Outdoor Inspection

This segment is intended to introduce the building inspector to how the ICC code applies to outdoor solar heating equipment for domestic hot water

We will look at the following topics: third party certification of solar thermal equipment; material compatibility for outside components; mounting and anchoring of collectors to the roof structure; any valves that might be found outdoors; outdoor insulation issues; correct installation of sensors and their wiring. We will wrap up with how to properly flash the plumbing and mounts, and how to penetrate through the water proof membrane to the roof structure.

Only glazed, liquid-based solar water heaters are considered here. Swimming pool heaters such as the one seen here, as well as air-based collectors and solar space heating are not expressly considered in this segment, although many aspects considered in this segment will also apply to those technologies.

When inspecting a solar water heating system, a good place to start is with the collector and other outdoor equipment. This would of course include the required piping and valves connecting the collector to the storage tank. The collector might be found on the ground, or even as an awning. However, the collector usually is found on the roof like this one here. As mentioned in a previous segment, outdoor equipment may also include the solar tank, such as in a thermosyphon system or integral collector storage system.

So, what are the relevant issues in the International Code that apply to outdoor solar equipment? Factory-built collectors shall be listed and labeled. There are two entities in the US that list solar collectors: SRCC and FSEC. The certification process is very similar in both programs. A fundamental difference is that FSEC Certification is mandated by the State of Florida for any collector manufactured or sold in Florida. It uses slightly different procedures and assumptions to calculate energy ratings than those used by SRCC. SRCC is a voluntary national Solar Rating and Certification Corporation. Otherwise, testing standards, design review protocols, fees and all other aspects are almost identical. Both entities require labeling of certified collectors.

Certified solar collectors carry labels providing relevant information put forth in the Code. Any plastic collectors or covers must be of materials meeting the requirements for plastic roof panels in the building code. Most glazed collectors use a low iron safety glass, but some certified collectors use polyethylene or polycarbonate plastics such as Twinwall. They are not permitted on High Hazard Group H, or Institutional Groups I-2 or I-3 with more than five residents. They are permitted in all other groups if the building is sprinkled, or if the roof construction is not required to have a fire-resistant rating by Table 601 of IBC or the roof panels meet the requirements for roof coverings in accordance with Chapter 15.

Certified collector covers made of glass are required to use safety glass. Safety glass will have a small logo stamped in one corner. Glass is also necessary for well-insulated collectors designed to reach higher temperatures than those with less insulation. Although collectors typically run at 120 to 140 degrees F during normal operation, temperatures under no-flow conditions can get quite hot, exceeding 300 degrees F in some well-insulated collectors.

Certified collectors have had their materials checked for durability against maximum anticipated temperatures in the collector’s life. This maximum temperature is sometimes called stagnation temperature, and occurs under no-flow, high-sun conditions.

Specific installation procedures may be required for some collectors, such as keeping the collector covered with an opaque material while dry or during installation. These special installation procedures will be called out in the installation manual.

Also, sites that require freeze protection but that might also experience stagnation conditions in the summer usually should use a drain back design for freeze protection, rather than a glycol solution.

An example would be systems on houses in the north that are vacant during summer vacations. This is because overheating the glycol solution would cause it to boil over, accelerating its breakdown and encouraging system failure.

One newly certified design accounts for this boil over problem in glycol systems by using a small radiator to dissipate heat above certain temperatures.

Code requires that collectors and mounting equipment shall be constructed of noncombustible materials or fire-retardant wood.

Generally, lags into wood mounts will require tightening over time if the wood dries. Properly flashed and sealed threaded rod passing all the way through the mounts is a better choice for this mounting. Integrally mounted collectors must conform to the building code. This might include ventilation requirements to avoid condensation. An integrally mounted collector would be any collector that itself penetrates the roof membrane and itself acts as a part of the water barrier.

Solar collectors qualify as components or elements of the building envelope that do not count as part of the main windforce-resisting system. Net design wind pressures can be calculated per IMC Section 1609. Testing may also be required. Some systems have already been tested to required wind-loading standards such as ASCE 7. Roof top equipment shall be anchored to resist wind-induced overturning, uplift and sliding, and to provide a continuous load path for these forces to the foundation.

Collector arrays might be rack mounted. That is, they may be tilted up from the roof plane to maximize the amount of sunlight intercepted.

To maximize annual performance, that is, to maximize the amount of solar energy collected over a year, the collector should face south and be tilted off horizontal at an angle equal to the latitude. If the anticipated load is greater in the winter, then the collector may be tilted off horizontal by an angle as much as latitude plus 15 degrees. However, the performance benefits gained with rack mount often are outweighed by aesthetics or wind loading concerns.

Collector arrays might be on a stand-off mount with the collectors mounted parallel to the roof plane. Stand-off mounts are often chosen for better aesthetics or for better wind-load resistance.

Regardless of anchoring technique, collector mounting materials must be compatible with the collector frame, corrosion resistant, UV-resistant, and able to transmit wind-induced or seismic-induced forces to the building structure without failure. The most common collector mounting materials are extruded aluminum or steel. Isolated galvanized steel or UV resistant plastic might also be found in HECO regions.

Galvanized steel is not recommended in coastal areas due to corrosion issues. Wood products are not acceptable for the collector mountings. However, rooftop piping support blocks might be of pressure-treated wood, UV-resistant plastics or similar material.

All anchoring hardware, including strut-nuts, ‘All-Thread’ or equivalent through-bolts, and lag screws, must be made of stainless steel or equivalent.

Hardware must either be compatible with other metals or be galvanically isolated from other metals in the structural system. Generally, minimum bolt thickness is 5/16 inches.

Roof penetrations and mounting hardware should not weaken or otherwise compromise the structural strength of the joists, studs, and roof assembly.

There are several different mounting techniques commonly used to secure solar equipment to rafters. Lag screws penetrate through into the rafter. These might be a plate with multiple small screws or a single large screw.

Lag screw mounting is perhaps the most common mounting means found, especially for asphalt shingle roofs and for retrofit jobs. A critical issue is during the mounting of lag screws through the roof into joists. Certified systems have had their mounting hardware and installation procedure checked for acceptability.

However, the actual mounting installation should be carefully checked to make sure that it complies with the recommended procedure, and that it does not compromise the strength of the joist.

For example, if a single lag screw is used, it must be of the correct dimensions and materials, and penetrate the exact center of the joist.

If multiple screws are used in a single mounting as in this mounting for a photovoltaic array, the correct minimum number of screws must penetrate the joist, and care must be taken to properly seal the space between the mounting and the shingle since there are now multiple penetrations.

On a composition or asphalt shingled roof, an experienced installer can quickly find the center of the joist from the outside by tapping on the shingles and listening to the change in tone. However, this is difficult on other roof surfaces. Spanner mounts or J bolt mounts might be required on other roofs to avoid removing tiles or roof panels.

Besides Lag screw mountings, spanner beams and J bolts are also used. These offer more strength than lag screws.

Both spanners and J bolts require access to the attic for installation when retrofitting to an existing roof.

If a spanner design is used, it must be properly installed with a compression block. Here, the arrows point to the compression block next to the threaded rod.

Here, the compression block is missing, since the rafter is too far from the All-Thread rod. The nut must not overly tightened or it will cause strain in the spanner. This will strain the roof deck. Further, the mount may loosen up over time.

In this spanner mount, the spanner acts as the compression block. The hole must be centered.

If a J-bolt is used, it should penetrate the roof deck right next to the joist.

This requires a long drill bit. When the nut is tightened, cinching the collector mount to the standoff, the J bolt should be snug against the joist.

If the J bolt shaft is too far from the truss, undue strain may be placed on the roof deck and the mount may loosen over time.

As with the tank in the utility room, all sections of the plumbing loops that are capable of developing excessive pressures shall have a relief device. This would include the tank, and the collector loop if the collector loop can be isolated from the tank. Relief valves and discharge must meet Code: they must be listed and labeled and their rated capacity must exceed the equipment they are protecting. Their setting must be less than the nameplate pressure rating of the equipment.

Discharge pipes must be rigid and approved for the system temperature and the discharge shall not be a hazard or nuisance. As with all relief valves, the discharge must be plumbed to a safe location.

This photo shows a typical pressure relief valve.

Note that, although the Mechanical Code requires pressure-temperature relief valves for protection against exceeding design limits, relief valves located near the collector should be pressure-relief only since they may otherwise open unnecessarily during stagnation conditions. Note that a PT valve with the probe cut off does not satisfy this requirement. Components that can not withstand any design vacuum conditions shall be protected with a vacuum relief valve. SRCC certified systems have been checked to meet this requirement, but proper installation must be confirmed in the field. Check the field installation against the approved installation manual, which must be present at the installation site. Note that certified systems must have means to release trapped air at all high points in the collector loop. These air vents might be manual, or they might be automatic.

The system must be freeze-protected to the lowest ambient temperature expected during the life of the system. Note the green fluid in the flow meter and the small pump on this glycol system.

Freeze protection mechanisms were discussed in a previous segment. Statistical data is available from the National Climatic Data Center database or ASHRAE."

This can be compared against the Freeze Tolerance Limit of an SRCC certified system.

Plumbing and piping to and from the collector must be properly insulated. Certified systems have indicated the correct type and thickness of insulation in the Owner's Manual or the Installation Manual. Outdoor insulation of a certified system must also be protected from UV degradation with either an approved paint or cover. Approved paints may require more maintenance than jackets over the years, but often are less expensive and easier to apply. Aluminum tape can be used with good results. Properly installed jackets give a clean professional appearance. Insulation covers protect the insulation from being degraded by ultraviolet radiation. Without protection from UV radiation, degradation of the insulation will occur over time. The insulation often becomes brittle or powdery, and disintegrates. Loss of insulation results in reduction of efficiency and increased losses of collected solar energy. Insulation covers may also provide some protection from attack by birds or animals. Although not specifically called out in the Code, pipe insulation should be properly cut and glued to give a professional appearance and to fully cover the pipe. The insulation should extend all the way down to a termination. A little extra length should be included to account for shrinkage over time. Corners should either be bevel cut, or made from a continuous piece for appearance and full coverage. Also, improper materials can melt at high collector temperatures. Insulation specified in certified systems has been checked and approved, but proper installation must be confirmed in the field. Check the field installation against the approved installation manual, which must be present at the installation site.

If the system is an active, or pumped system using a differential controller, then you will find the hot temperature sensor, or thermistor, at the hot outlet of the collector array. A common reason for callbacks is a failed thermistor. If the sensor is correctly installed, the solar heating system will function properly for a much longer time.

Generally, this sensor is a small thermistor clamped to the pipe. The sensor portion of the thermistor must be in good thermal contact with the pipe, underneath the insulation, and as close as possible to the collector outlet. It should be no more than six inches away from the collector outlet. Thermistor type sensors should be clamped at the flat sensor end, not around the thermistor 'barrel'. This ensures that the actual sensor portion is in good thermal contact of with the collector outlet pipe. An acceptable alternative is to squeeze the flat end between the outlet pipe and collector frame grommet. The sensor should be connected to the sensor wire with all plastic wire nuts or with connectors supplied by the manufacturer. The plastic wire nuts should be sealed with silicone and wrapped with electrician's tape. Sensor wire should be UV-protected and generally is attached to the outside of the pipe insulation rather than the inside next to the pipe. This is to minimize exposure of the wire to high temperatures.

If the system is an active, or pumped system using a photovoltaic panel to power the pump, then the panel will be found next to the collector, usually at the same tilt and orientation as the collector.

The PV panel must not be shaded. Certified systems have been reviewed and confirmed that the PV panel is sized to match the DC circulating pump.

The wire from the panel to the pump should be properly sized and UV-protected, wire nuts should be all plastic, sealed with silicone and wrapped with electrician's tape.

Wire specified in certified systems has been checked and approved, but proper installation must be confirmed in the field. Check the field installation against the approved installation manual, which must be present at the installation site. All penetrations must be properly flashed.

One common method for collector mounts and piping penetrations on flat roofs and built-up roofs is the 4-inch or the 6-inch pitch pan. Care should be taken that the pitch pan is installed properly so that shrinkage and leakage does not occur over time. Pitch should completely fill the pan and be sloped such that water will not pool in the pan. Pitch should be recovered with gravel, paint or roofing material so as to not dry out and crack. Installing pitch pans on sloped roofs is not recommended since pitch may soften and flow out of the pan during hot summers.

None the less, pitch pans might be required in some jurisdictions regardless of roof slope.

Another common method of roof penetration for plumbing and sensor wiring is the coolie cap flashing. Note that the copper flashing is compatible with the copper piping. The coolie cap provides a water tight and resilient seal around the roof penetration, while allowing the plumbing to move freely as it expands and contracts. The roof penetration is drilled, the base is properly flashed, the piping is fed up through the base, and the cap is soldered onto the pipe over the base. The sensor wire might also be fed through the coolie cap penetration. However, this is not recommended, since one must take extreme care not to pinch or crimp the wire, and the wire is unduly exposed to the hot collector return pipe. A preferred variation of the coolie cap flashing provides a separate gooseneck for the sensor wire. This protects it from the hot pipe. Other penetrations might also be used. As with any equipment installed on the roof, care must be taken to ensure that the penetrations through the watertight membrane do not result in leaks later. Also, the material used must be compatible with any materials in contact with it, and all materials must be able to stand up to sun and weather for many years to come.

This concludes our inspection of the outdoor components in a solar water heating system. Now let's go inside and look at the proper installation of indoor components.