

DESIGN REQUIREMENTS

SECTION 301—GENERAL

301.1 General. Components used as part of a *solar thermal system* shall be installed in accordance with the component manufacturer's installation instructions and the plumbing code and/or mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code*, *International Mechanical Code*, *International Residential Code*, or Appendix B.

301.2 Temperature resistance. Solar thermal system components shall be capable of withstanding localized internal and external temperatures arising from system operation within the manufacturer's specified design temperature range without reducing the design life of the system.

301.2.1 High temperature resistance. Means shall be provided to limit the temperatures of system components to values not to exceed their respective maximum design operating temperatures. Pressure/temperature relief valves shall not be used for this purpose.

301.2.2 Stagnation. The system shall be able to withstand *stagnation* conditions without degradation of the system. This includes conditions that occur during loss of electric power to the system.

301.2.3 Freeze protection. Protection from freezing temperatures shall be provided for all system components subject to damage. The supplier shall specify a *freeze tolerance limit* for each system. Solar thermal systems shall comply with Section 301.2.3.1 through 301.2.3.2.

301.2.3.1 Water exposed to freezing temperatures. For solar thermal systems in which water is exposed to freezing temperatures, a minimum of two freeze protection mechanisms shall be provided on each system. Manual intervention in accordance with Section 301.2.3.2 shall be considered as one mechanism. Other acceptable mechanisms include but are not limited to thermal mass (protection, but protection is limited to the thermal capacitance of the system), automatic draining and closed-loop recirculation (with uninterruptible power supply).

301.2.3.2 Manual intervention freeze protection. For solar thermal systems that rely on manual intervention for freeze protection, not less than one freeze protection mechanism shall be provided to protect components from freeze damage under all conditions, including in the event of power failure.

Acceptable manual intervention actions include but are not limited to draining. A system in which components and/or piping are subject to damage by freezing shall have the proper fittings, pipe slope and collector design to allow for manual gravity draining and air filling of the affected components and piping. Pipe slope for gravity draining shall have a minimum 1-cm vertical drop for each meter of horizontal length (1/8 inch per foot). This also applies to any header pipes or absorber plate riser tubes internal to the collector.

301.2.4 Thermal expansion. The system design, components and subassemblies shall include provisions for the thermal contraction and expansion of *heat transfer fluids* and system components that will occur over the manufacturer(s) specified operating temperature range.

Exception: Thermal expansion control devices shall not be required in the drain-back section of *drain-back systems*.

301.3 Pressure resistance. Solar thermal system components shall be capable of withstanding localized pressures arising from system operation within the manufacturer's specified design pressure range without reducing the *design life* of the system.

301.3.1 High pressure resistance. Each portion of the system in which excessive pressures can develop shall be protected by a pressure-relief device. Means of rendering a pressure-relief device ineffective shall not be allowed under this standard, and each portion shall not be able to be isolated from pressure-relief devices. Automatic pressure-relief devices shall be designed to open at or below the maximum pressure design of the system component that has the lowest pressure rating.

301.3.2 Domestic water supply pressure resistance. Components connected to service mains and/or domestic distribution systems shall have a maximum design pressure of not less than 100 psi (690 kPa) at 180°F (82°C).

301.3.3 Vacuum pressure protection. Systems shall be designed to withstand the maximum vacuum pressure that can occur during normal operation, maintenance or draining at any point in the system.

301.4 Flow-induced erosion resistance. Solar thermal system components shall be capable of withstanding localized design fluid flowrates during all system operating conditions without incurring erosion or corrosion that reduces the system's *design life*.

301.5 Outdoor installation. Solar thermal systems, components and portions of systems intended for installation in unconditioned spaces and outdoors shall be capable of withstanding the environmental conditions anticipated in service without reducing the *design life* of the system, when installed in applications and locations complying with manufacturer's installation instructions.

301.6 Loss of service. The system shall be designed so that, in the event of an electrical power failure, loss of water pressure, or loss of internet service, the temperatures, pressures or other conditions developed in the *solar thermal system* will not damage the system or the building or endanger its occupants.

301.7 Workmanship. Solar thermal systems and components shall be free of sharp edges or projections that could present a hazard under normal use or during installation or servicing activities.

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301.8 Design operating conditions. The manufacturer shall specify the design operating conditions for components and subassemblies of solar thermal systems installed indoors and outdoors. The design operating conditions shall include the following parameters:

1. Minimum outdoor air temperature.
2. Maximum water supply temperature.
3. Approved heat transfer fluids.

SECTION 302—MATERIALS

302.1 General. Materials used in the construction of solar thermal system components and assemblies shall be appropriate for their intended function throughout the range of localized design operating and ambient environmental conditions specified by the manufacturer. Materials shall not be corroded or otherwise adversely affected by contact with approved heat transfer fluids during the design life of the solar thermal system.

302.2 Galvanic corrosion. Where dissimilar metals are in direct contact, they shall be isolated or treated to reduce the potential for galvanic corrosion under wet and dry conditions.

302.3 Protection of potable water from contamination. Materials that come in direct contact with *potable water* shall not adversely affect the taste, odor or physical quality and appearance of the water; shall comply with NSF 61 and NSF 372; and shall have a weighted average lead content of 0.25 percent or less.

SECTION 303—HEAT TRANSFER FLUIDS

303.1 General. Specific heat transfer fluids shall be approved for use with *solar thermal systems* as specified in Section 301.8 and indicated on the product label and manuals. The use of fluids in the solar thermal system other than those specified and labeled is prohibited. Heat transfer fluids approved for use in a system shall meet the requirements of this section.

303.1.1 Fluid flammability. *Flammable liquids* shall not be used as heat transfer fluids. For a liquid to be considered flammable, the closed-cup flashpoint of heat transfer fluids exceeds the maximum design temperature to be reached by the fluid in the collector by 50°F (28°C), or more.

303.1.2 Fluid toxicity. Heat transfer fluids used in solar thermal systems shall have a Gosselin Toxicity Index of 2 or less. Ethylene glycol, hydrocarbon oils, ammonia and hydrazine shall not be used as heat exchange fluids in any concentration. The use of *toxic fluids* shall comply with the *Title 15 of the Federal Hazardous Substances Act* and the requirements of the local jurisdiction.

303.2 Fluids used with single-wall heat exchangers. Heat transfer fluids used in single-wall heat exchangers shall comply with the requirements of the local jurisdiction and at least one of the following:

1. NSF HT1 registered to demonstrate compliance to the *Code of Federal Regulations, Title 21, Food and Drugs, Chapter 1, Food and Drug Administration, Parts 178.3570*.
2. Listed and labeled to ISO 21469.
3. Listed and labeled to EN 1717 as a Category 2 or 3 fluid.
4. Water.

SECTION 304—SYSTEM DESIGN

304.1 General.

304.1.1 Use of listed components. Listed components incorporated into *solar thermal systems* shall be used and installed in compliance with the component manufacturer's instructions and the conditions of listing. Listed components shall not be modified in any way that invalidates the listing of the component.

304.1.2 Thermosiphon management. Means shall be provided to control energy losses from thermal storage tanks and supplemental heating equipment caused by undesirable thermosiphon action.

Exception: *Passive solar thermal systems* utilizing thermosiphon action to induce flow within solar loops.

304.1.3 Entrapped air. Means shall be provided for air and gas removal from heat transfer fluid in closed flooded liquid systems during filling and as needed for maintenance.

304.1.4 Maximum delivered water temperature. *Solar thermal systems* designed for domestic water heating applications shall include one or more thermostatic mixing valves listed and labeled as required in Section 304.4.4 to control the maximum temperature of the hot water delivered to the load. The valve shall be installed in accordance with the device and system manufacturer's requirements and local codes. A thermostatic mixing valve shall be placed upstream of *auxiliary heating equipment* that is not rated for the temperature of water delivered by upstream solar collectors or storage tanks.

304.1.5 Operating indicators. *Solar thermal systems* shall include means for an observer to readily determine that the system is operating properly.

304.1.6 Safety device bypass. Safety devices shall not have provision for bypass or override.

304.2 Heating energy sources. Solar thermal systems shall include at least one solar thermal collector complying with Section 304.2.1. Auxiliary water heaters and boilers included as part of solar thermal systems shall comply with Section 304.2.3. Supplemental heaters incorporated into solar tanks that are not listed as standalone water heaters shall comply with ICC 903/SRCC 500.

304.2.1 Solar thermal collectors. Solar thermal collectors installed as part of solar thermal systems shall be listed and labeled to ICC 901/SRCC 100 and shall be used in the system in accordance with the collector manufacturer's instructions.

Exception: Solar thermal collectors inseparable from solar tanks for testing purposes [i.e., integrated collector storage (ICS) and inseparable thermosiphons] shall comply with ICC 901/SRCC 100 but shall not be required to be separately listed and labeled.

304.2.2 Photovoltaic solar water heating collectors. Where one or more photovoltaic (PV) modules are used as part of a *PV water heating system*, they must supply power exclusively to electrical water heating devices installed on the solar water heating system. The electrical output of such modules shall not be connected to, or supply any power to any other electrical device or the main electrical panel, or be exported to the electrical grid. PV modules, inverters, power conditioners, controls, tracking systems, wiring and connectors used as part of a PV solar water heating system shall comply with and be installed in accordance with the requirements of Section 304.10 and all applicable local codes.

304.2.3 Auxiliary water heaters and boilers. Auxiliary water heaters and boilers used as part of *solar thermal systems* shall be listed and labeled to at least one of the standards listed in Table 304.2. Water heating equipment installed in outdoor locations shall be listed and labeled for outdoor installation.

TABLE 304.2—AUXILIARY WATER HEATER LISTING STANDARDS

WATER HEATING EQUIPMENT	STANDARD
Electric resistance storage water heaters	UL 174; UL 1453
Electric resistance tankless water heaters	UL 499
Heat pump water heater	UL 60335-2-40
Oil-fired storage water heaters	UL 732
Solid-fuel-fired water heaters	UL 2523
Gas-fired water heaters	ANSI Z21.10.1/CSA 4.1; ANSI Z21.10.3/CSA 4.3
Packaged oil-fired boilers	UL 726
Packaged electric boilers	UL 834
Solid fuel-fired boilers	UL 2523
Gas-fired boilers	UL 795; ANSI Z21.13/CSA 4.9; ASME <i>Boiler and Pressure Vessel Code</i> , Sections I, II, IV, V and IX

304.3 Solar and drain back tanks. Tanks used to store heated liquids in solar thermal systems, including solar tanks, drain back tanks, unfired vessels and storage water heaters used as solar tanks, shall comply with the requirements of this section. This section shall apply to both pressurized and unpressurized tanks. This section shall not apply to expansion tanks.

304.3.1 Tank listings. Tanks used as part of solar thermal systems to store heated liquids shall be listed and labeled to at least one of the following standards, as applicable: UL 174, UL 1453, UL 732, UL 60335-2-40, ANSI Z21.10.1/CSA 4.1, Z21.10.3/CSA 4.3, or ICC 903/SRCC 500 or constructed and certified to the ASME *Boiler and Pressure Vessel Code*, Section IV or VIII. Tanks installed in outdoor locations shall be specifically certified for outdoor use.

Exception: Solar tanks inseparable from solar thermal collectors [i.e., integrated collector storage (ICS) and inseparable thermosiphons] shall comply with ICC 903/SRCC 500 but shall not be required to be separately listed and labeled.

304.3.2 Water heaters used as solar tanks. Storage water heaters shall be permitted to be used as solar tanks within solar thermal systems if all of the following conditions are met:

1. Storage water heater is installed and used within the solar thermal system in a manner complying with the storage water heater's instructions and conditions of listing.
2. Storage water heater shall not be modified in any way that is not specifically prescribed by the water heater manufacturer. Connection of the integral heater (e.g., gas burner, oil burner or electrical heating element) shall not be required unless specifically prohibited by the water heater manufacturer or conditions of listing.
3. Storage water heater shall be equipped with a temperature and pressure relief valve sized and installed in accordance with the manufacturer's instructions and local codes.

304.4 Valves. Valves used as part of solar thermal systems shall comply with and be sized and installed in accordance with the system manufacturer's instructions and local codes. In the absence of applicable local codes, valves installed as part of solar thermal systems shall comply with the *International Plumbing Code*, *International Mechanical Code*, *International Residential Code*, or Appendix B of this standard, as applicable.

304.4.1 Shutoff and diverter valves. Shutoff and diverter valves used as part of solar thermal systems shall comply with and be sized and installed in accordance with the system manufacturer's instructions and local codes. In the absence of applicable local codes, shutoff and diverter valves installed as part of solar thermal systems shall comply with the *International Plumbing Code*, *International Mechanical Code*, *International Residential Code*, or Appendix B, as applicable.

304.4.1.1 Service water shut-off. *Solar thermal systems* shall have valves to provide for shut off from the service water supply without interrupting cold water service to the remaining portion of the water distribution system.

304.4.1.2 Drain valves. One or more valves shall be provided to the drain section of *solar thermal systems*.

304.4.1.3 Component isolation valves. Where installed, the following components in *solar thermal systems* shall be provided with valves to allow the isolation and maintenance of the component for service or replacement. Isolation valves shall be installed immediately upstream and downstream of the component unless such valves are integral to the component. If several components requiring isolation are incorporated into a pump station, the entire pump station shall be equipped with isolation valves, as an alternative to isolation valves on each component.

1. Filters.
2. External heat exchangers.
3. Circulation pumps.
4. Pump stations.

304.4.2 Vacuum relief valves. Where vacuum pressure relief valves are used in solar thermal systems, they shall be listed and labeled to ANSI Z21.22/CSA 4.4.

304.4.3 Pressure and temperature relief valves. Pressure, temperature and combination temperature and pressure relief valves shall comply with ANSI Z21.22/CSA 4.4.

304.4.4 Thermostatic mixing valves. Thermostatic mixing valves shall comply with ASSE 1017 or CSA B125.3.

304.5 Piping and fittings. Piping, pipe fittings and joints used as part of *solar thermal systems* shall comply with and be sized and installed in accordance with the system manufacturer's instructions and local codes. In the absence of applicable local codes, piping, pipe fittings and joints installed as part of solar thermal systems shall comply with the *International Plumbing Code*, *International Mechanical Code*, *International Residential Code*, or Appendix B, as applicable.

304.5.1 Pipe temperature resistance. Piping and fitting materials and joints used in *solar thermal systems* upstream of thermostatic mixing valves shall be rated to withstand the *maximum operating pressure* of the *solar thermal system* at the *maximum operating temperature*.

304.5.2 Pipe insulation. Insulation shall be installed on solar loop piping, all piping conveying heated fluids, and the final 5 feet (1.5 m) of cold-water supply piping leading into the system. Insulation shall have a value of $R-2.6^{\circ}\text{F} \times \text{ft}^2 \times \text{hr} / \text{Btu}$ ($R-0.46^{\circ}\text{K} \times \text{m}^2 / \text{W}$) or greater. Pipe insulation shall be tested in accordance with ASTM E84 or UL 723 using the specimen preparation and mounting procedures of ASTM E2231 and shall have a maximum flame spread index of 25 and a smoke-developed index not exceeding 450.

Exception: Nonmetallic pipe and fittings exposed to solar radiation to contribute to the collection of energy that is approved for outdoor use.

304.6 Heat exchangers. Where external heat exchangers are used in solar thermal systems, they shall be approved for the intended use. Heat exchangers integrated into solar tanks shall comply with ICC 903/SRCC 500.

304.6.1 Cross connection control in heat exchangers. Heat exchangers used in *solar thermal systems* shall be double-walled. *Double-wall heat exchangers* shall be vented such that any failure of a barrier will result in the discharge of *heat transfer fluid* or potable water to the atmosphere to a readily observable location.

Exception: *Single wall heat exchangers* shall be permitted when both of the following two conditions are met:

1. Comply with one or more of the requirements in Section 303.2 for all fluids approved for use.
2. The maximum operating pressure of the nonpotable *heat transfer fluid* within the *heat exchanger* is less than the normal minimum operating pressure of the *potable water system*.

304.7 Pumps. Circulation pumps powered by AC electrical power used in *solar thermal systems* shall be listed and labeled to UL 778 or CSA 22.2, No. 108.

Exception: Circulating pumps operating on direct-current (DC) electrical power, including those that are powered by a dedicated PV module.

304.8 Subassemblies and pump stations. Components used in pre-assembled subassemblies designed for use in *solar thermal systems*, including *pump stations*, shall comply with the requirements of this standard and shall be assembled in accordance with the requirements of the *International Plumbing Code*, *International Residential Code* or Appendix B. Where the factory-built subassembly or *pump station* is listed and labeled as subassembly, apart from the rest of the system, it shall comply with Appendix D.

304.9 Controls and sensors. Where controllers are used in solar thermal systems, they shall facilitate installation, startup, operation, shutdown and maintenance of the solar thermal system without the need for an internet connection.

304.10 Electrical systems.

304.10.1 Protection of electrical components. Overload and overcurrent protection of electrically operated components shall be consistent with the maximum current rating of the device and NFPA 70.

304.10.2 Internal wiring. Electrical wiring integral to *solar thermal systems* shall be sized and installed in accordance with NFPA 70 and manufacturer's instructions. Wiring shall be approved for the temperature, voltage and applicable service conditions. Wiring subjected to direct sunlight shall be rated for the application or shall be protected by an approved method.

304.10.3 Electrical components. Electrically powered components greater than 24 volts used within systems shall be listed and labeled to standards referenced by NFPA 70. Electrically powered components greater than 24 volts shall also be listed and labeled to one or more of the standards specified in Table 304.10, as applicable.

TABLE 304.10—ELECTRICAL COMPONENT REFERENCE STANDARDS	
ELECTRICAL COMPONENT	STANDARD
Controllers	CSA E60730-1, EN 60730-2-9, UL 60730-1, UL 873
Pumps	CSA 22.2, No. 108, UL 778
Photovoltaic modules	UL 1703, UL 61730-1
Inverters and power conditioners	UL 1741
Metal-sheathed heating elements	UL 1030
Wiring connectors	UL 1977
Solar trackers	UL 3703