inspections, but it is recommended due to the inherent risk. The Inspector should bring adequate safety equipment to access the roof to ensure proper protection during the Inspection.

The ***Inspection Checklist*** for this section is organized into the following categories:

- **Collectors:** The collectors must be inspected to ensure they are sited, oriented, and inclined correctly. Multiple-collector arrays must be installed to balance flow through individual collectors.
- **Collector racking:** This category refers to the mechanical attachments between the collector and the roof attachment. For tilt racks, this includes the tilt rack and the collector attachments. For a flush-mounted collector, this includes the collector attachment.
- **Attachment to structure:** The attachment of the collectors to the structure must be able to withstand the various forces on the collectors and ensure the integrity of the building or ground-mount to which it is attached.
- **Exterior piping:** This category refers to the piping that connects the collectors to the balance-of-system, the pipe covering, and the penetration of the piping into the structure.

(A) COLLECTORS

(i) Shading analysis is accurate

Incentive programs may require a shading analysis to be submitted with the program application. This shading analysis details the accessible solar energy at the installation site. The Inspector may be responsible for conducting an independent shading analysis to verify that the site will receive sufficient sunlight throughout the year. If there is a major discrepancy between the independent shading analysis and the one submitted with the program analysis, this issue will likely need to be resolved by the Installer to comply with the incentive program.

A shading analysis can be performed using several different instruments. The two most common tools for this purpose are the Solar Pathfinder and Solmetric SunEye.

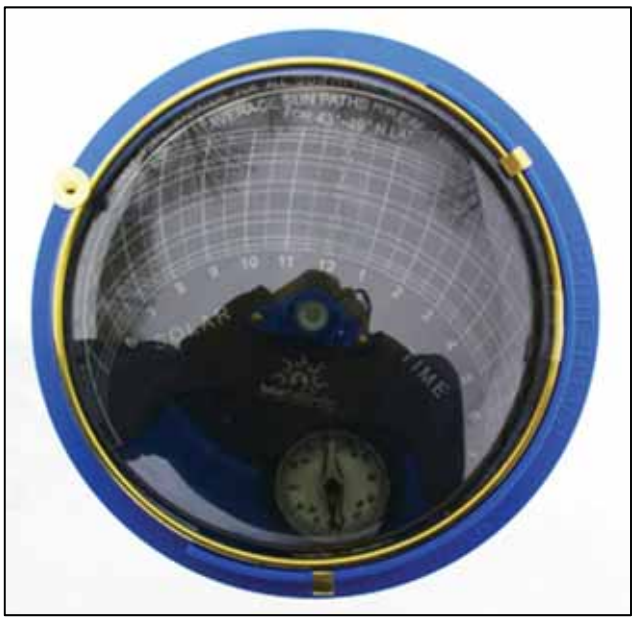


Figure 1-1 – View of Solar Pathfinder plastic dome from above (photo courtesy of Kennebec Valley Community College)

Solar Pathfinder

The Solar Pathfinder is a tool that reflects the horizon on a plastic dome (See Figure 1-1). By superimposing the reflection atop a stereographic diagram that illustrates the paths the sun takes throughout the year, a derating can be determined to account for shading.

The *Solar Pathfinder Assistant software with Thermal Plug-In* allows the Installer to import a digital photo of the Solar Pathfinder dome into a program that can provide precise shading estimates and approximate system performance based upon the specific components used and the tilt and orientation of the collector array.

In order to work properly, the Solar Pathfinder should be placed on a level surface in the site where the collectors are (or will be) situated. After orienting the Solar Pathfinder's compass towards true south, the shading obstructions can be traced on the stereographic chart to estimate their impact on the amount of solar energy available at the site. Alternately, the device can be leveled and oriented towards magnetic south, a digital photo can be taken, and the photo can be imported into the Solar Pathfinder Assistant Software. For more detailed information, including an instructional manual, visit www.solarpathfinder.com.

In the state of New York, magnetic declination varies from roughly 10°W in Ripley to 14°W in Montauk. It is important to consider the site's magnetic declination when preparing an accurate site assessment. Site-specific magnetic declination is available at the National Oceanic and Atmospheric Administration's National Geophysical Data Center website: http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination.

> **Important note:** If manually tracing the stereographic diagram, the results will only account for derating due to shading. A report generated by the Pathfinder Assistant software will also account for derating *due the tilt and orientation of the array*. See Section 1, (A)(ii) below for details regarding the effects of tilt and azimuth (the orientation of the collectors in relation to true south) on a system's performance.

SunEye

The Solmetric SunEye is a handheld digital device (see Figure 1-2) that can provide instantaneous analysis of a site based on its shading profile, tilt, and azimuth. When performing a site assessment, information about the project is imported into the SunEye and a digital fish eye lens displays an image similar to the one that appears when looking down upon the Solar Pathfinder. Once the SunEye is leveled and oriented towards true south, the image is captured by the device and the derating due to shading and orientation is determined immediately. More information on the SunEye is available at www.solmetric.com

Figure 1-2 – The SunEye 210 (photo courtesy of Solmetric)

Evaluating
The Inspector should verify that the site meets relevant program requirements by performing an independent shading analysis. If the solar energy at the site is marginal but acceptable (75-80%) and future tree growth is likely to limit the system's performance, this should be noted.

(ii) Tilt and azimuth consistent with application

The tilt and azimuth of the collector array is required on the application for some incentive programs. The as-built tilt and azimuth must be obtained during the inspection and compared to the values submitted on the application.

Tilt
The tilt of the collector array is determined by using an inclinometer (see Figure 1-3).

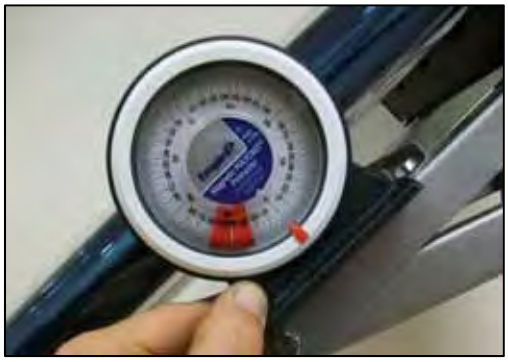


Figure 1-3 – An inclinometer is used to determine the tilt angle of a collector.

Azimuth
The azimuth of the array can be determined several ways:

- For collectors mounted in-line with the structure, an aerial photograph of the site (see Figure 1-4) can be accessed prior to or during the Inspection. These maps are oriented to true south, so the measure of the azimuth can be derived by using a protractor to measure the angle between the building orientation and a vertical line on the map. If using this method, the azimuth must be determined prior to leaving the site. Some sites do not have adequate aerial maps due to cloud cover or other issues (see Figure 1-5).
- When orienting the Solar Pathfinder or SunEye for the shading analysis in Section 1, (A)(i), the angle between solar south and the collector array can be approximated. This is best done from behind the collector array. Be aware that metal objects may affect the accuracy of a magnetic compass.

Figure 1-4 – Aerial photograph of a prospective installation site (©2011 Google, TerraMetrics)

Figure 1-5 – The limitations of aerial photographs (photo from Google Maps)

Important notes:

- Consideration should be taken when flush-mounting evacuated tube collectors. Due to their low thermal losses, evacuated tubes tend to shed snow poorly (see Figure 1-6). When snow is shed, it can collect between the tubes of the array. On roofs that are less than 10:12 in slope, it is *recommended* that evacuated tubes are installed on tilt racks to increase the slope, allow wind to get behind the collectors for removing snow, and to allow space between the collector and roof where snow can shed.

Figure 1-6 - Evacuated tube collectors flush-mounted on a roof with an 8:12 slope (photo courtesy of Kennebec Valley Community College)

- Flat plate collectors may benefit from being flush-mounted rather than installed on a tilt rack. If the roof slope is steep enough to maintain adequate available solar insolation (see the discussion of "Surface Orientation Factors" below), a flush-mounted system may provide aesthetic benefits and reduce concerns associated with wind loading.
- Evacuated tube collectors may require a minimum collector slope for proper functionality. Consult the manufacturer's specifications to ensure proper installation.

In addition to the use of shading tools, the effect of tilt and azimuth on available *annual* solar insolation can be quantified through the use of Surface Orientation Factor charts. These charts illustrate the amount of energy available at specific sites for various orientations (see Figure 1-7).

These figures illustrate the acceptable margin of error for sites with an orientation that is different than the one profiled on program application form. For example, a system in Syracuse was initially planned to be installed at a tilt angle of 40 degrees and an azimuth of 165 degrees. This system could be installed at the same azimuth and a tilt angle of 50 degrees without a significant drop in *annual production*. Annual production is not always the greatest concern in solar heating systems; the most important consideration is to match the amount of energy generated to the hot water demand.

See http://www.solmetric.com/annualinsolation-us.html for site-specific Surface Orientation Factors.

Evaluating
As mentioned in the discussion of shading analyses (Section 1(A)(i)), effects of tilt and azimuth must be considered when assessing the performance of the system. To facilitate this, Inspectors should use a SunEye tool for verification. If a Solar Pathfinder is used, a digital photo must be taken for use with the Pathfinder Assistant software.

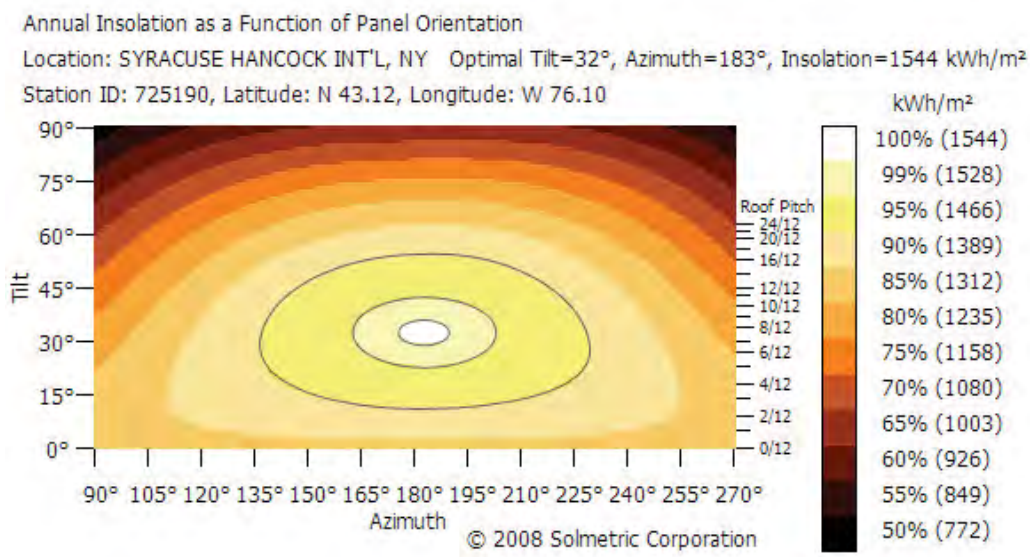


Figure 1-7 – Surface Orientation Factor diagram for Syracuse, NY

(iii) Collector manufacturer, model, and quantity matches application
(iv) Collector certified by SRCC OG-100

All qualified SWH collectors must be certified by the Solar Rating and Certification Corporation (SRCC). Collector certifications are found on the frame of flat plate collectors and on the manifold for evacuated tube collectors (see Figure 1-8). These labels indicate the manufacturer and model. Collectors must be certified under SRCC Operating Guidelines (OG-100) to qualify for the federal tax credit and many local incentives.

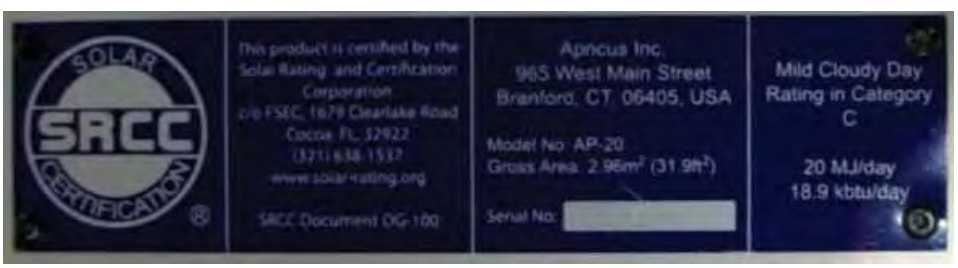


Figure 1-8 - SRCC OG-100 Certification plate for an Apricus AP-20 Collector

> ***Evaluating***
> The Inspector should verify that the collectors are OG-100 certified.

(v) Inlet and outlet piping plumbed correctly

The heat transfer fluid in the system must travel from the coolest part of the collector to the hottest part in order to absorb the sun's heat efficiently. In evacuated tube collectors, the inlet and outlet ports of the collector are often interchangeable (see Figure 1-9). In harp-style flat plate collectors, the inlet and outlet ports are distinct (see Figure 1-10). Serpentine/meander-style flat plate collectors may or may not have distinct inlet and outlet ports (see Figure 1-11 and Figure 1-12).

Note: Some serpentine/meander-style flat plate collectors are manufactured in models specifically designed for landscape mounting (the long side oriented to horizontal). It is critical to verify that serpentine/meander-style flat plate collectors mounted landscape (sometimes referred to as "horizontal") are designed for this purpose. Otherwise, the collectors could create steam traps during stagnation that increase system pressures and temperatures. Likewise, serpentine/meander-style collectors designed as horizontal collectors should not be mounted in portrait orientation.

Figure 1-9 – Sample evacuated tube schematic. Flow of the heat transfer fluid is shown from right to left, but could also go from left to right (image courtesy of Solar Panels Plus)

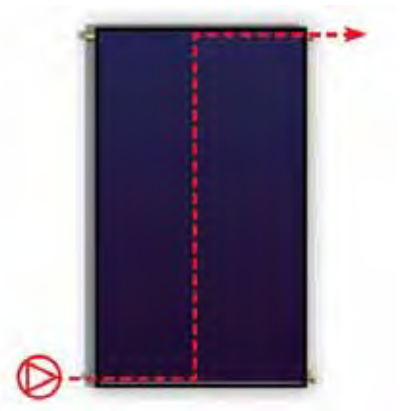


Figure 1-10 – Grid-style flat plate collector. The inlet is on the bottom and the outlet is on top. This collector could also be plumbed with the inlet on the bottom right and the outlet on the top left, but not with flow from top to bottom (image courtesy of Heliodyne).

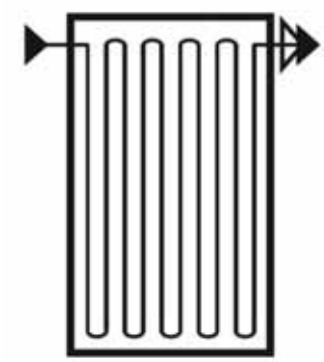


Figure 1-11 – Serpentine/meander-style flat plate collector with interchangeable inlet and outlet. This collector could also be plumbed right to left (image courtesy of Schuco).

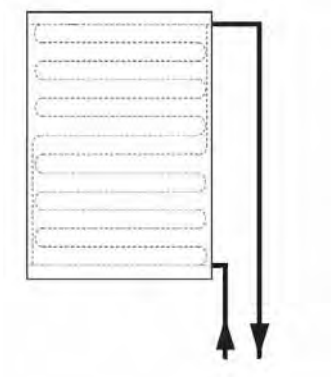


Figure 1-12 – Serpentine/meander-style flat plate collector with distinct inlet and outlet. This collector can be plumbed with the inlet on either side of the bottom header and the outlet at either side of the top header, but not from top to bottom (image courtesy of Buderus).

Evaluating
The Inspector should verify that the collectors are plumbed properly. If unfamiliar with the style of collector used in the system, the Inspector should refer to the collector manufacturer's documentation.

(vi) Multiple-collector banks plumbed and balanced properly

Many systems in New York utilize more than one collector. It is critical that these systems are properly installed to ensure proper utilization of each collector in the array.

Flat plate collectors – Harp-style

Harp-style flat plate collectors should always be installed *in parallel*. This is accomplished by connecting the collectors header-to-header as illustrated in Figure 1-13. Most harp-style flat plate collectors can be arranged in arrays of six collectors. Larger arrays may needed to be plumbed in separate arrays due to frictional head loss in the collector array, excessive fluid velocities, and/or the inability for large arrays to balance flow through each of the risers (the tubing that connects one header to the other). Consult the collector manufacturer's recommendations for banks with five or more collectors.

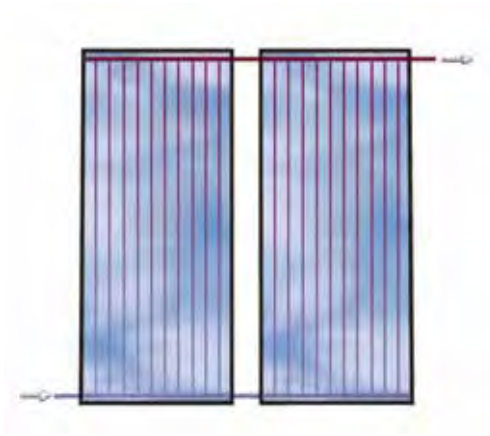


Figure 1-13 – Grid-style flat plate collectors plumbed in parallel (image courtesy of AET).

Harp-style flat plate collectors should not be plumbed in series (see Figure 1-14). Plumbing collectors in parallel leads to equivalent temperatures across the array. When plumbed in series the last collector will be hotter than the first collector. Because of the thermal losses of typical flat plate collectors, such an arrangement leads to inefficient solar collection. The additional piping required to connect the headers in series creates further inefficiency.

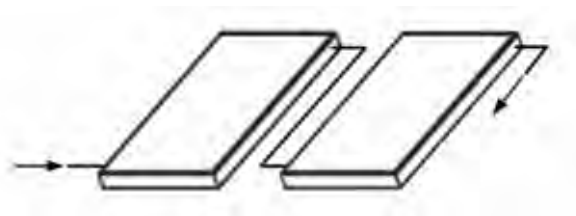


Figure 1-14 - Flat plate collectors plumbed in series

When typical harp-style collectors are oriented horizontally (or "landscape"), extra piping must be installed to plumb the collectors in parallel (see Figure 1-15). Some companies manufacture harp-style collectors with rotated headers that allow them to be plumbed in parallel similar to the style shown in Figure 1-13.

Figure 1-15 – Horizontal flat plate collectors plumbed in parallel

Flat plate collectors – Serpentine/Meander-style

Serpentine/meander-style collectors should always be connected *in parallel* (see Figure 1-16). The method for plumbing serpentine/meander collectors in parallel may vary by manufacturer. The Inspector should refer to the collector manufacturer's documentation if unfamiliar with the model of serpentine/meander-style collector used in the system. It is important to also verify the maximum number of serpentine/meander collectors allowed in each individual bank.

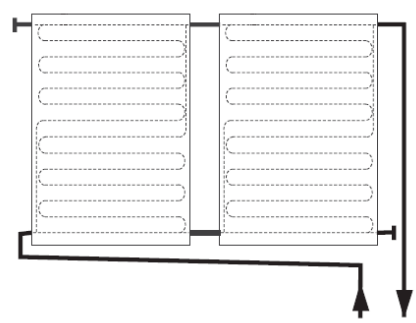


Figure 1-16 – Serpentine/meander-style collectors plumbed in parallel (image courtesy of Buderus)

Evacuated tube collectors

The benefit of evacuated tubes is their lower thermal losses when compared to typical flat plate collectors. Due to this phenomenon and the typical design of evacuated tube manifolds, it is appropriate to connect evacuated tube collectors *in series*. Evacuated tube collectors are connected in series by directly connecting the manifold headers to one another (see Figure 1-17 and Figure 1-18).

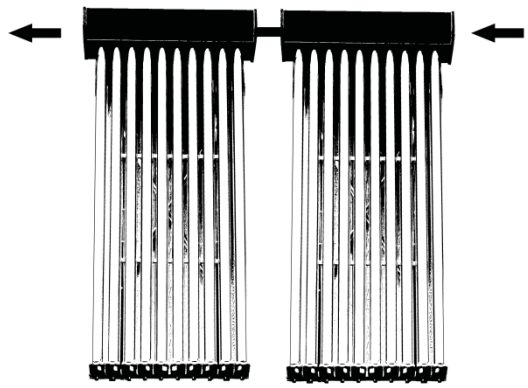


Figure 1-17 – Evacuated tubes connected in series. This collector could also be plumbed with flow from right to left.

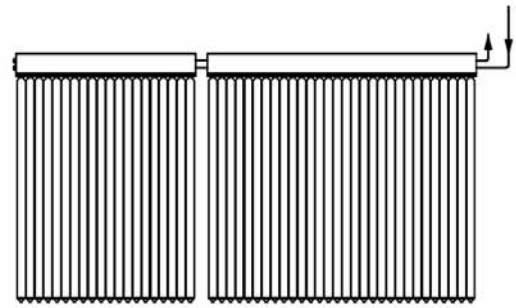


Figure 1-18 - Evacuated tubes connected in series. The inlet and outlet in this installation could also be located on the left side of the array. Note that this is an example of an evacuated tube collector with a distinct inlet and outlet, unlike the models in Figure 1-9 and Figure 1-17 (image courtesy of Viessman).

There are limits to connecting evacuated tube collectors in series. Too many collectors in series will increase the thermal losses to an unacceptable level, result in high fluid velocities, and may lead to unacceptable stagnation temperatures. Consult the collector manufacturer's recommendations for arrays with four or more evacuated tube collectors.

Evaluating

The Inspector should verify that the collectors are plumbed properly. If unfamiliar with the style of collector used in the system, the Inspector should refer to the collector manufacturer's documentation.

(vii) Multiple banks plumbed and balanced properly

Multiple banks should be connected in parallel with balanced flow. SRCC OG-300 Guidelines stipulate that the variation in flow between multiple collector banks shall not exceed 10%. The flow can be balanced as follows:

Reverse return

Multiple banks can be balanced by plumbing them reverse return (see Figure 1-19). When done correctly, this method ensures that the heat transfer fluid experiences roughly the same flow through both collector banks if the piping is the same diameter and the

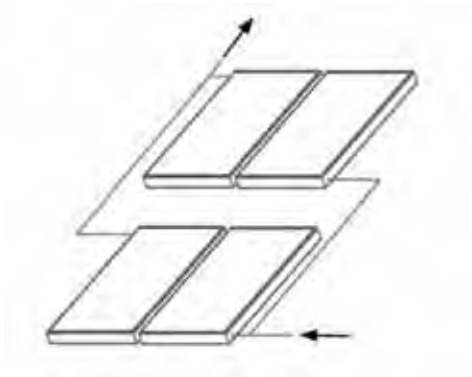


Figure 1-19 – Multiple banks balanced with reverse return piping

difference in pipe length between the banks is 10% or less. Care should be taken when connecting collector banks in parallel with a drainback system, as a minor difference in flow between banks may lead to inadequate filling of portions of the system.

Balancing valves

While it is best to use piping strategies to balance collector flow in small residential systems, when more precise balancing of collector banks is required, balancing valves can be utilized. A ball valve or specialized balancing valve (see Figure 1-20) may be used for this purpose. If ball valves are used, temperature gauges or flow meters must be installed to determine whether the flow is properly balanced.

Figure 1-20 – Balancing valve (image courtesy of Taco, Inc.)

Multiple pumps

Through the use of advanced controls, multiple pumps can be used to circulate heat transfer fluid through separate collector banks to heat a common storage tank (see Figure 1-21). Flow meters should be installed on each collector loop to verify balanced flow through the arrays.

Evaluating

The Inspector should verify that the collectors are plumbed properly. If unfamiliar with the style of collector used in the system, the Inspector should refer to the collector manufacturer's documentation.

(viii) Collector sensor(s) securely attached in appropriate location

It is critical that collector sensors are installed appropriately to ensure that system operates as designed. Most installation manuals for OG-300 certified systems will specify the appropriate sensor locations.

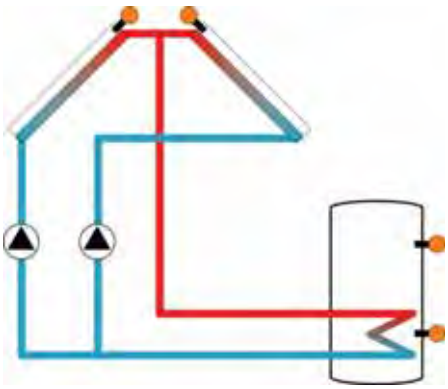


Figure 1-21 – Simple schematic of the use of multiple pumps for balancing flow (image courtesy of Resol)

The sensors must be placed to measure the hottest temperature in the collectors. If sensor locations are not specified by the collector manufacturer, appropriate sensor locations include:

- ***Directly on the absorber plate of a flat plate collector.*** This can be achieved by feeding the sensor through a collector vent (see Figure 1-22) or by drilling a hole in the collector frame. Holes drilled in the collector frame must be installed in accordance with the collector manufacturer's recommendation.
- ***Inside a dry well.*** Some collectors have a pre-installed dry well that is in direct contact with the header (see Figure 1-23). Dry wells – typically with threaded male fittings – are available from certain collector manufacturers and plumbing supply houses and can be installed in a tee at the hot outlet pipe of the collector. The sensor probe should be coated with heat transfer paste (thermal grease) and inserted into the well. The end of the well should then be sealed with silicone caulk to ensure accurate sensor readings.
- ***Between the collector header and the header gasket.*** Many collectors utilize a rubber gasket or synthetic heat shield to isolate the copper header from the collector frame or manifold (see Figure 1-24). If the entire sensor probe can be inserted between these surfaces, this is an appropriate location.

- ***Clamped to outlet piping*:** It is common practice to clamp a sensor on the hot outlet piping with a stainless steel hose clamp or with copper wire. This method relies heavily on the integrity of the pipe insulation and gives temperature readings that are significantly lower than the methods listed above in cold weather locations such as New York. If this method is used, the sensor should be clamped as close as possible to the collector outlet and the pipe insulation must be robust and secured properly at the sensor location. There should be no section of uncovered pipe between the sensor and the collector.

In all of the methods listed above, it is critical that the sensor wiring is secured with wire ties to eliminate sensor displacement. The sensor wire should be supported within 12" of the sensor (minimum) and every 24" with wire ties or the pipe covering. Sensor wire that is in contact with the collector piping shall be insulated with material that is rated for 400F.

Important note: In ground-mounted systems, the sensor wire must be installed inside of conduit to protect the wire.

Evaluating
The Inspector shall verify that:
- the sensor is installed in an appropriate location,
- the sensor is insulated appropriately,
- the sensor wire is proper secured.

Figure 1-22 – Sensor probe installed on absorber plate through collector vent

Figure 1-23 – Sensor installed in collector dry well. The well is partially visible behind the glazing.

Figure 1-24 – Sensor installed between header and heat shield (sensor wire must be secured to piping and have a high-temperature coating)

(ix) Sensor wire properly protected from UV degradation and excessive heat

Standard wire coatings will degrade over time when exposed to ultraviolet (UV) radiation. All exposed solar sensor wire shall be rated for UV-exposure. Sensor wire that is not UV-rated must be concealed via a UV-rated conduit or by the UV-protected sleeve for the exterior pipe insulation. Sensor wire that is in contact with the collector piping shall be insulated with material that is rated for 400F.

Evaluating
The Inspector should verify that any exposed sensor wire is UV-rated.

(x) Collectors sloped ¼" per foot (minimum) towards the collector inlet *for drainback systems*

Drainback systems utilize water or a low-concentration glycol/water solution as a heat transfer fluid. In order to avoid freeze damage, these systems depend upon drainage of the heat transfer fluid when the pump is not in operation. To accomplish this, collectors must be sloped towards the collector inlet.

There is concern about using a low-concentration mixture of glycol in a drainback system that consistently shuts down during full sun due to reaching the tank's high temperature limit. Some systems have shown significant glycol degradation under these conditions.

> **Important note:** The collectors in a drainback system must be able to drain. Most harp-style flat plate collectors are appropriate for drainback systems. Serpentine/meander-style flat plate collectors cannot be used in drainback systems due to their inability to drain properly. For evacuated tube collectors, consult the manufacturer's literature to determine whether the collector is designed to be used with drainback systems. While some evacuated tube collectors can be used in drainback systems, the warranty may be voided if used for this purpose or the warranty may be voided if the collectors are empty for extended periods of time (15 days or more).

Evaluating
The collector slope can be determined with a two-foot level and tape measure.

(xi) Manual or automatic air vent installed at high point of system –or- alternate OG-300 design for air elimination *for pressurized glycol systems*

An air vent is typically required in pressurized glycol system to allow the release of trapped air at the top of the system and to facilitate system draining for maintenance. There are two industry-accepted methods for doing this:

Manual air vent
A manual air vent, also referred to as a coin vent, can be installed at the top of the system.

Automatic air vent
Another option is an automatic air vent. The air vent must be installed with a shutoff valve that allows the vent to be isolated after the initial commissioning of the system. This is necessary to avoid the entrance of air into the system during low pressure circumstances.

> **Important note:** Because the vent is typically installed near the hottest location in the system – collector temperatures may exceed 400F during stagnation - the vent must be rated for working temperatures of at least 360F and be located several inches from the collector outlet. Typical air vents used in boiler systems are not rated for these temperatures.

Alternately, there are proprietary designs for air elimination that are approved under SRCC OG-300 Certification.

Evaluating
The Inspector shall verify that a manual or automatic high vent is installed for pressurized glycol systems or that the OG-300 Certification for the system does not require a high air vent.

(B) COLLECTOR RACKING

(i) (a) Collector racking installed per manufacturer's specifications –OR-
(b) Custom rack engineered and installed per design specifications

Manufacturers have proprietary designs for attaching their collectors to a roof, wall, or ground-mount foundation. These designs are typically engineered and are specific to the collector.

Flat plate collectors

Flat plate collectors are typically attached by one of three methods:

- **Clamp system:** with this method, a clamp slides into a groove or flange in the side of the collector frame to clamp the collector to a backing strut (see Figure 1-25).
- **Bracket with set-screw:** some collectors are attached via a groove on the back of the collector frame. This design typically utilizes a set-bolt to clamp a bracket to the collector (see Figure 1-26).
- **Direct attachment to collector frame:** Some manufacturers attach a bracket to the collector frame using stainless steel self-tapping screws (see Figure 1-27).

Evacuated tube collectors

Unlike flat plate collectors, evacuated tubes are not self-supporting, thus they require a metal frame to support the manifold, tubes, and attachment strut that secures the bottoms of the tubes. The manifold and strut are typically attached to the frame via clamps (see Figure 1-28) or bolts.

Tilt racks

Most collector manufacturers offer optional tilt racks that can be used to increase the tilt angle of the collector. These are proprietary and must be installed per the manufacturer's specifications.

Custom racks

Occasionally, an Installer will utilize a custom tilt rack. The rack must be designed to withstand the weight of the collector and heat transfer fluid, seismic loads, snow loads, and – most importantly – wind loads. Custom tilt racks should be engineered.

Figure 1-25 – Clamp style collector attachment

Figure 1-26 – Set-screw style collector attachment

Figure 1-27 – Direct attachment to collector frame

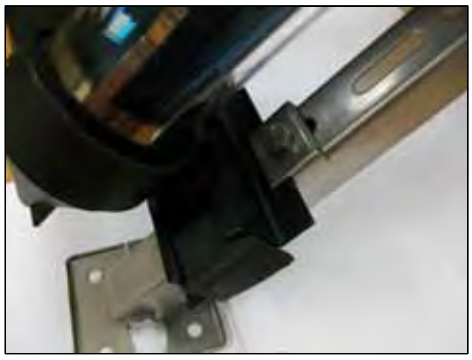


Figure 1-28 – Clamp connecting evacuated tube collector to mounting rack

Evaluating
Plans should be made available to the Inspector for the particular racking system being used. The Inspector should verify that all components are installed as specified by the manufacturer or engineer.

(ii) Attachment between collector(s) and rack fastened properly

The Inspector should verify that the attachment points between the collector and the rack have been tightened properly.

(iii) Dissimilar metals galvanically isolated between collector rack and metal roofing

Most proprietary racks are designed of aluminum or stainless steel with stainless steel fasteners to ensure material compatibility and eliminate the potential for galvanic corrosion. Improper isolation of dissimilar metals can lead to galvanic corrosion, as seen in Figure 1-29. Custom engineered racks must take this into consideration and connections between any rack and a metal roof must use an appropriate gasket. Paint alone is not an adequate means to isolate dissimilar metals due to the deterioration of the finish over time. All methods for ensuring galvanic isolation shall be installed per the roofing manufacturer's specifications.

Figure 1-29 – Galvanic corrosion on a collector array due to direct contact of dissimilar metals between the collectors and racking

Evaluating
The Inspector shall provide details from the roofing manufacturer regarding galvanic isolation of the collector rack and the metal roof. The Inspector should verify that all components are installed as specified by the manufacturer.

(iv) (a) Collector rack connected to structure in accordance with building permit –OR- (b) Collector rack connected to structure in accordance with collector manufacturer specifications -OR- (c) Collector rack connected to structure in accordance with engineered design

The connection between the collector rack and the structure is a critical consideration. The Mechanical Code of New York State stipulates that "the building or structure shall not be weakened by the installation of mechanical systems." Improper installation of solar collectors can lead to collectors detaching from the roof or *failure of the roof structure*.

Roof integrity
The Installer must verify that the roof structure is capable of supporting the collector array. For buildings that are constructed to current building codes, a flush-mounted collector will not add significant loads to the roof. The dead load of a filled collector is roughly 2-3psf. Older structures

that are not built to current codes should be evaluated for their structural integrity. A roof that shows significant visual dips in the roof rafters is likely structurally inadequate for installing collectors. Such a roof needs to be reinforced prior to collector installation.

When collectors are mounted on tilt racks, wind loads will increase the required structural strength significantly. Many manufacturers will provide guidelines for determining loads on the tilt rack, which can be used to determine the affect the system will have on the structure. When tilt racks are mounted on a low-sloped roof, wind loading will be amplified and the roof should be evaluated by an engineer to determine whether the wind loads on the array will exceed the structural strength of the roof members.

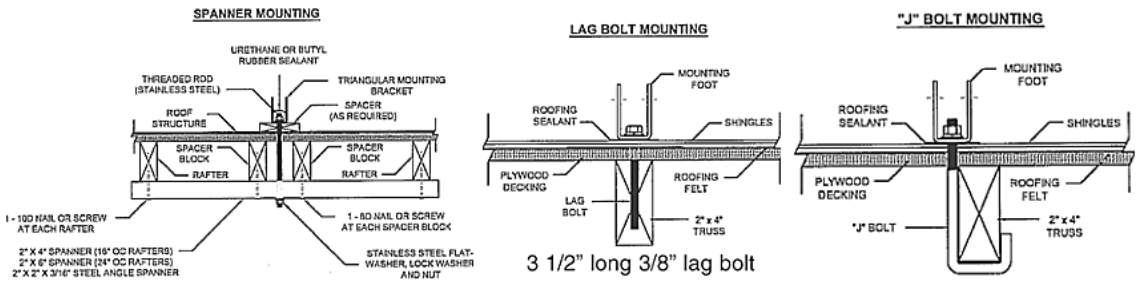


Figure 1-30 – Appropriate attachments to a building's roof structure (images courtesy of *Solar Hot Water Systems: Lessons Learned 1977 to Today* by Tom Lane*).*

Connection points

Collector frames must be attached to structural members. Examples include rafters, roof trusses, or wall studs. Sheathing is not an acceptable attachment point. The frame can be attached to the structure by using appropriately sized lag screws, spanners, or J-bolts (see Figure 1-30). On structures with standing-seam metal roofs, collectors can be flush-mounted on proprietary clips that are attached to the metal seams of the roof (see Figure 1-31). Tilt racks should not be attached to these seams. Additionally, proof of attachment of the standing seam metal roofing to the roof structure shall be provided to verify the integrity of the attachment points.

Figure 1-31 – Standing seam clamp attached to collector bracket

Lag screws

Due to the structural integrity of spanners and J-bolts, these two connections are preferred. When installed correctly, lag screws are also acceptable. Concern arises when lag bolts split out the rafter or roof truss (see Figure 1-32). When using lag screws, the Installer must verify that the lag screw is properly embedded. When rafters are exposed in an attic, this can be done by visual inspection. If the underside of the rafter is concealed in a cathedral ceiling, verification must be made while drilling pilot holes and installing the lag screws. Lag screws that spin once torqued indicate improper installation (typically due to missing or blowing out the side of a rafter or roof truss).

Figure 1-32 – Improperly installed lag bolt (image courtesy of Mark Thornbloom)

The depth of the lag screw is critical. Withdrawal – where

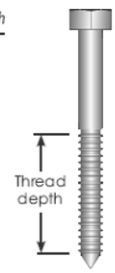
the lag screw is being pulled out of the structural member – is the critical design scenario for common tilt racks. Figure 1-33 shows standard design values per inch of thread depth for a 5/16" lag screw installed in various species of wood.

When installing the feet of a tilt rack, a minimum of two lag screws must be installed per attachment point. Using just one lag screw allows for prying action of the foot (see Figure 1-34).

> ***Evaluating***
> Ideally, the Authority Having Jurisdiction will require a building permit and ensure that the design for collector attachment to the structure is compliant. If this is not available, the Installer is responsible for justifying the roof connection through manufacturers' specifications or an engineered design. Consideration must be made for the roof structure. If the roof system appears marginal for the installation, it should be noted on the ***Inspection Checklist***.

Lag pull-out (withdrawal) capacities (lbs) in typical roof truss lumber

		Lag screw specifications		
	Specific gravity	5/16" shaft,* 2½" thread depth	5/16" shaft,* per 1" thread depth	3/8" shaft,* per 1" thread depth
Douglas Fir, Larch	0.50	665	266	304
Douglas Fir, South	0.46	588	235	269
Engelmann Spruce, Lodgepole Pine (MSR 1650 f & higher)	0.46	588	235	269
Hem, Fir	0.43	530	212	243
Hem, Fir (North)	0.46	588	235	269
Southern Pine	0.55	768	307	352
Spruce, Pine, Fir	0.42	513	205	235
Spruce, Pine, Fir (E of 2 million psi and higher grades of MSR and MEL)	0.50	665	266	304



Sources: Uniform Building Code; American Wood Council.

Notes: (1) Thread must be embedded in a rafter or other structural roof member.
(2) Pull-out values incorporate a 1.6 safety factor recommended by the American Wood Council.
(3) See UBC for required edge distances.

**Use flat washers with lag screws.*

Figure 1-33 – Withdrawal capacities for 5/16" lag screws (image courtesy of EcoFasten Solar)

(v) Attachment points flashed and sealed properly

Any penetration made through the water-tight membrane of the building – typically the roof surface - must be properly sealed. If the roof is warrantied, the installer of the roof should be consulted to ensure that any new attachments will not void the roof warranty. Acceptable methods for sealing structural penetrations may include:

- **Mechanical flashing:** There are numerous products on the market that utilize mechanical means for sealing roof penetrations. These products typically use gaskets and flashing plates and do not require chemical sealants. The Inspector should ensure that these flashings have been installed in accordance with the manufacturer's specifications.

Figure 1-34 - Example of improper attachment of tilt rack foot. Without a bolt in the front hole, live loads would pry the foot from the roof surface. A neoprene gasket should also be installed between the foot and metal roofing to provide a durable seal for the bolt penetration and to isolate dissimilar metals.

- **Roof boots:** Mounting systems that utilize cylindrical standoffs can utilize standard roof boots to seal around the standoff (see Figure 1-35). Boots should be installed in accordance with the manufacturer's specifications. This typically requires the use of sealant and a stainless steel hose clamp to seal the rubber boot to the standoff.
- **Gasket sealing:** The use of proprietary or custom neoprene or EPDM gaskets is suitable when used in conjunction with appropriate chemical sealants (see Figure 1-36). The gasket should be cut to fit the bottom of the mounting foot and sealant should be applied to the bottom of the gasket, the threads of the lag bolt, and the head of the lag bolt (once the bolt is installed). The gasket and sealant shall extend sufficiently beyond the mounting foot to allow for inspection.

Figure 1-35 – Roof boot (on right) used to seal cylindrical standoff (copper top hat pipe flashing on left)

> ***Evaluating***
> The Inspector shall verify that the type of flashing used is appropriate for the application and that it was installed properly.

(vi) Foundation installed per specifications detailed in building permit *for ground-mounted systems*

When new foundations are installed to support a ground-mounted collector array, a building permit should be obtained. The Inspector should verify that the foundation has been installed in accordance with the construction plans submitted with the permit, including depth of foundation(s), size of foundation(s), and spacing of foundation components. Acceptable means for ground-mounted foundations include, but are not limited to:

- Cast-in-place concrete piers
- Cast-in-place concrete slabs
- Precast concrete piers
- Posts appropriately anchored into bedrock
- Helical piles

Figure 1-36 – Custom EPDM gasket for mounting foot. Sealant should be applied between gasket and roof and gasket and foot before installing the lag screws.

> ***Evaluating***
> The Inspector shall verify that the ground-mounted foundation is constructed as designed.

(C) EXTERIOR PIPING

(i) Exterior piping supported properly

Copper piping should be used for most exterior piping. Where system specifications allow for other types of piping (stainless steel linesets or, in rare occasions, PEX), the system must adhere to SRCC's ruling on the acceptable use of PEX in drainback systems (see http://www.solar-rating.org/certification/ogdocuments/PEX_policy_for_drainback_systems.pdf) or written

justification from the piping manufacturer must be presented to the Inspector to ensure the equipment is rated for the appropriate pressure and temperature.

Copper tubing must be supported as follows (per the Mechanical Code of New York State):

Size	Maximum horizontal spacing	Maximum vertical spacing
1¼-inch diameter and smaller	6 feet	10 feet
1½-inch diameter and larger	10 feet	10 feet

Unless it is part of a heat dissipation zone, piping should be supported on the outside of the insulation to avoid thermal bridging between the piping and outside air through the pipe support. This also ensures proper isolation of dissimilar metals.

Exterior piping can be supported as follows:

- **By the collector or collector rack:** Support mechanisms, such as threaded rod or conduit clamps, can be attached to the structure of the collector and/or rack.
- **By the roof:** For long runs along the roof, the piping can be supported by stands that are attached to the roof. All penetrations must be sealed per Section 1(B)(v) of this manual. Piping should not be laid on the roof for support.
- **Immediately under the roof:** Where the distance between the pipe penetration and the collector is less than those stipulated above, the piping can be supported by a roof joist or roof rafter immediately adjacent to the pipe penetration. It is critical that the pipe support is rigid enough to eliminate pipe movement that may displace the pipe flashing while also allowing for thermal expansion.

Ground-mounted systems

Piping between the collector array and heat exchanger in a ground-mounted system should be located underground. The piping between the collectors and the ground shall adhere to these standards. Details about appropriate practices for burying piping are covered in Section 2(A) of this manual.

Evaluating

The Inspector shall verify that the exterior piping is appropriately supported at intervals less than or equal to the minimum support spacing detailed above.

(ii) Exterior piping insulated properly

Types of insulation

Due to the maximum temperatures associated with SWH systems, only particular types of pipe insulation are appropriate. These include fiberglass, mineral wool, and elastomeric rubber. Pipe insulation must be rated for stagnation conditions, which may reach 400F.

Elastomeric (rubber) pipe insulation is the most common type used in residential SWH systems (see Figure 1-35), due to its ability to withstand the temperatures present in the collector loop. Polyethylene pipe insulation, which is typically used to insulate domestic water lines, cannot withstand these temperatures and will melt when used on the collector loop piping. Fiberglass is appropriate for interior applications, but should not be used in exterior applications due to its

ability to saturate with moisture. Mineral wool is less hydroscopic than fiberglass but is not recommended for exterior applications. Only hydrophobic materials, such as elastomeric rubber or foam glass should be used.

Thickness of insulation
The Energy Conservation Construction Code of New York State states that mechanical system piping in residential systems must be insulated to a minimum of R-3 when carrying fluids above 105°F. Due to higher temperature differentials in exterior applications, elastomeric insulation used for exterior applications should be a minimum of ¾" (R-4).

Installation
It is critical that the insulation provides full coverage for external piping – this includes the pipe connections between collectors and header pipes that are capped. Pipe insulation should be sealed at the seams and care should be taken to ensure that all fittings are properly insulated.

Ground-mounted systems
Piping between the collector array and heat exchanger in a ground-mounted system should be located underground. The piping between the collectors and the ground shall adhere to these standards. Details about appropriate practices for insulating buried piping are covered in Section 2(A) of this manual.

Evaluating
The Inspector shall verify that the exterior pipe insulation is high-temperature, hydrophobic pipe insulation with a minimum thickness of ¾".

(iii) Pipe insulation protected from UV degradation

All exterior insulation must be protected from UV degradation. Often, exterior piping is treated as a service item due to the impacts of UV radiation and other exterior conditions. The Installer should exercise due diligence to minimize this need to service the pipe insulation. This can be done in a variety of ways:

- **UV-resistant coating**: Some types of elastomeric insulation have a UV-resistant coating on them. A material that is rated as "UV-resistant" can still degrade under conditions typically seen in solar heating systems. The Installer should determine the length of the warranty for insulation that is exposed to the sun if a coating is the only means of protection used.
- **Sheathing/cladding**: Metal or PVC cladding (see Figure 1-37) can be used to protect exterior insulation.
- **Paint**: Some elastomeric insulation can be painted with latex paint to provide additional UV protection.
- **Wrap**: UV-resistant wraps, such as silicone tape, can be used to protect the pipe insulation.

Figure 1-37 – PVC cladding over exterior insulation

Evaluating
The Inspector shall verify that the exterior pipe insulation has appropriate UV-protection.

(iv) Pipe penetrations flashed and sealed properly

Pipe penetrations present a unique challenge in solar water heating systems. Due to stagnation temperatures in pressurized systems, some pipe flashing systems that are used for standard plumbing vents are not adequate. Typical EPDM roof boots are rated to 180F. Flashing materials should be rated to 400F in pressurized glycol systems if placed in direct contact with the solar piping. Therefore, pipe penetrations should be flashed as follows:

Figure 1-38 – Copper top hat flashing with gooseneck for sensor wire. In this example, the flashing sheet was installed entirely under a course of shingles. If the flashing falls on a seam or has inadequate coverage by the upper course, this is necessary.

Asphalt shingle roof

The standard detail for asphalt shingled roofs is the "copper top hat" flashing. This flashing is sheet copper with a copper collar soldered on (see Figure 1-38). A cap slides down over the piping and is soldered *to the piping but not the collar*. If the cap is soldered to the collar, it will affect the integrity of the flashing as the piping expands and contracts. The flashing extends under the upper course of shingles. The bottom of the upper course of roofing shingles should be sealed to the flashing with roofing cement. Roofing cement should be used on the bottom of the flashing, as well. The copper top hat flashing is secured in place with roofing nails; these should be driven under the upper course of shingles.

Figure 1-39 – Silicone pipe flashing on metal roof. Note that the sealant between the flashing and the roof should extend beyond the flange for inspection purposes. Also, care should be taken to avoid squeezing the silicone through the hose clamp, as it is here.

Another option on asphalt-shingled roofs is a silicone vent flashing (aka "roof boot") that slides under an upper course of shingles. Silicone is rated for 500F intermittent and 437F for continuous and can be used in direct contact with piping in a pressurized glycol system. For drainback systems, EPDM vent flashing is appropriate (rated for 275F intermittent and 212F continuous). Vent flashing should be installed in accordance with the manufacturer's specifications. This typically requires the use of sealant and a stainless steel hose clamp to seal the boot to the standoff.

Metal roofs

Another type of silicone or EPDM boot is typically used on metal roofs (see Figure 1-39). A malleable flange is attached to the roof with self-tapping stainless steel screws and a bead of silicone caulk is applied between the flange and roofing. Silicone should be used for direct contact with piping in pressurized glycol systems.

Evaluating

The Inspector shall verify that all piping penetrations are flashed, that the flashing system used is appropriate for the application, and that the flashing is installed properly.

(v) Piping sloped ¼" per foot, minimum, *for drainback systems*

Drainback systems utilize water or a low-concentration glycol/water solution as a heat transfer fluid. In order to avoid freeze damage, these systems depend upon drainage of the heat transfer fluid when the pump is not in operation. To accomplish this, all piping must be sloped towards the pump.

> ***Evaluating***
> The slope of piping can be determined with a two-foot level and tape measure.

(vi) Dissimilar metals isolated properly, if required

Black iron or galvanized fittings should not be used in exterior applications. Brass, copper, and stainless steel can be joined together by mechanical and/or soldered joints.

> ***Evaluating***
> The Inspector shall look for any joints in the piping to ensure proper material compatibility.

(vii) Polymer materials are not used in the collector loop unless approved by the SRCC in a specific OG-300 certified system

There have been numerous attempts to incorporate polymer materials, such as cross-linked polyethylene (PEX), within pressurized solar heating systems to reduce labor and material costs. Unless designed appropriately, these systems will fail due to the temperatures and pressures experienced during stagnation. The SRCC allows the use of polymers only in very specific applications.

> ***Evaluating***
> If any polymer materials are used in the collector loop, the Inspector must verify that the system is OG-300 Certified and that the materials were installed in accordance with the OG-300 Installation Manual.

SECTION 2: SOLAR LOOP

The solar loop between the collector array and heat exchanger includes the critical components that ensure the proper operation of SWH systems. This section of the system includes piping, valves, gauges, pumps, insulation, and heat transfer fluid.

The ease of inspection of the solar loop will vary by installation. In new construction, some of the components will have been buried in insulation, chases, or the walls of the structure. It is important that the Inspector inquires about these sections and inspects the portions of the loop that are accessible. Care should be taken when accessing attics during the inspection – this includes eye and respiratory protection, as well as maintaining proper footing. If the Inspector accesses the attic, s/he can also verify that the lag bolts did not split out the side of a rafter or truss chord.

Section 2 is organized as follows:

- **Piping considerations:** Piping must be insulated, supported properly, and allow for system draining.
- **Heat transfer fluid:** Because there is risk of contamination between the heat transfer fluid and potable water supply, and because the heat transfer fluid may be subjected to extreme conditions, proper attention must be paid to its selection.
- **Pressure considerations:** While SWH systems typically operate under pressures common to other hydronic systems, during stagnation events they may see pressures above 100psi. This section discusses appropriate techniques for mitigating issues resulting from these pressure spikes.
- **Other considerations:** This category covers other items relating to the solar loop that are necessary for proper system operation.

(A) PIPING CONSIDERATIONS

(i) Piping supported by appropriately-spaced hangers

Copper tubing must be supported as follows (per the Mechanical Code of New York State):

Size	Maximum horizontal spacing	Maximum vertical spacing
1¼-inch diameter and smaller	6 feet	10 feet
1½-inch diameter and larger	10 feet	10 feet

Other piping materials must be installed in accordance with the Mechanical Code of New York 305.4 or the manufacturer's specifications.

Evaluating
The Inspector shall verify that all piping supports are spaced at proper intervals.

(ii) (a) Hanger material compatible with piping material –OR- (b) Hangers isolated properly from piping

To avoid the effects of galvanic corrosion between dissimilar materials, appropriate hangers must be used with system piping. Hangers that directly support copper must be made of copper or be plated with a material that isolates the copper from the hanger material. Examples of appropriate hangers include:

Figure 2-1 – Split ring, threaded rod, and plate

Figure 2-2 – Bell hanger

Figure 2-3 – Milford hanger

- **Split ring connectors:** these connectors are made of plated steel and clamp the piping (see Figure 2-1). Threaded rod is used to connect the split ring to a plate that is attached to the structure. Nuts should be used on the threaded rod to properly secure the support.
- **Bell hangers:** these hangers are typically plated metal that clamp around the pipe and connect directly to the structure (see Figure 2-2). The "bell" portion of the hanger holds the pipe approximately 1" from the surface of the structure.
- **Milford hangers:** this style of hanger is used to hang piping below a structural support, such as a floor joist. The device consists of a clamp and strapping (see Figure 2-3). These hangers are typically made of plated steel.

Piping can also be supported on the outside of the insulation. When done this way, either with clevis hangers (see Figure 2-4), conduit straps, or plumber's strap, consideration must be made to keep the support from compressing the insulation. This can be done using a bearing strip, either custom-made or similar to the one seen in Figure 2-4.

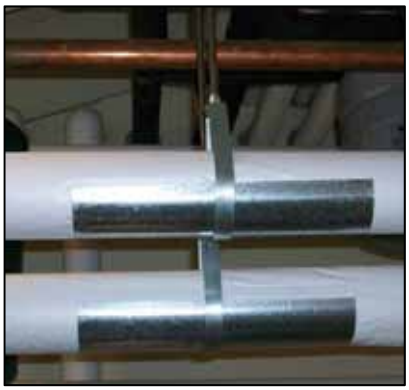


Figure 2-4 – Clevis hanger with bearing strip to protect pipe insulation

Evaluating
The Inspector shall verify that all piping supports are galvanically isolated from the piping.

(iii) Piping insulated properly

Types of insulation
Pipe insulation must be rated for high solar loop temperatures. Appropriate pipe insulation materials include: elastomeric rubber, fiberglass, and mineral wool.

Thickness of insulation
The Energy Conservation Construction Code of New York State states that mechanical system piping in residential systems must be insulated to a minimum of R-3 when carrying fluids above 105°F. The minimum thicknesses for various types of pipe insulation are listed below:

- Elastomeric: ½”
- Mineral wool: 1”
- Fiberglass: 1”

Installation
Pipe insulation must be installed on the entire solar loop to ensure efficient delivery of solar heat from the collectors to the heat exchanger(s). When split-style insulation is used, the seam must be sealed. Care should be taken to fully insulate fittings.

Ground-mounted systems
Elastomeric insulation should be used for underground pipe runs. Underground solar piping is typically insulated utilizing one of the following methods:

- The use of proprietary, pre-insulated linesets that are rated for the temperatures and pressures of a pressurized glycol system;
- Soft copper with elastomeric pipe insulation encased in a sealed PVC conduit;
- Soft copper with elastomeric pipe insulation sprayfoamed in a trench. The elastomeric insulation is used to isolate the copper from the sprayfoam, which can melt when exposed to stagnation temperatures.

Evaluating
The Inspector shall verify that the interior pipe insulation on the collector loop is either high-temperature elastomeric with a minimum thickness of ½”, or fiberglass or mineral wool pipe insulation with a minimum thickness of 1”.

(iv) Dissimilar materials isolated properly, if required

Galvanized steel should not be used for solar piping in pressurized glycol systems as it will react with the inhibitors in glycol to create a sludge. Black steel should not be used in systems with entrained air, such as drainback systems. Where cast iron components are necessary, a dielectric fitting or brass fitting must be used to transition to copper or stainless steel.

Evaluating
The Inspector shall look for any joints in the piping to ensure proper material compatibility. Particular points of interest include transitions between piping materials, most notably at the storage tank and pump station.

(v) Penetrations through structural members consistent with code

When piping must be run through structural members, such as floor joists or rafters, care must be taken to retain the integrity of the member. Figure 2-5 illustrates the restrictions on notching and boring through wooden joists.

When drilling through wood studs in bearing walls, the hole cannot exceed 40% of the depth of the stud. In non-loadbearing walls, a hole cannot exceed 60% of the depth of the stud. The hole must be at least 5/8” from the edge of the stud.

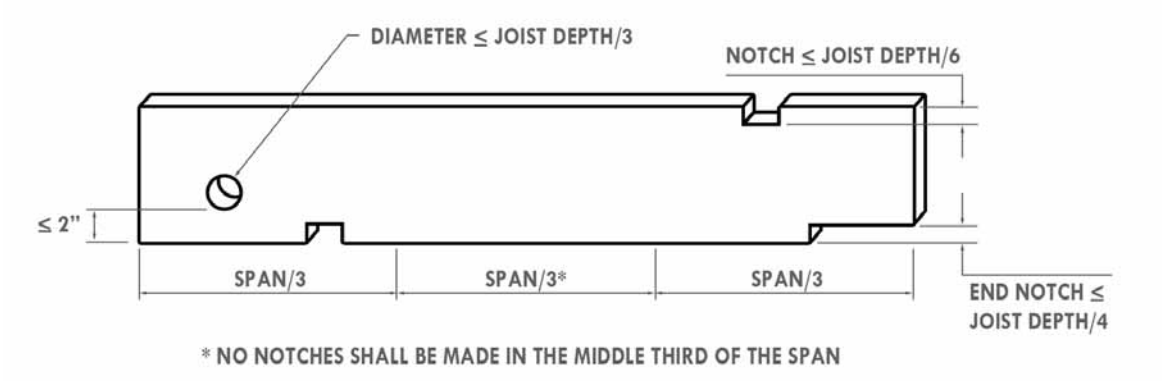


Figure 2-5 – Code requirements when notching or boring through joists

The Installer and Inspector must consult the manufacturer’s recommendations when holes are required in trusses or engineered wood products.

> ***Evaluating***
> The Inspector shall verify the proper location of penetrations in all exposed structural members.

(vi) Piping backfilled properly *for ground-mounted systems*

Because the solar piping in a ground-mounted system is already frost protected in a pressurized glycol system, burial below frost depth is not required – it is recommended where possible, though. Displacement of the piping due to frost action is a concern and should be considered since the structure and the ground-mount are designed to be rigid.

The Mechanical Code of New York State requires piping to be covered with a minimum of 12” of backfill. Other requirements for buried pipe include:

- Pipe must be supported for its entire length
- Backfill beneath pipe shall be compacted in 6” layers
- Backfill shall be loose earth free from rocks, broken concrete, construction debris, or frozen chunks
- Backfill must be placed in 6” layers and tamped in place
- At least 3” of backfill must be placed on top of removed rock to provide a proper bed for the buried piping

> ***Evaluating***
> The Installer shall keep any trenches open until the Inspector has verified the piping and insulation. Backfill material should be present during the inspection.

(vii) Piping installed to allow system draining

Solar piping must be installed to permit draining of the system for servicing. In sections of pressurized glycol systems where a trap is formed because the piping cannot be sloped

appropriately, a drain shall be installed. Buried pipe is exempt from this requirement. Drainback systems must be sloped to allow for system draining during normal operation.

> ***Evaluating***
> The Inspector should verify the presence of a drain in any sections of the system that cannot drain by gravity or with the use of pressurized air.

(B) HEAT TRANSFER FLUID

(i) (a) System utilizes water as heat transfer fluid –OR- (b) System utilizes propylene glycol solution as its heat transfer fluid

While the New York State Codes technically allow for the use of toxic heat transfer fluid when using a double-wall heat exchanger, there is no practical reason to include ethylene glycol or any other toxic fluid in a residential system. Leaks are common in the lifetime of a SWH systems; the use of toxic fluids puts people and pets at serious risk.

Drainback systems use either water or a propylene glycol and water solution as a heat transfer fluid.

> ***Evaluating***
> The Inspector shall verify the heat transfer fluid used in the system.

(ii) Heat transfer fluid is rated for solar applications

The fluid in a SWH system can be subjected to high temperatures, especially in pressurized systems that can stagnate. Propylene glycol is a nontoxic antifreeze that includes inhibitors to protect the fluid's stability when subjected to high temperatures. It is possible for the inhibitors to degrade under prolonged exposure to high temperatures, which leads to acidification of the glycol. If this occurs, the glycol will destroy components in the solar loop. As a result, glycol should be rated to 325F.

Water is stable as a heat transfer fluid for the temperatures experienced in a SWH system.

> ***Evaluating***
> The Inspector shall verify the type of heat transfer fluid used in the system.

(iii) Propylene glycol concentration is appropriate for application

Figure 2-6 shows the temperature ratings for various concentrations of one brand of propylene glycol rated for solar applications. The freeze point represents the temperature at which ice crystals begin to form. The flow point is the temperature at which the solution will still flow. The burst point is the temperature at which the fluid becomes solid and threatens to burst

NOBURST HD	Freeze Point	Flow Point	Burst Point
100%	-60°F	-70°F	-100°F
75%	-60°F	-60°F	-100°F
50%	-30°F	-40°F	-75°F
40%	-7°F	-15°F	-60°F
35%	0°F	-10°F	-60°F

Figure 2-6 - Temperature ratings for NoBurst HD propylene glycol (image courtesy of the Noble Company)

the piping and components of the solar loop.

For pressurized glycol systems, the glycol concentration should reflect the minimum ambient temperatures for the site. For New York, this translates to a glycol concentration of 40-50%.

Glycol can be used as a heat transfer fluid in drainback systems, as well. The glycol adds a secondary freeze protection, thus a lower concentration of glycol (25-30%) can be used. Glycol is only required in drainback systems where a component failure could lead to catastrophic system failure, such as a system that utilizes pumps in series. The use of glycol in drainback systems may lead to the accumulation of residue in collector piping and the breakdown of glycol inhibitors if the system constantly shuts down due to reaching the storage tank high limit.

Figure 2-7 - Refractometer for measuring concentration of propylene glycol solution (image courtesy of ExTech)

The glycol concentration can be verified by use of a glycol refractometer (see Figure 2-7).

> ***Evaluating***
> The Inspector shall verify the concentration of the heat transfer fluid in the system documentation.

(C) PRESSURE CONSIDERATIONS

(i) Pressure relief valve and relief drain installed properly
(ii) Pressure relief valve cannot be isolated from collector array

All systems in New York must have a pressure relief valve to protect system components from pressure due to the expansion of fluids. The rating of pressure relief valves ranges from 30-150psi, depending upon the type of system and design. In pressurized glycol systems, there is an inverse correlation between the rating of the pressure relief valve and the size of expansion tank required – systems with lower rated pressure relief valves require larger expansion tanks.

Some manufacturers require 150psi rated valves in order to prevent steam formation in the collectors during system stagnation. Stagnation occurs in pressurized glycol systems when there is solar insolation on the collectors and the heat transfer fluid is not circulating, either due to a component failure or in order to protect the solar storage tank from excessive temperatures.

The pressure relief valve shall be installed in a location where the valve cannot be isolated from the collectors. The relief drain shall be piped to within 6 inches of the floor, cannot contain any traps, reducers, or valves, and should be directed to an area that is visible and will not cause damage to the structure or its inhabitants. A container is also an acceptable means for collecting discharged fluid.

> ***Evaluating***
> The Inspector shall verify that there are no means by which to isolate the collectors from the pressure relief valve and that the discharge piping is installed properly.

(iii) All system components rated higher than pressure relief rating

During times of stagnation, the collector array may reach temperatures exceeding 400F. This increases the system pressure and can cause catastrophic failure if the components are not protected adequately by the pressure relief valve.

Collectors, expansion tanks, heat exchangers, flow meters, piping, and all other components must be rated to a pressure exceeding the pressure rating of the relief valve. Component ratings are listed on the component itself or in the manufacturer's documentation. Relief valves exceeding 100psi should only be used in systems that are OG-300 certified.

In drainback systems, the drainback tank is typically the lowest rated component for pressure. The relief valve must be rated at a pressure less than or equal to the maximum design pressure of the drainback tank.

Evaluating
The Inspector shall verify the rating of the pressure relief valve and compare to the pressure ratings of system components.

(iv) Expansion tank sized and installed properly *for pressurized glycol systems*

Hydronic expansion tanks are used to buffer the pressure variations that exist in pressurized glycol systems. Expansion tanks must be installed in accordance with manufacturer's specifications. These usually specify the orientation of the tank.

The expansion tank should be pre-charged to a pressure 2-3psi less than the initial fill pressure of the solar loop. If the bladder is pre-charged too low, it will limit the acceptance volume of the expansion tank. If it is pre-charged too high, the expansion tank is unable to appropriately buffer the solar loop during times of fluid contraction.

The Mechanical Code of New York State requires sizing expansion tanks for pressurized glycol systems using the same technique as is used for boilers. The formula for sizing is given in Section 1009.2 of the code. <u>This method is only adequate if the system never stagnates</u>. It is impossible to ensure the system does not stagnate. If the expansion tank is sized in accordance with this code and stagnation occurs, the relief valve will release glycol and a service call may be required.

Correct sizing of the expansion tank will alleviate the need for a service call under these conditions. In addition to buffering the expansion caused by the thermal expansion of the heat transfer fluid, a solar expansion tank must also account for steam formation in the collectors. An appropriately-sized expansion tank to can absorb the normal expansion of the system fluid and accommodate the fluid in the array during a stagnation event.

Some OG-300 certified systems may use a steam prevention method that involves using a much smaller expansion tank that significantly increases pressures during stagnation, which in turn increases the boiling point of the heat transfer fluid. This is an engineered process and must be approved by the manufacturer.

Evaluating
It is impractical for the Inspector to determine the precise expansion tank sizing for each system. The following guidelines should be used for inspection purposes:

- For OG-300 systems, expansion tank sizing guidelines from the manufacturer should be used (where available).
- For systems without expansion tank sizing guidelines, Figure 2-8 can be used to determine the minimum expansion tank size for the system. The expansion tank size should be within 10% of the value given in the graph.

Important note: The values contained in Figure 2-8 are based on system assumptions and should not be used for design purposes.

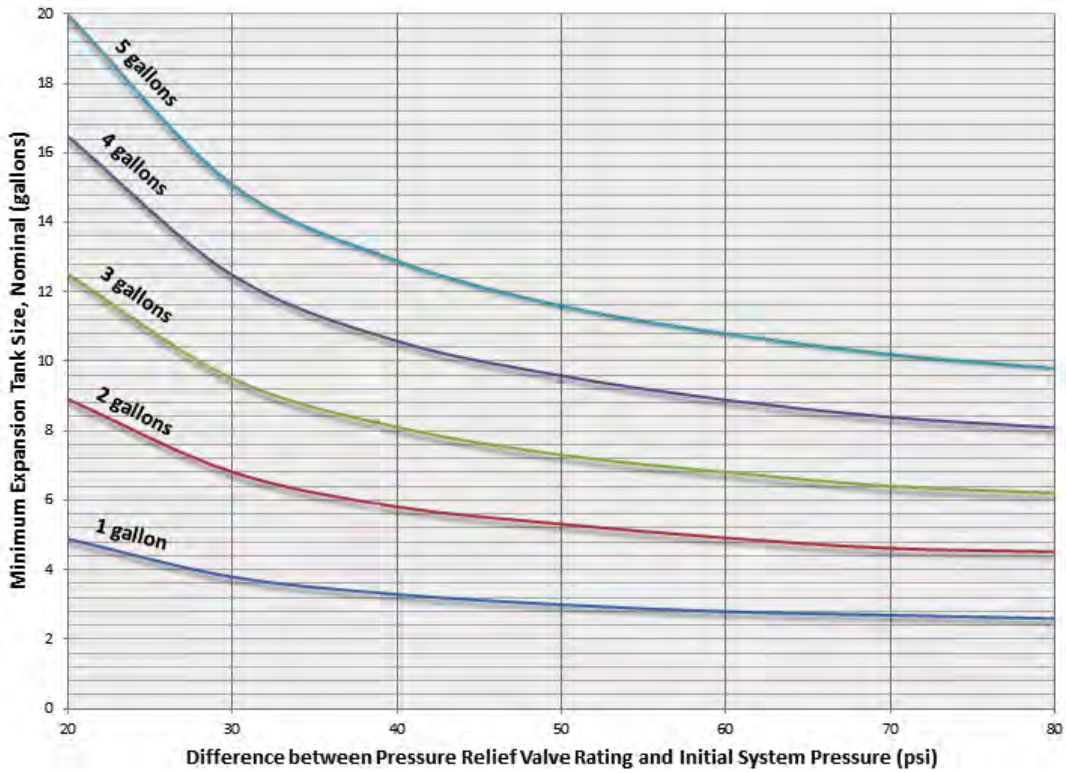


Figure 2-8 – Approximate expansion tank sizes for Inspection purposes. The curves in the figure represent the fluid capacity of the collector(s). Based on this model, a system with a two-gallon collector capacity that is initially charged to 30psi and utilizes a 90psi pressure relief valve would require a 4.9-gallon expansion tank.

(v) System test to 100psi for at least 15 minutes *for pressurized glycol systems*

For pressurized systems, the Mechanical Code of New York State requires that SWH piping shall be tested "at one and a half times the maximum system design pressure, but not less than 100psi" for at least 15 minutes.

Pressure testing SWH systems provides some challenges in comparison to other hydronic systems due to the presence of solar collectors. Dramatic changes in weather during the pressure test can influence system pressures.

The Installer must isolate any components that are not rated to the test pressure to avoid damage.

Evaluating
The Inspector must ask the Installer the pressure to which the hydronic piping was tested during the Inspection.

(vi) System pressure is within standard limits

The minimum pressure for pressurized glycol system should be 20psi at the pump station pressure gauge. For systems where the collector array elevation is more than 33 feet above the pump station, the minimum initial system pressure should be:

$$P_{min} = 0.45h + 5$$

where: P_{min} = minimum system pressure (psi)
h = the height of the collector array above the pressure gauge (in feet)

The initial system pressure should reflect the initial design pressure for the system used for sizing the solar expansion tank.

Though drainback systems are often installed at atmospheric pressure, they may be pressurized to improve performance. In drainback systems with high flow rates or significant gravity head, pressurization alleviates pump cavitation. Cavitation occurs when negative pressure before the pump cause fluid to boil at lower temperatures. This leads to the formation of bubbles that can damage the pump impeller and cause poor performance of the system.

Evaluating
The system pressure during the Inspection may be different from the initial pressure depending upon the outdoor ambient air temperature, available solar insolation, and whether the system is in operation. The Inspector should verify the initial system pressure with the Installer and observe conditions at the site to determine whether the system is pressurized properly.

In pressurized glycol systems, the system pressure may be higher than the initial pressure if the circulator is running or there is significant sun on the collectors. If it is winter and there is minimal solar energy available, the pressure should be below the initial system pressure. If the pressure is at or near zero, the system will need to be repressurized.

(D) OTHER CONSIDERATIONS

(i) Penetrations between conditioned and unconditioned space airsealed

Whenever the piping in a SWH system passes through the building's envelope – the surface that separates the indoor air that is heated from areas that are unheated (the outdoors, cold attics, crawlspaces, etc.) – the penetration must be sealed to prevent the movement of air through the building envelope.

Caulk and sprayfoam are the standard materials used for this purpose. Insulation itself is not an adequate air barrier. Air moves through certain types of insulation, thus stuffing fiberglass into the gap will not work. The seal should be installed between the piping and the envelope to ensure conditioned air cannot escape around pipe penetrations.

Evaluating
The Inspector shall identify all penetrations in the building envelope and verify proper airsealing.

(ii) Check valve properly installed to prevent passive cooling *for pressurized glycol systems*

Without a check valve, a pressurized glycol system will surrender its heat in the evening by allowing cooler fluid in the collectors to sink down the piping on the feed side and return warmer fluid in the heat exchanger to flow to the collectors through the return line.

A swing check valve (see Figure 2-9) must be installed horizontally to function properly. A spring check valve (see Figure 2-10) can be installed in any direction.

Many pre-manufactured pump stations utilize ball valves with integrated check valves that have three settings: "fully open", "open with check valve", and "closed" (see Figure 2-11). The Inspector should assure that these valves have been set in their proper configuration.

Figure 2-9 - Swing check valve with indication for direction of flow

Figure 2-10 - Spring check valve with indication for direction of flow

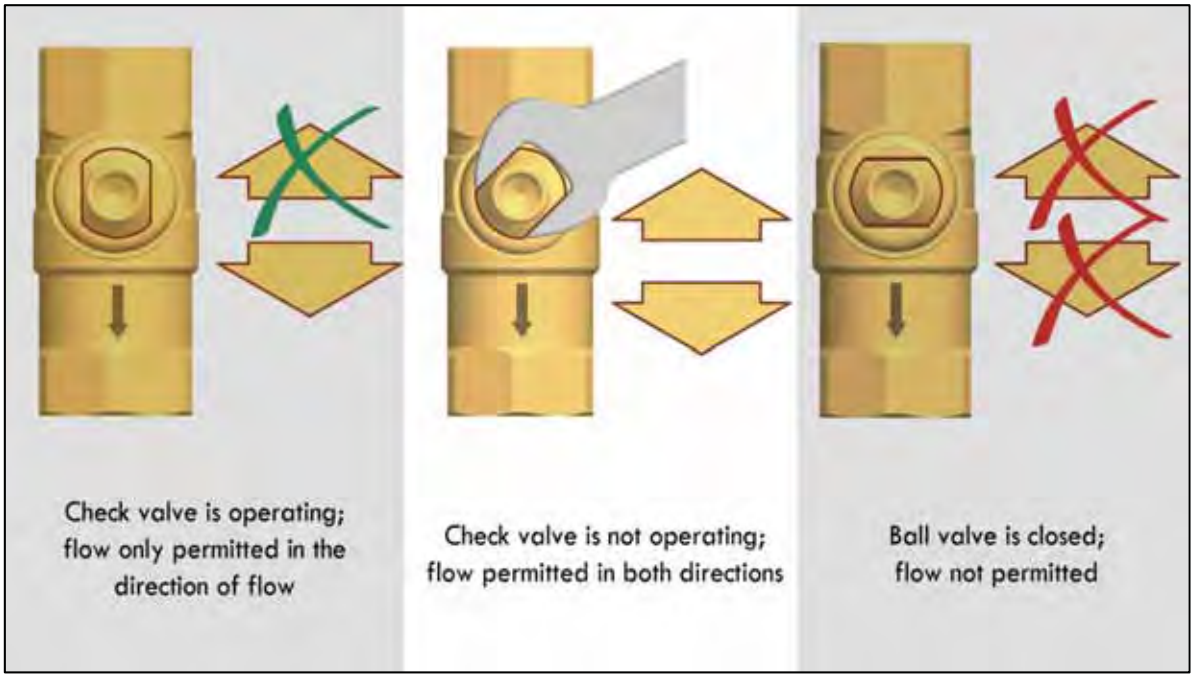


Figure 2-11 - Diagram illustrating the three settings of a specialized ball valve with an integrated check valve (image courtesy of PAW)

Evaluating
The Inspector shall verify that a check valve has been installed properly in pressurized glycol systems.

(iii) Expansion tank located between check valve and collector array *for pressurized glycol system*

During stagnation, steam should be able to evacuate out the inlet and outlet to the collector array. The steam is only able to push out the inlet piping if the expansion tank is located between the collector array and the check valve (see Figure 2-12).

Evaluating
The Inspector shall verify that the check valve has been located properly in pressurized glycol systems.

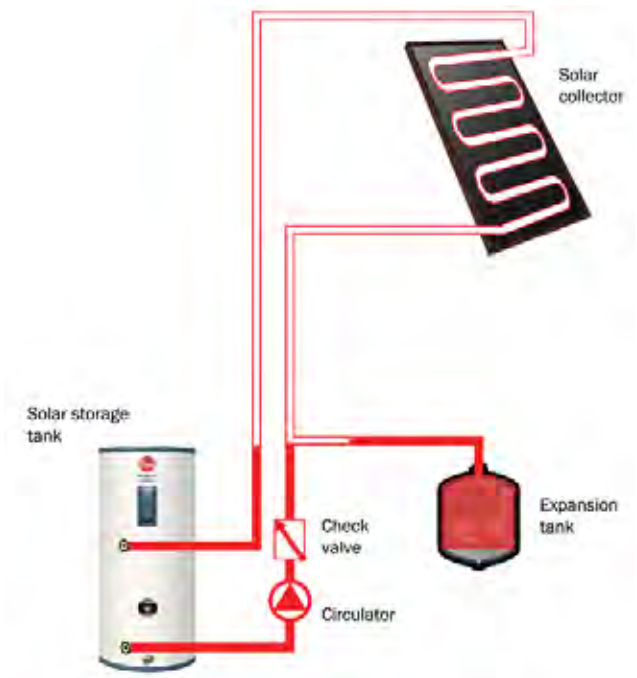


Figure 2-12 - Diagram illustrating the behavior of the heat transfer fluid in a pressurized glycol system during stagnation. The lower portion of the system remains filled with liquid while steam forms in the collector and adjacent piping. With the expansion tank positioned between the check valve and the collector array, the steam is able to push the fluid into the expansion tank from the collector inlet and outlet. If the check valve were installed above the tee to the expansion tank, steam would only be able to leave the collector through its outlet. This would lead to excessive steam development in the system and potential damage to system components (image courtesy of Kennebec Valley Community College).

(iv) System drains correctly *for drainback systems*

During the Inspection of a drainback system, the pump must be turned on until the system is filled and then turned off to verify the draining of the system. A site glass, or other appropriate method, should be installed to monitor the level of fluid in the system. It may take several minutes for the system to fill and several minutes for it to fully drain. The initial level of the system should be marked on or near the site glass for reference.

Evaluating
The Inspector shall verify that the system drains properly. The test should not be performed during freezing conditions unless the system is already running. The Inspector should then have the Installer turn off the pump manually to verify that the system drains properly.

(v) Piping labels show type of fluid and direction of flow

The solar loop piping must have a moisture-tolerant label that indicates the direction of flow and the type of piping. Labels may be purchased or custom made by laminating paper or card stock and attaching the label to the pipe insulation. Labels must be at least 8” long and lettering must be at least ½” in height.

Evaluating
The Inspector shall verify the proper installation of labels.

(vi) Drain and fill valves labeled

Drain and fill valves must be labeled with a warning that identifies the fluid in the solar loop and includes a warning that the fluid may be discharged at high temperature and pressure. Drain caps should also be installed at all drain and fill valves.

Evaluating
The Inspector shall verify the proper installation of labels.

SECTION 3: SOLAR STORAGE AND POTABLE PIPING

The solar storage tank typically represents the interconnection between the mechanical portion of the system (collectors and solar loop) and the potable portion of the system. For indirect systems, which are the most appropriate for New York, the interface between the systems is the heat exchanger. The plumbing on the solar side of the heat exchanger is governed primarily by the Mechanical Code of New York State (or the mechanical code for the local jurisdiction), while the potable side of the heat exchanger falls under the Plumbing Code of New York State (or the plumbing code for the local jurisdiction).

Section 3 deals with the potable side of the heat exchanger and contains the following sections:

- **Storage tank:** Due to the effects of pressure, temperature, and potability, the codes are very specific about the proper installation of water heaters. This category summarizes those codes requirements.
- **Potable piping:** This category summarizes the valves, temperature settings, and other requirements for connecting to the domestic water supply.

Figure 3-1 illustrates some of the key requirements of this section for a standard one-tank system.

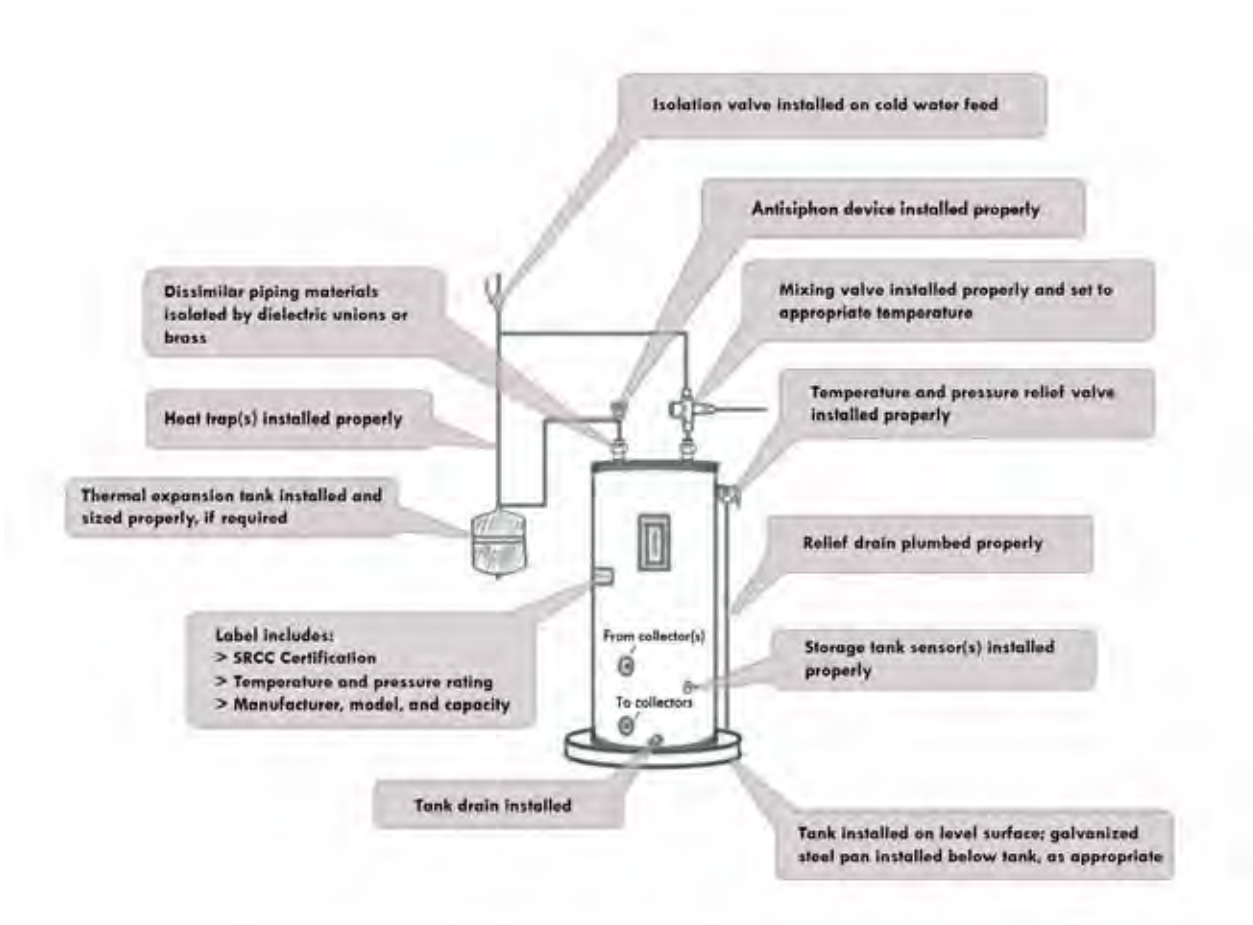


Figure 3-1 – Standard requirements for a pressurized solar storage tank in a one-tank system. Two-tank systems have similar requirements but will vary in plumbing configuration from the illustration above.

(A) STORAGE TANK

(i) Tank manufacturer, model, and capacity matches program application

Each storage tank will have a label that details the manufacturer, model, and storage capacity of the tank (see Figure 3-2). This information should be consistent with the information provided on the Application.

> ***Evaluating***
> The Inspector shall verify that the tank matches the program application.

(ii) Tank labeled with pressure rating *for pressurized storage tanks*

By code, tanks must have a label that lists their pressure ratings (see Figure 3-3). Where this information is located will depend upon the manufacturer. The pressure rating of the tank must exceed the pressure rating of the temperature and pressure relief valve.

Figure 3-2 – Manufacturer's label with information regarding the model and storage capacity

Figure 3-3 – Example of tank label with pressure rating

> ***Evaluating***
> The Inspector shall verify the pressure rating of the tank.

(iii) Temperature and pressure relief valve installed properly *for pressurized storage*
(iv) Relief drain plumbed properly *for pressurized storage*

Pressurized storage tanks must be equipped with a relief valve to protect the tank from excessive temperature and pressure. The relief valve must be installed within the top 6 inches of the tank vessel and cannot have any valves located between it and the tank. The temperature probe of the valve should be located *in the tank*.

The discharge piping for the relief valve must be plumbed to within 6 inches of the floor, cannot contain any traps, reducers, or valves, and must drain to an area that is visible and will not cause damage to the structure or its inhabitants.

> ***Evaluating***
> The Inspector shall verify that there are no means by which to isolate the tank from the temperature and pressure relief valve and that the discharge piping is installed properly.

(v) Tank drain installed *for pressurized storage*

It is critical that the tank is able to be drained conveniently for routine maintenance and service. In order to facilitate this, a low point drain must be installed.

> ***Evaluating***
> The Inspector shall verify installation of a drain.

(vi) Tank vented to atmosphere *for atmospheric tank*
(vii) Tank water adjusted to proper pH level *for atmospheric tank*

Unpressurized tanks typically utilize synthetic vessel liners and copper heat exchangers (see Figure 3-4). The fluid contained in an unpressurized tank is stationary – it is used solely as a medium for storing transferring heat from the solar collectors to the various demands in the facility. Heat may be transferred to the tank fluid directly (in the case of atmospheric drainback systems) or indirectly (through a heat exchanger). The water in the tank is not connected to the potable water source for the facility and must maintain certain characteristics to ensure proper performance of the system. These requirements include venting the tank to the atmosphere to ensure that is does not pressurize and to ensure the pH of the stored water does not cause deterioration of the heat exchanger(s). The Installer and Inspector should refer to the manufacturer's documentation for specifications regarding the pH level.

Figure 3-4 – Interior view of unpressurized tank (image courtesy of Liquid Solar Systems).

> ***Evaluating***
> The Inspector shall verify that a vent has been installed, and that the pH of the water is within acceptable limits. The Installer shall provide manufacturer's specification on required pH levels and a pH testing kit for the Inspector's use.

(viii) Galvanized steel pan installed below tank, as appropriate

When solar storage tanks are installed in areas where leakage would cause damage (such as when installed on wood-framed floors), a galvanized pan must be installed beneath the water heater. The pan drain must be piped to an appropriate location with ¾" piping, minimum.

> ***Evaluating***
> The Inspector shall verify the installation of a pan and drain, where appropriate.

(ix) Tank installed on level surface
(x) Tank supported for seismic loads, if applicable

It is critical that the storage tank is sited in a stable location. An 80-gallon stone-lined tank weighs approximately 1000 pounds when filled! It is critical that the surface is capable of supporting the weight of the filled tank, that the tank is installed on a level surface to ensure stability of the tank, and that the tank is braced properly in jurisdictions that require support for seismic loads.

For most residential applications in New York, seismic considerations for tanks are negligible. Where required, possible seismic support includes: properly strapping the tank to a wall that is capable of supporting such loads –or- anchoring the feet or sidewalls of the water heaters into the support structure. Seismic requirements will depend upon the application and jurisdiction.

Evaluating
The Inspector shall verify the suitability of the tank foundation and whether seismic support is adequate, where required.

(xi) Tank meets requirements for installation in attic or garage, if applicable

In rare instances, storage tanks may be installed in an attic or garage. When installed in an attic, the tank must be able to fit through the access to the attic to accommodate future replacement, a drain pan must be installed, and a passageway must be provided to service the appliance. Water heaters installed in a garage must be elevated 6 feet above the floor or must be protected from being hit by a vehicle by a permanent wall or properly-rated guardrail.

Evaluating
The Inspector shall verify clearances, access, and protection for tanks located in an attic or garage.

(xii) Storage tank sensor(s) installed properly

It is critical for proper operation of the differential controller, for system efficiency, and to protect the tank against overheating that the tank sensor(s) are located and installed properly.

Lower tank sensor
The lower tank sensor is a requirement for systems with differential controls. This sensor measures the temperature of the potable water near the heat exchanger in order for the controller to determine then temperature differential between the tank and the collector. If the sensor is placed inappropriately, the controller will be unable to accurately respond to the conditions of the system, which may lead to the pump or circulator running longer than optimal, shorter than optimal, or cycling on and off. All of these situations affect the efficiency of the system.

Upper tank sensor
Depending upon the system, the upper tank sensor may be optional or required. Where it is optional, an installed sensor acts a reference sensor for monitoring the potable water temperature at the top of the tank. In systems that utilize a second relay for dumping or recirculating heat, the upper tank sensor may be used for determining the temperature at which the second relay should be activated. When this configuration is used, a fourth sensor (including the collector sensor) may be required on a secondary tank.

Appropriate sensor locations include:

- ***Sealed in an immersion well.*** Many solar storage tanks are equipped with a pre-installed immersion well that allows the sensor to be positioned within a channel in the tank. When installed correctly, this is the most effective method for determining the tank temperature. Correct installation includes:
    - Coating the sensor probe with heat transfer paste
    - Feeding the entire probe into the immersion well
    - Sealing the immersion well with silicone caulk
    - Securing the sensor wire to protect against displacement

  For tanks without a pre-installed immersion well, immersion wells can be purchased and installed in appropriate ports in the tank or tees in piping that allows for the well to be situated in the tank.

Figure 3-5 – Properly installed sensor in immersion well. Care must be taken to ensure bend in sensor wire is at an appropriate radius.

Figure 3-6 – Sensor placed between insulation and vessel wall. This area should be insulated before replacing plastic cap to limit heat loss and increase accuracy of sensor location.

- ***Against the vessel.*** Where immersion wells are unavailable, the sensor probe can be install led between the tank vessel and the insulation or a bolt-on style sensor can be used. This location is less responsive and less accurate than an immersion well, but is appropriate when insulated properly.

- ***Clamped to outlet piping*****:** When measuring the temperature of the top of the storage tank, it is common practice to clamp a sensor on the hot outlet piping with a stainless steel hose clamp. This method requires pipe insulation for reasonably accurate temperature readings.

Figure 3-7 – Bolt-on style sensor (image courtesy of Resol)

The sensor wire should be supported within 12 inches of the sensor (minimum) and the controller and intermediately every 36 inches.

Important note: There are several different types of sensors (e.g. 5k, 10k, Pt1000) commonly used in SWH installations. It is critical that the sensors used in the system are supported by the specific controller being used.

Evaluating
The Inspector shall verify that:
- the sensor is installed in an appropriate location,
- the sensor is insulated appropriately,
- the sensor wire is proper secured.

(B) POTABLE PIPING

(i) Mixing valve installed properly

(ii) Mixing valve set to appropriate temperature

The water temperatures produced by SWH systems can reach 180F or higher. In order to protect residents, a thermostatic mixing valve must be installed to temper the water below 140F. The recommended set temperature for the mixing valve is 110F based on the Energy Conservation Construction Code of New York.

Figure 3-8 – Thermostatic mixing valve with integrated thermometer (image courtesy of Caleffi)

The mixing valve must be rated for potable use and should be an anti-scald type valve to protect the building occupants. The mixing valve should be installed to eliminate heat migration and to ensure that hot water does not enter the cold lines. This is typically accomplished with check valves that are installed on the cold and hot feed piping. Some models come with check valves already integrated into the mixing valve body.

The Inspector should verify that the mixing valve set temperature is 110F-125F. The Installer should install a thermometer at the mixed outlet of the mixing valve for verification.

Important note: In two-tank systems, where the solar storage tank preheats water before it enters an auxiliary water heater, the mixing valve should be installed on the hot outlet of the auxiliary tank. This increases system performance by keeping the solar storage tank temperatures lower and increasing collection efficiency. <u>It is critical in two-tank systems to verify that cold water is feeding the mixing valve, rather than preheated water from the solar storage tank (see Figure 3-9 and Figure 3-10).</u>

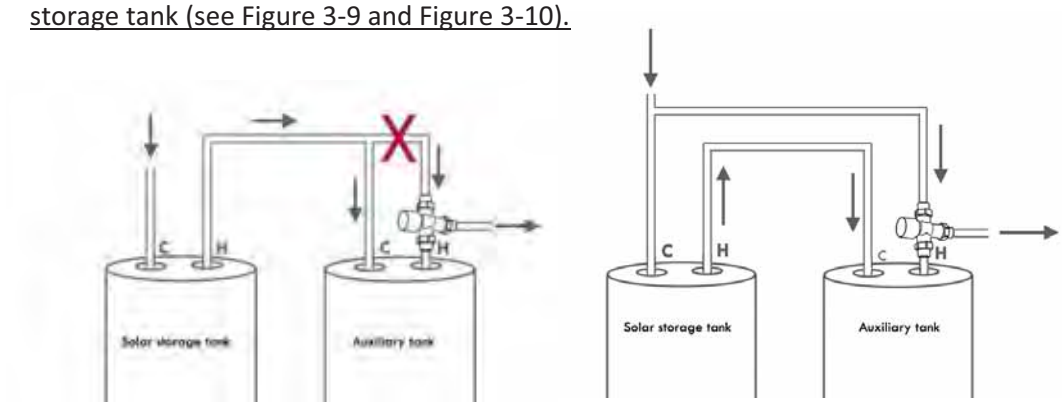


Figure 3-9 (left) and Figure 3-10 (right) – In the schematic on the left, the mixing valve is tempered by water from the solar storage tank, which could exceed the setpoint on the mixing valve and expose the user to scalding temperatures. The arrangement on the right shows correct plumbing – the mixing valve is tempered by water from the cold supply.

Evaluating
The Inspector shall verify that:
- the mixing valve has been installed per system and manufacturer specifications,
- the mixing valve is rated for potable use, and
- the set temperature is appropriate.

(iii) Isolation valve installed on cold water feed to water heater

In order to isolate the tank for servicing, a ball valve must be installed on the cold water feed to the water heater. If this valve is installed after the tee for supplying the mixing valve, a separate ball valve is required on the feed line between the tee and the mixing valve.

Evaluating
The Inspector shall verify that the isolation valve is installed.

(iv) Isolation valves installed to allow bypass of solar storage tank

In a two-tank system, a three-valve configuration must be used to allow for proper operation and to allow isolation of the solar storage tank for maintenance. In this configuration, the ball valve on the line to the solar storage tank and the ball valve on the line from the solar storage tank remain open during normal operation, while the third ball valve remains closed to divert flow through the solar storage tank (see Figure 3-11). When the solar storage tank is serviced, the ball valves to and from the tank are closed and the third ball valve is opened to allow cold water to feed the auxiliary water heater (Figure 3-12). This arrangement allows continuous hot water service in the building while servicing the SWH system.

Evaluating
The Inspector shall verify that the isolation valves are installed correctly for two-tank systems.

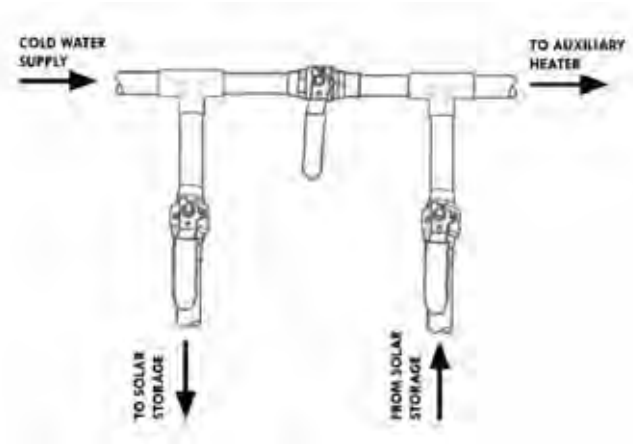


Figure 3-11 – Ball valve configuration for two-tank system during normal operation

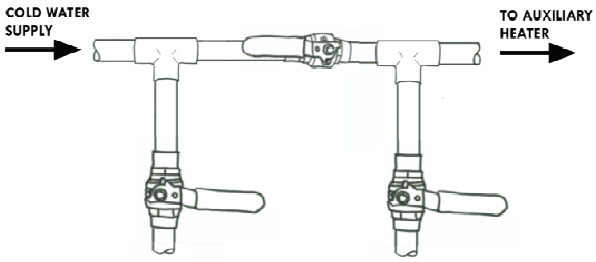


Figure 3-12 – Ball valve configuration for two-tank system during service of solar storage tank

(v) Heat traps properly installed

Heated water rises due to its lower density than cooler water. Due to this phenomenon, fittings at the top of a hot water tank – either from potable piping or from auxiliary heat sources – can be significant sources of heat loss if piped improperly. To avoid losses due to this thermosiphoning, all piping in the upper portion of a solar storage tank must have heat traps installed. Some tanks have heat traps integrated into the nipples where potable piping is connected. If these integrated heat traps are not present, a 6" heat trap must be installed.

Figure 3-13 is an infrared image that illustrates the effectiveness of a heat trap on a boiler feed line into the top of a solar storage tank. As can be seen, the trap isolates the hot water at the trap, giving it limited surface area to radiate heat.

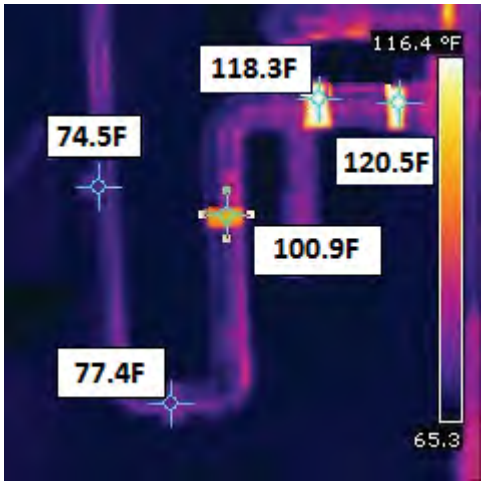


Figure 3-13 – Pipe temperatures at a properly installed heat trap. Without a heat trap, the heat from the tank would flow up the pipe and increase standby losses.

Important note: Alternately, a spring check valve can be used as a heat trap *on the hot outlet*. A spring check on the cold inlet will eliminate the ability for heated water to expand through the cold water lines and will lead to overpressurization of the potable water system. See 3(B)(viii) in this manual for properly addressing systems where a check valve is already installed.

Evaluating
The Inspector shall verify that all fittings in the upper half of the tank have integrated heat traps or that appropriate traps have been installed in the system piping. This applies to the cold inlet, the hot outlet, and any inlets and outlets for auxiliary water heating, such as an upper heat exchanger.

(vi) Antisiphon device installed properly

A vacuum relief valve must be installed immediately before the cold inlet to a water heater on bottom-fed water heaters and should be installed at a height above the top of the tank (see relief valve installation instructions). There can be no valve between the vacuum relief valve and the tank. This valve protects the tank vessel from negative pressures and prevents siphoning of the fluid from the tank into the potable water supply. For top-fed water heaters, a hole in the cold water dip tube qualifies for antisiphon protection.

Evaluating
The Inspector shall verify that the dip tube or an external vacuum relief valve provides antisiphon protection.

(vii) Dissimilar metals isolated properly, if required

Black iron or galvanized steel should not be used for potable piping. Where cast iron components are necessary, such as tappings in the tank vessel, a dielectric fitting or brass fitting must be used to transition to copper.

Evaluating
The Inspector shall look for any joints in the piping to ensure proper material compatibility. Particular points of interest include transitions between piping materials, most notably at the storage tank.

(viii) Thermal expansion tank installed and sized properly *for cold water supply with check valve or backflow prevention*

In buildings with backflow prevention or a check valve (such as is used in a well pump), a thermal expansion tank must be installed to absorb the expansion of water as it is heated (see Figure 3-15). The Inspector should verify that the expansion tank is rated for potable applications.

Evaluating
The Inspector shall verify the presence (or lack thereof) of backflow prevention on systems connected to public water supply. In systems where backflow prevention is present and on all systems connected to a private water supply, the Inspector shall verify that an appropriate thermal expansion tank is installed.

(ix) Interconnecting piping insulated properly

Types of insulation
Potable piping temperatures (<180F) allow for a variety of different pipe insulation materials. These include polyethylene, fiberglass, mineral wool, and elastomeric, among others.

Thickness of insulation
The Energy Conservation Construction Code of New York State states that mechanical system piping in residential systems must be insulated to a minimum of R-3 when carrying fluids above 105°F. The minimum thicknesses for various types of pipe insulation are listed below:

- Elastomeric: ½”
- Mineral wool: 1”
- Fiberglass: 1”
- Polyethylene: ¾”

Figure 3-15 - Thermal expansion tank (image courtesy of Amtrol)

Installation
Pipe insulation must be installed on cold water piping within 5 feet of the solar storage tank and water heater and on all accessible hot water piping. When split-style insulation is used, the seam must be sealed. Care should be taken to fully insulate fittings. Additionally, any spare ports on the water heater must be insulated.

Evaluating
The Inspector shall verify that the interior pipe insulation on potable piping is either elastomeric with a minimum thickness of ½”, polyethylene with a minimum thickness of ¾”, or fiberglass or mineral wool pipe insulation with a minimum thickness of 1”.

(x) All valves and fittings are rated for potable systems

There are a number of components used in SWH systems that might not be rated for use in potable water systems. The Inspector must ensure that any components used in the potable portion of the system meet the low-lead guidelines to protect homeowners and are resistant to the corrosion that can occur between certain materials and water with entrained air, such as service water. Components that are rated for use in hydronic systems that might be mistakenly installed in potable piping include:

- Backflow preventers
- Mixing valves
- Diverting valves
- Expansion tanks
- PEX tubing
- Circulators
- Leaded solder

Evaluating
The Inspector shall verify that the components listed above are rated for potable applications. The Installer must provide proper documentation.

(xi) Isolation valves labeled with normal operating position

To ensure proper system operation, isolation valves must be labeled with a description of their normal operating position. Labeling can be accomplished in one of two ways:

- The valves can be labeled with numbers and a sheet with description of the valve and its functioning can be posted in a visible location near the solar storage tank, or
- Laminated labels with a full description of the purpose of the valve can be placed at each valve

All systems that are SRCC OG-300 certified will have a list of labels needed for the system (see Figure 3-16)

VALVE NO. 23 COLD WATER SUPPLY LINE ISOLATION BALL VALVE THIS VALVE IS NORMALLY OPEN AND ALLOWS POTABLE WATER TO FILL THE SOLAR STORAGE TANK. WHEN CLOSED THE SOLAR STORAGE TANK IS IOSOLATED FROM THE PRESSURIZED CITY COLD WATER SUPPLY LINE PIPING.
VALVE NOS. 5 AND 10 VALVES 5 AND 10 ARE NORMALLY OPEN. WHEN CLOSED THE SOLAR STORAGE COLLECTOR LOOP PIPING IS ISOLATED FROM THE SOLAR STORAGE TANK.
VALVE NOS. 12 AND 14 VALVES 12 AND 14 ARE NORMALLY OPEN. WHEN CLOSED THE CIRCULATING PUMP IS ISOLATED FROM THE SOLAR COLLECTOR LOOP PIPING. **NEVER** SHUT THESE VALVES WHILE THE CIRCULATING PUMP IS IN OPERATION. TURN THE TOGGLE SWITCH, NO. 21, TO THE "OFF" POSITION

Figure 3-16 - Sample labels for the isolation valves in a SWH system (courtesy of SunEarth)

Evaluating
The Inspector shall verify that isolation valves are properly labeled.

SECTION 4: CONTROLS

While many of the technologies utilized in SWH systems have remained fairly consistent in recent years, the field of controls has seen rapid development. The introduction of affordable advanced controllers and heat measurement equipment has led to – and will continue to lead to – changes in control strategies and increased ability to troubleshoot systems.

It is extremely important the Installer is knowledgeable in controls and properly configures the settings of the control system, whether it is a differential control or a PV-control. The Inspector must review the system to determine whether the controls meet electrical codes and operate correctly.

Section 4 discusses the electrical requirements of solar heating controls.

(i) Wiring between controller and outputs (pumps, motorized valves, external relays, etc.) installed properly

The *minimum* cable size used between the controller and any output powered by line voltage (120V) is 14 AWG and the wire gauge must be sized appropriately for the load per NEC. A properly insulated and protected conductor shall be used – this may include either or a conductor enclosed in conduit or an appropriately rated cord. All cable systems shall be supported in accordance with the NEC. Wiring shall also have strain relief to prevent the wiring and equipment from being damaged or disconnected (see Figure 4-1). Any splices or connections must be concealed in a junction box.

Figure 4-1 – Strain relief clamp used at circulator junction box to protect the integrity of the corded connection.

> ***Evaluating***
> The Inspector shall verify that the wiring between the controller and output(s) is/are installed properly.

(ii) (a) Controller relay(s) rated higher than each output -OR- (b) Appropriately rated intermediate relay(s) installed between controller and output(s)

The outputs for small residential systems typically include circulators, pumps, and motorized valves. Typically these loads draw less than 1A of current at 110V. For loads over 1A, the rating of the controller relay should be verified to ensure that it exceeds the draw. If the output load is higher than the rating of the load, an exterior relay must be used (see Figure 4-2).

Figure 4-2 – Example of an external relay used when the load exceeds the amperage rating of the controller relay. The external relay must be rated higher than the load (image courtesy of Functional Devices, Inc.).

Typical amperage requirements for standard solar heating system components are as follows:

- Standard circulator: 0.5A-1.0A
- Large circulator or drainback pump: 1.5A-2.5A
- Motorized diverting valve: <0.1A

Evaluating
The Inspector should verify the load of each output and compare it to the amperage rating on the controller, which is found in the controller instruction manual.

(iii) Wiring between controller and power source (line voltage) installed properly

The minimum cable size used between the controller and the power source is 14 AWG. For large systems that exceed 15A, the National Electrical Code (NEC) must be referenced to determine the appropriate wire gage. A properly insulated and protected conductor shall be used – this may include either or a conductor enclosed in a conduit or an appropriately rated cord. Wiring shall be supported within 12" of the controller and power source and at 54" intervals intermediately. Wiring shall also have strain relief to prevent the wiring and equipment from being damaged or disconnected. Any splices or connections must be concealed in a junction box.

Evaluating
The Inspector shall verify that the wiring between the controller and power source is installed properly.

(iv) Wiring to PV module installed and sized appropriately *for PV-controlled systems*

In PV-controlled systems, the wiring between the module and the circulator (or controller, if used) must have a disconnect switch and be sized to carry 125% of the maximum amperage output of the module (refer to NEC for specific wiring and switch requirements). Outside wiring and junction boxes must be rated for outdoor use and be resistant to water and sunlight. Interior wiring must be contained inside metal raceways, such as metal-clad conduit.

Evaluating
The Inspector shall verify that the wiring between the module and circulator (or controller) is installed properly.

(v) PV module sized appropriately for DC pump *for PV-controlled systems*

DC-pump manufacturers will specify the output requirements of the PV panel used to power their equipment. The Installer must verify that the system operates at the desired flow rate under typical solar loads.

Evaluating
The Inspector must ensure that the PV module meets the pump manufacturer's requirements.

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Field Inspection Guidelines for Solar Heating Systems

State of New York

State of New York
Andrew M. Cuomo, Governor

New York State Energy Research and Development Authority
Francis J. Murray, Jr., President and CEO

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