International Code Council

BSR/ICC 900/SRCC 300, Solar Thermal System Standard

First Public Comment Draft

December 4, 2024

The first public comment draft of BSR/ICC 900/SRCC 300-202X, Solar Thermal System Standard was released on December 4, 2024. Public comments will be accepted through January 27, 2025. Comments must be submitted using the ICC Public Comment Form (click here to download the form). Comments must contain both specific changes proposed and a rationale statement, in order to be accepted. See the public comment form for more instructions.

This document contains proposed revisions to the current edition of the standard, ICC 900/SRCC 300-2020. The current, published version of the standard may be viewed for reference purposes at the following link: ICC 900/SRCC 300-2020 This draft document proposes both changes to the content and a significant reorganization of the content. Therefore comments will be accepted on the entire document, not just the portions that were revised. All qualifying comments submitted by the deadline will be adjudicated by the IS-STSC in accordance with ICC's ANSI-approved Standard development procedures.

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CHAPTER 1

APPLICATION AND ADMINISTRATION

SECTION 101 GENERAL

101.1 Purpose. This standard sets forth the minimum criteria for the design and installation of *solar thermal system*s used to heat fluids. Furthermore, this standard describes the requirements and methodology for standardized *solar thermal system* design evaluation, including the analytical evaluation of its components.

SECTION 102 SCOPE

102.1 Scope. This standard shall apply to solar energy systems used in applications for water heating—generally referred to as *solar thermal systems*.

This standard shall not apply to:

1. *Solar thermal system*s designed to heat fluids for the exclusive purpose of electrical power generation,
2. *Solar thermal systems* designed exclusively to heat pools or spas.

Solar thermal systems within the scope of this document shall consist of the assemblage of components comprising a system that converts solar radiation to thermal energy for subsequent use heating water. Solar thermal systems shall be comprised of components that include, but are not limited to: solar thermal collectors, piping, storage tanks, auxiliary water heaters, pumps, controllers, valves, expansion control devices, heat exchangers and pump stations. Such systems may be wholly or partially factory or site built.

Exception: Solar collector mounting brackets and racking systems are not included within the scope of this standard.

SECTION 103 REFERENCED DOCUMENTS

103.1 Referenced documents. The codes and standards referenced in this standard shall be considered to be part of the requirements of this standard to the prescribed extent of each such reference. Chapter 4 contains a complete list of all referenced documents.

CHAPTER 2

DEFINITIONS

SECTION 201
GENERAL

201.1 General. For the purpose of this standard, the terms listed in Section 202 have the indicated meaning.

201.2 Undefined terms. The meaning of terms not specifically defined in this document or in the referenced standards shall have ordinarily accepted meanings such as the context implies.

201.3 Interchangeability. Words, terms and phrases used in the singular include the plural and the plural include the singular.

201.4 Solar vocabulary. Where terms relating to solar energy are not given in Section 202, the terms and definitions in ISO 9488 shall apply.

SECTION 202
DEFINED TERMS

ACCESS (TO). That which enables a device, appliance or equipment to be reached by ready access or by a means that first requires the removal or movement of a panel, door or similar obstruction [see also “Ready access (to)”].

ACTIVE SYSTEM. A *solar thermal system* using a pump to circulate fluid through any part of the system.

APPROVED. Acceptable to the code official or other authority having jurisdiction.

AUXILIARY WATER HEATER. Water heating equipment utilizing energy sources other than solar incorporated into solar thermal systems to supplement the output provided by the solar thermal collectors.

BACKFLOW. The flow of water or other fluids, mixtures or substances into the distribution pipes of a potable water supply from any source except the intended source.

CONTROLLER. Any device or part thereof that regulates the operation of the solar thermal system or component.

DESIGN LIFE. The intended useful operational life of a *solar thermal system* or component, as defined by the supplier.

MAXIMUM DESIGN SUPPLY PRESSURE. Maximum pressure of the water supplied to the system without experiencing degradation, damage or a reduction of the design life, as specified by the manufacturer.

MINIMUM DESIGN OPERATING TEMPERATURE. Minimum outdoor temperature in the solar thermal system without experiencing degradation, damage or a reduction in design life, as specified by the manufacturer.

FLAMMABLE LIQUID. A liquid having a closed cup flash point below 100°F (38°C). Flammable liquids are further categorized into a group known as Class I liquids. The Class I category is subdivided as follows:

> Class IA. Liquids having a flash point below 73°F (23°C) and having a boiling point below 100°F (38°C).
>
> Class IB. Liquids having a flash point below 73°F (23°C) and having a boiling point at or above 100°F (38°C).
>
> Class IC. Liquids having a flash point at or above 73°F (23°C) and below 100°F (38°C).

HEAT EXCHANGER. A device that transfers thermal energy from one fluid to another.

DOUBLE-WALL HEAT EXCHANGER. A *heat exchanger* design in which a single failure of any fluid barrier will not cause a cross connection or permit backflow of heat transfer fluid between two separate fluid systems.

SINGLE-WALL HEAT EXCHANGER. A *heat exchanger* design in which a single failure of any fluid barrier will cause a cross connection or permit backflow of heat transfer fluid between two separate fluid systems.

HEAT TRANSFER FLUID. The operating or thermal storage fluid in a *solar thermal system*, including water or other base, and additives at the concentration present under operating conditions used to move heat from one location to another.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

MANUAL. The total documentation package provided by the manufacturer describing the installation, operation and maintenance of the *solar thermal system*.

NONPOTABLE WATER. Water not safe for drinking, personal or culinary use.

PHOTOVOLTAIC (PV) SOLAR WATER HEATING COLLECTOR. A subsystem that converts solar radiation into electrical potential using one or more photovoltaic modules, used to supply power directly and exclusively to an electrical water heating device. Typically, a combination of one or more PV modules, DC-AC inverters or DC-DC converters and other controls that are used to provide electrical power directly to one or more electrical water heating devices and/or electrical water heaters

PHOTOVOLTAIC THERMAL HYBRID SOLAR COLLECTOR (PVT). A photovoltaic thermal hybrid solar collector is a solar collector using photovoltaic panels or cells as a thermal absorber and therefore converts solar radiation into electrical and thermal energy.

POTABLE WATER. Water free from impurities present in amounts sufficient to cause disease or harmful physiological effects and conforming to the bacteriological and chemical quality requirements of the Public Health Service Drinking Water Standards or the regulations of the public health authority having jurisdiction.

PUMP STATION. A factory-built *subassembly* of components containing a pump and other components to moves fluid around and through a *solar thermal system.*

READY ACCESS (TO). That which enables a device, appliance or equipment to be directly reached without requiring the removal or movement of any panel, door or similar obstruction and without the use of a portable ladder, step stool, or similar device [see “Access (to)”].

SOLAR LOOP. The portion of the *solar thermal system* that transports the *heat transfer fluid* in the form of gas or liquid through the *solar thermal collector*.

SOLAR THERMAL COLLECTOR. Components in a *solar thermal system* that collect and convert solar radiation to thermal energy.

SOLAR THERMAL SYSTEM. A system that converts solar radiation to thermal energy in a fluid for use in heating applications.

> **DRAIN-BACK SYSTEM.** *Solar thermal systems* in which the fluid in the solar loop is drained from the collector into a holding tank under prescribed circumstances.
>
> **DRAIN-DOWN SYSTEM.** *Solar thermal systems* in which the fluid in the solar collector is drained from the system to an *approved* disposal area under prescribed circumstances.
>
> **INDIRECT SYSTEM.** *Solar thermal system* in which the fluid in the solar loop circulates between the solar collector(s) and a heat exchanger and during normal operation such fluid is not drained from the system and is not supplied to the load.
>
> **SOLAR WATER HEATING SYSTEM (SOLAR WATER HEATER)**. A *solar thermal system* designed to heat potable water for domestic use.
>
> > **PHOTOVOLTAIC (PV) WATER HEATER.** A *solar water heating system* designed to convert energy contained within solar radiation using one or more photovoltaic modules supplying electricity to electric water heaters and/or electric heating elements solely for the purpose of heating water.

STAGNATION. A condition where no heat is removed from a collector or system by a heat transfer fluid and the gain from solar radiation is balanced by the heat loss.

SOLAR TANK. Hot water storage tank designed for use within solar thermal systems to accept and store fluid heated by solar collectors. Solar tanks may incorporate integral heat exchangers and supplemental heating equipment and may be pressurized or unpressurized. Solar tanks are not designed or listed to function stand-alone hot water heaters (without solar energy input).

SUBASSEMBLY. A separable, functional assembly of components used in a solar thermal system.

THIRD-PARTY TESTED. Procedure by which an *approved* testing laboratory provides documentation that a product, material or system conforms to specified requirements.

TOXIC FLUIDS. Fluids that are poisonous or irritating in nature or composition with a Gosselin Toxicity Index greater than 2.

CHAPTER 3

DESIGN REQUIREMENTS

SECTION 301
GENERAL

301.0 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.

301.1 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.

301.1.1 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.

301.1.2 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.

301.1.4 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*.

301.1.3 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 302.1.3.1 through 302.1.3.2.

301.1.3.1 Water exposed to freezing temperatures. For solar thermal systems where 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 301.1.3.2 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).

301.1.3.2 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 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.

301.2.1 High pressure resistance. Each portion of the system where 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 design pressure of the system component that has the lowest pressure rating.

301.2.2 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 180ºF (82ºC).

301.2.3 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.

301.3 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*.

301.4 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.

301.5 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.

301.6 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.

301.7 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:

- Minimum outdoor air temperature,
- Maximum water supply temperature,
- 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 and 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 301.7 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. The closed cup flash point of heat transfer fluids shall exceed 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 304.4.6 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.

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

304.1.7 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 304.2.2. 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.

304.2.2 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 Boiler and Pressure Vessel Code, Sections I, II, IV, V and IX

304.3 Solar and drainback tanks. Tanks used to store heated liquids in solar thermal systems, including solar tanks, drainback 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 & 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, 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 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-0.46°K • m^2/W (R-2.6°F • ft^2 • hr /Btu) 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, and
2. The maximum operating pressure of the non-potable *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 sub-assemblies 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 over 24 volts used within systems shall be listed and labeled to standards referenced by NFPA 70. Electrically powered components over 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
Inverters and power conditioners	UL 1741
Metal-sheathed heating elements	UL 1030
Wiring connectors	UL 1977
Solar trackers	UL 3703

CHAPTER 4

TESTING

SECTION 401
GENERAL

401.1 General. Solar thermal water heating systems are subject to testing to confirm basic safety and durability compliance. This standard prescribes two methods to satisfy testing requirements, applicable per system type as shown in Table 401. The Component-Based Testing Method, described in Section 402, is based on testing and listing of individual solar thermal components apart from the rest of the system. The second, System Assembly Testing Method in Section 403, requires testing of the complete, assembled solar thermal system. Each system shall comply with either Section 402 or 403, as prescribed by Table 401. Regardless of the method used, all applicable requirements in Chapter 3 must be satisfied for each system.

TABLE 401
SYSTEM TYPE TESTING METHODS

SYSTEM TYPE	SECTION 402 COMPONENT-BASED TESTING	SECTION 403 SYTEM ASSEMBLY TESTING
Separable Pumped Systems	x	x
Separable Thermosiphon Systems	x	x
Inseparable Thermosiphon Systems		x
Integrated Collector Storage (ICS) Systems		x
Photovoltaic Water Heating Systems	x	x

SECTION 402
COMPONENT-BASED TESTING METHOD

402.1 General. Systems assessed by means of the Component-Based Testing Method are not tested as an assembly but are evaluated using the testing and listing of the components as specified in Chapter 3. Each component in the system must be installed and operated within the system in accordance with its installation and operating instructions, design operating conditions, and all conditions of listing.

SECTION 403
SYSTEM ASSEMBLY TESTING METHOD

403.1 General. Systems assessed by the System Assembly Testing Compliance Method shall be tested in accordance with the requirements in this section.

403.2 Tests required. Tests required under the System Assembly Testing Method are specified below. Tests shall be conducted in the order given.

403.2.1 Stagnation temperature. The stagnation temperature within the collector shall be determined as specified in this section.

403.2.1.1 No controls employed. If controls are not employed, the collector's standard stagnation temperature shall be determined in accordance with ISO 9806, Section 9.

Exception: Stagnation temperature testing for PVT collectors shall be performed as specified in ISO 9806, Section 9.2. The standard stagnation temperature shall be calculated as specified in ISO 9806, Section 9.3.

403.2.1.2 Controls employed. If fail-safe controls are employed, the collector's standard stagnation temperature shall be determined in accordance with manufacturer's stated maximum operating temperature.

403.2.2 Exposure test. Exposure testing shall be in accordance with ISO 9806, Section 10 using a minimum of Class B climate conditions, for no less than 30 days of exposure to adverse conditions.

Exception:

1. Exposure testing for systems incorporating PVT collectors shall be performed as specified in ISO 9806, Section 10 for a half exposure, using a minimum of Class B climate conditions, for no less than 15 days of exposure to adverse conditions.

2. Exposure testing shall not be required for PV water heating systems.

403.2.3 External thermal shock test. Two external thermal shock tests shall be performed as specified in ISO 9806, Section 11, using a minimum of Class B conditions.

403.2.4 Internal thermal shock test. Two internal thermal shock tests shall be performed as specified in ISO 9806, Section 12, using a minimum of Class B conditions.

403.2.5 Rain penetration test. Where the system incorporates roof-mounted storage, a rain penetration test of the collector and storage assembly shall be conducted in accordance with ISO 9806, Section 13.

403.2.6 Hydrostatic pressure. A hydrostatic pressure test shall be performed as specified in ICC 903/SRCC 500. For tanks with integral heat exchangers, both sides of the heat exchanger shall be tested as specified in ICC 903/SRCC 500.

403.2.7 Mechanical load. The ability of the collector to withstand loading by wind or snow shall be determined as specified in ISO 9806, Section 15, except for PV water heating systems.

403.2.8 Impact resistance. The ability of the collector to withstand impact shall be determined as specified in ISO 9806, Section 16. Where reflectors and receivers are separated, both elements shall be subjected to impact, unless specified below. The optical elements of the collector shall withstand impacts without adverse effect on operation or performance.

Exception: Impact-resistance testing shall not be required in the following cases:

1. Where the outer cover is constructed of flat glass, tempered in accordance with ASTM C1048.

2. Where a PVT collector assembly utilizes a photovoltaic module tested in accordance with the Impact Test specified in UL 1703, or Module Breakage Test in UL 61730, and the solar thermal components are not subject to direct solar irradiance (i.e.,completely obscured by the PV module).

3. For PV water heating systems without solar thermal collectors.

403.2.9 Final Inspection. After completing the applicable test sequence, the system shall be disassembled, its subassemblies visually inspected and their condition noted as specified in ISO 9806, Section 17, to determine final condition and actual or potential points of failure.

403.3 Setup. Solar thermal systems shall be setup for testing as prescribed in each test method in this section. For each test, the complete system shall be assembled as specified by the manufacturer in the system installation instructions.

403.3.1 Active mechanisms. If the system incorporates active mechanisms that are intended to be functional during operation, those mechanisms shall be operational during all testing. The function and activation of all controls during testing shall be reported. Where control systems have multiple modes, the default mode shall be selected.

403.3.2 Systems with PVTs. For systems incorporating photovoltaic-thermal hybrid collectors (PVTs), all tests shall be conducted using the fully assembled PVT, with all electrical generation and solar thermal components installed.

Testing prescribed below shall be conducted where the electrical power generation components are not connected to any electrical load, in an open-circuit configuration in accordance with ISO 9806, Section 5.2.3.1. The operating mode of the electrical generating components shall be reported for all tests in accordance with ISO 9806, Section 5.2.3.2.

Exception: Thermal Performance Testing shall be conducted with electrical power generation components operating at maximum power as specified in ISO 9806, Section 5.2.3.1.

403.3.3 In-situ testing. Systems that are unable to be tested in a testing laboratory because of size or transportability or are designed for a specific installation may be tested in-situ, in whole or in part.

403.3.5 Auxiliary water heaters. Auxiliary water heaters shall not be installed as part of the *solar thermal system* for the testing specified above.

403.3.6 Supplemental heaters. If the *solar thermal system* includes a supplemental heater installed in the tank or collector, it shall be installed and enabled during all tests. The setpoint of the supplemental heater shall be 50°C (122°F).

403.4 Gross area. Gross area of the collectors in the system shall be determined as defined in ISO 9488.

Exception: The gross area of a PVT shall be determined utilizing the full projected area of the PV module and solar thermal collector assembly. Gross area shall not include junction boxes or microinverters projecting beyond the projected area of the PVT assembly.

403.5 Final inspection. After completing the test sequence, the system shall be disassembled, its subassemblies visually inspected and their condition noted to determine post-testing condition and actual or potential points of failure.

403.5.1 Inspection criteria. Components and inspection criteria shall be in accordance with Table 403.1.1(a). Test specimens and their components shall not exhibit conditions capable of producing premature failure including, but not limited to the items listed in Table 403.1.1(b).

TABLE 403.5.1(a)
COMPONENT INSPECTION CRITERIA

COLLECTOR COMPONENT	INSPECTION CRITERIA
Collector box/fasteners	Cracking, warping, corrosion, rain and penetration
Mountings/structure	Strength and safety
Seals/gaskets	Cracking, adhesion and elasticity
Cover/reflector	Cracking, *crazing*, buckling, delamination, warping and outgassing
Absorber coating	Cracking, *crazing* and blistering
Absorber tubes and headers	Deformation, corrosion, leakage and loss of bonding
Absorber mountings	Deformation and corrosion
Insulation	Water retention, outgassing and degradation

TABLE 403.5.1(b)
PREMATURE FAILURE CONDITIONS

Severe deformation[a] of the absorber
Severe deformation[a] of the fluid flow passages.
Loss of bonding between fluid flow passages and absorber plate.
Leakage from fluid flow passages or connections.

Loss of mounting integrity.
Severe corrosion[a] or other deterioration caused by chemical action.
Crazing, cracking, blistering or flaking of the absorber coating or concentrating optical element surfaces.
Excessive retention of water anywhere in the collector.
Swelling, severe outgassing or other detrimental changes in the collector insulation that could adversely affect collector performance.
Cracking, loss of elasticity, or loss of adhesion of gaskets and sealants.
Leakage or damage to hoses used inside the collector enclosure, or leakage from mechanical connections.
Cracking, crazing, permanent warping or buckling of the cover plate.
Cracking or warping of the collector enclosure materials.

a. Deformation or corrosion shall be considered severe if it impairs the function of the collector or there is evidence that it will progress.

CHAPTER 5

LABELING, MARKING AND DOCUMENTATION

SECTION 501 GENERAL

401.1 General. *Solar thermal systems* shall be provided with marking, labeling and documentation to facilitate installation, inspection, operation, and maintenance. Where components or subassemblies are listed individually, this section shall not supersede the labeling and marking requirements associated with the component listings.

SECTION 502 PRODUCT MARKING AND LABELING

502.1 General. *Solar thermal systems* shall include one or more indelible labels containing system information as established in this section. the label shall be permanently affixed in a readily accessible location at ground level. Where systems do not include a dedicated solar storage tank, the label shall be affixed to the auxiliary water heater. For PV water heaters, the label may also be affixed to an inverter.

502.2 Label content. The information specified in this section shall be provided with one to two labels in a clearly readable size and format. Where two labels are utilized, they shall be affixed in proximity to each other. The label(s) shall include the following information:

1. Manufacturer’s name and/or trademark.
2. Model number of the solar thermal system.
3. Third-party certification agency name and/or trademark and listing number.
4. Collector model number and peak power rating as specified in ISO 9806.
5. Heat transfer fluid volume
6. Storage tank volumetric and energy capacity determined as specified in ICC 903/SRCC 500.

7. Relief valve specifications and setpoints.
8. Maximum water supply pressure.
9. Maximum solar loop pressure.
10. Freeze protection instructions.
11. Auxiliary and supplemental heater energy ratings. For electrical, include phase/volts/amps. For gas, include minimum pressure.
12. Installation date field (to be entered by the installer in the field).
13. Installation and operation manual location with a URL. The link should lead directly to current versions of the specified documents. Optionally, a machine-readable QR code, compliant with Section 5.2.2.1, may also be provided.

502.2.1 Machine-readable codes. Where machine-readable codes (QR codes) are provided on labeling, they shall be given with the associated URL spelled out in text adjacent to it. QR codes shall be a minimum size of 2 cm x 2 cm (0.8 in x 0.8 in). Machine-readable codes may not be used instead of the label content specified in Section 502.2.

SECTION 503 MANUALS

503.1 General. One or more manual shall be provided with each *solar thermal system*. Manuals shall address procedures for installation, operation and maintenance of the *solar thermal system* as specified in this Section.

503.1.1 Listee information. Each manual shall include the following minimum information regarding the system listee and system identifiers:

1. Name and address of the system listee.
2. System model name or number.

503.1.2 System specifications. At least one manual shall include the following minimum information on the system specifications and operational limits.

1. Maximum water supply pressure.
2. Maximum solar loop pressure.
3. Typical heat transfer fluid fill volume.
4. Approved heat transfer fluids, stating whether each fluid is toxic or hazardous
5. System storage tank volumes.
6. Auxiliary and supplemental water heater sizes and types approved for use with the system including energy ratings. For electrical, include phase/volts/amps. For gas, include maximum hourly BTU input rating.
7. Outdoor operating conditions including maximum and minimum environmental temperature.
8. *Freeze tolerance limit* and freezing control measures and include the statement:

"Freeze tolerance limits are based upon an assumed set of environmental conditions." Where the freezing point of the fluid in an exposed part of the system is above the freeze tolerance limit specified for the system, the following statement shall be provided: "Extended periods of cold weather, including ambient air temperatures above the specified limit, might cause freezing in exposed parts of the system. It is the owner's responsibility to protect the system in accordance with the supplier's instructions if the air temperature is anticipated to approach the specified freeze tolerance limit."

503.1.3 System design information. At least one manual shall include the following minimum information:

1. Description of the operation of the system,
2. Master wiring diagram identifying electrical components, connections and wire types with system electrical supply requirements including, but not limited to, electrical phase, voltage and maximum current. .

3. Mechanical diagram showing all major system components and connections The diagram shall identify operation of valves for bypass, filling, draining and shutdown operations.
4. Parts list containing all major system components shown on the mechanical diagram. The parts list must include the manufacturer, model and quantity of the solar collectors approved for use in the system. The manual shall include a list of all consumable items and replacement parts to facilitate maintenance and repair for the system.

503.1.4 Safety information. At least one manual shall include the following minimum information:

1. Warning against any health and safety hazards that could arise in the operation and maintenance of the system and that must be taken to avoid these hazards.

2. Proper procedures for handling, safe disposal, and first aid shall be provided for each nonwater fluid approved for use in the system. A technical data sheet shall be provided for each nonwater fluid or additives for water used in the system.

503.2 Installation. A manual shall be provided that includes general procedures for proper installation of the *solar thermal system*. Installation instructions shall prescribe installation complying with the building code, plumbing code, mechanical code, fire code and electrical code adopted by the authority having jurisdictions, or in the absence of such codes, shall comply with the *International Building* Code, *International Plumbing Code, International Mechanical Code, International Fire Code,* and *National Electrical Code (NFPA 70) or International Residential Code* or Appendix B.

503.2.1 Leakage testing. Installation instructions shall include a procedure for leakage testing of the system following installation.

503.2.2 Gravity drain checks. If the system incorporates gravity drain-down processes, instructions for verification of proper draining of the system shall be provided.

503.2.3 Pipes fittings and connectors. The manual shall list the types and sizes of piping, fittings, joints, and pipe insulation approved for use in the system.

503.2.4 Auxiliary water heater or boiler installation. The manual shall specify that the auxiliary water heater or boiler be installed in accordance with the auxiliary water heater or boiler manufacturer's instructions and local codes.

503.3 Operation instructions. Information shall be provided in a manual addressing proper operation of the system. It shall include the following minimum information:

1. Procedures for system commissioning operation and restart.

2. Include instructions for isolating the system in emergency situations.

3. Instructions for leaving the system unattended and unused for long periods of time.

503.4 Maintenance instructions. Information shall be provided in a manual addressing proper maintenance procedures, practices and intervals for the system. The manual shall include a comprehensive plan and schedule for maintaining the specified performance of the *solar thermal system* over the *design life* of the system. Procedures for ordinary and preventive maintenance of the system shall be provided.

503.4.1 Heat transfer fluid maintenance. Procedures shall be described for maintaining the chemical composition of non-water heat transfer fluids at levels to minimize deposits on heat transfer surfaces, corrosion of heat transfer surfaces and loss of freeze resistance. Recommended inspection and test intervals for the heat transfer fluid shall be provided. Procedures for checking the heat transfer fluid fill level shall be provided.

503.4.2 Collector maintenance. Procedures and intervals for solar thermal collector inspection and cleaning shall be provided.

CHAPTER 6

REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section 103.1.

ANSI

American National Standards Institute
25 West 43rd Street, Fourth Floor
New York, NY 10036

Standard reference number	Title	Referenced in code section number
ANSI Z21.10.1/ CSA 4.1—2017	Gas Water Heaters, Volume 1, Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less	304.3.1, Table 304.2
ANSI Z21.10.3/ CSA 4.3—2019 (R2024)	Gas Water Heaters, Volume III, Storage Water Heaters with Input Ratings above 75,000 Btu per Hour, Circulating and Instantaneous	304.3.1, Table 304.2
ANSI Z21.13.3/ CSA 4.9—2022	Gas-Fired Low Pressure Steam and Hot Water Boilers	Table 304.3.1
ANSI Z21.22/ CSA 4.4—2015 (R2020)	Relief Valves for Hot Water Supply Systems	304.4.2, 304.4.3, B2.1.3

ASME

American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

Standard reference number	Title	Referenced in code section number
BPVC—2023	ASME Boiler and Pressure Vessel Code	304.3.1, Table 304.2
ASME A112.4.14/ CSA B125.14—2022	Manually operated valves for use in plumbing systems	Table B.2.9
ASME A112.18.1/ CSA B125.1—2023	Plumbing Supply Fittings	Table B.2.9
ASME A112.18.6/ CSA B125.6—2021	Flexible Water Connectors	Table B.2.7(a)
B1.20.1—2023	Pipe Threads, General Purpose, Inch	B.2.8.2
B16.3—2021	Malleable Iron Threaded Fittings, Classes 150 & 300	Table B.2.6(b), Table B.2.7(b)
B16.4—2021	Gray Iron Threaded Fittings Classes 125 and 250	Table B.2.6(b)
B16.5—2019	Pipe Flanges and Flanged Fittings NPS 1/2 through NPS 24	Table B.2.7(b)
B16.9—2023	Factory Made Wrought Steel Buttwelding Fittings	Table B.2.6(b), Table B.2.7(b)
B16.11—2021	Forged Fittings, Socket-welding and Threaded	Table B.2.6(b), Table B.2.7(b)
B16.12—2024	Cast Iron Threaded Drainage Fittings	Table B.2.6(b)
B16.15—2023	Cast Bronze Threaded Fittings	Table B.2.6(b), Table B.2.7(b)

B16.18—2023	Cast Copper Alloy Solder Joint Pressure Fittings	Table B.2.6(b), Table B.2.7(a), Table B.2.7(b)
B16.22—2023	Wrought Copper and Copper Alloy Solder Joint Pressure Fittings	Table B.2.6(b), Table B.2.7(b)
B16.23—2021	Cast Copper Alloy Solder Joint Drainage Fittings: DWV	Table B.2.6(b), Table B.2.7(b)
B16.24—2021	Cast Copper Alloy Pipe Flanges and Flanged Fittings: Class 150, 300, 400, 600, 900, 1500 and 2500	Table B.2.7(b)
B16.26—2023	Cast Copper Alloy Fittings for Flared Copper Tubes	Table B.2.6(b), Table B.2.7(b)
B16.28—1994	Wrought Steel Buttwelding Short Radius Elbows and Returns	Table B.2.6(b), Table B.2.7(b)
B16.29—2022	Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings (DWV)	Table B.2.6(b), Table B.2.7(b)
B16.34—2023	Valves-Flanged, Threaded, and Welding End	Table B.2.9

ASSE

ASSE International
18927 Hickory Creek Drive, Suite 220
Mokena, IL 98157

Standard reference number	Title	Referenced in code section number
1017—2023	Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems	304.4.4, D.4.4
1061—2020	Performance Requirements for Removable and Non-Removable Push-Fit Fittings	B.2.8.9, Table B.2.6(b)
1079—2024	Performance Requirements for Dielectric Pipe Unions	B.2.8.12.1, B2.8.12.3

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

Standard reference number	Title	Referenced in code section number
A53/A53M—2020	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	Table B.2.6(a), Table B.2.7(a)
A106/A106M—2019	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service	Table B.2.7(a)
A126—2004 (R2023)	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings	Table B.2.7(b)
A254/A254M—2012 (2019)	Specification for Copper-Brazed Steel Tubing	Table B.2.7(a)
A312/A312M—2021	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes	Table B2.6(b), Table B.2.7(a), B2.8.5
A420/A420M—2024	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	Table B.2.7(b)
A778/A778M—2021	Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a)
B42—2020	Specification for Seamless Copper Pipe, Standard Sizes	Table B.2.6(a), Table B.2.7(a)
B43—2020	Specification for Seamless Red Brass Pipe, Standard Sizes	Table B.2.6(a), Table B.2.7(a)
B75/B75M—2020	Specification for Seamless Copper Tube	Table B.2.6(a), Table B.2.7(a)
B88—2022	Specification for Seamless Copper Water Tube	Table B.2.6(a), Table B.2.7(a)
B135/B135M—2017	Specification for Seamless Brass Tube	Table B.2.7(a)
B251/B251M—2017	Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube	Table B.2.6(a), Table B.2.7(a)
B302—2017	Specification for Threadless Copper Pipe, Standard Sizes	Table B.2.6(a), Table B.2.7(a)
B447—2012 (2021)	Specification for Welded Copper Tube	Table B.2.6(a),
D1527—1999 (2005)	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80	Table B.2.7(a)

D1693—2021	Test Method for Environmental Stress-Cracking of Ethylene Plastics	Table B.2.7(a)
D1785—2021a	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120	Table B.2.6(a), Table B.2.7(a)
D2282—1999 (2017)	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)	Table B.2.7(a)
D2241—2024	Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)	Table B.2.6(a), Table B.2.7(a)
D2464—2023	Specification for Threaded Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	Table B.2.6(b)
D2466—2024	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40	Table 301.9.4.1, Table 301.9.4.2
D2467—2024	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	Table 301.9.4.1, Table 301.9.4.2
D2468—1996a	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40	Table 301.9.4.1, Table 301.9.4.2
D2513—2024	Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings	Table B.2.7(a)
D2609—2024	Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe	Table B.2.6(b)
D2683—2020	Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing	Table B.2.7(a), Table B.2.6(b)
D2837—2024	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products	Table B.2.7(a)
D2846/2846M—2024	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems	Table 301.9.2, Table B.2.7(a), Table B.2.6(b)
D3035—2022	Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter	Table B.2.7(a)
D3350—2024	Specification for Polyethylene Plastics Pipe and Fittings Materials	Table B.2.7(a)
F437—2024	Specifications for Threaded Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe fittings, Schedule 80	Table B.2.6(b)
F438—2023	Specification for Socket-type Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40	Table B.2.6(b), Table B.2.7(b)
F439—2019	Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80	Table B.2.6(b), Table B.2.7(b)
F441/F441M—2023	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80	Table B.2.6(a), Table B.2.7(a)
F442/F442M—2023	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe (SDR–PR)	Table B.2.6(a), Table B.2.7(a)
F876—2024b	Specification for Crosslinked Polyethylene (PEX) Tubing	Table B.2.6(a), Table B.2.7(a)
F877—2024	Specification for Crosslinked Polyethylene (PEX) Hot- and Cold-Water Distribution Systems	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a), Table B.2.7(b)
F986—2022	Standard Specification for Suction Strainer Boxes	Table B.2.7(b)
F1055—2022	Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing	Table B.2.6(b), Table B.2.7(a)
F1281—2024	Specification for Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a)
F1282—2023a	Specification for Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure Pipe	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a)
F1970—2023	Standard Specification for Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Systems	Table B.2.9
F1986—2001(2011)	Standard Specification for Multilayer Pipe Type 2, Compression Fittings, and Compression Joints for Hot and Cold Drinking-Water Systems	Table B.2.6(a), Table B.2.6(b)
F2080—2023	Specifications for Cold-expansion Fittings with Metal Compression-sleeves for Cross-linked Polyethylene (PEX) Pipe	Table B.2.6(b)
F2098—2024	Standard specification for Stainless Steel Clamps for Securing SDR9 Cross-linked Polyethylene (PEX) Tubing to Metal and Plastic Insert Fittings	Table B.2.6(b)
F2159—2023a	Specification for Plastic Insert Fittings Utilizing a Copper Crimp Ring for SDR9 Cross-linked Polyethylene (PEX) Tubing and SDR9 Polyethylene of Raised Temperature (PE-RT) Tubing	Table B.2.6(b), Table B.2.7(b)

F2262—2009	Specification for Multilayer Pipe Type 2, Compression Fittings, and Compression Joints for Hot and Cold Drinking-Water Systems	Table B.2.6(a)
F2389—2024a	Specification for Pressure-rated Polypropylene (PP) Piping Systems	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a), Table B.2.7(b), B.2.8.11, Table B.2.9
F2623—2024e1	Specification for Polyethylene of Raised Temperature (PE-RT) SDR 9 Tubing	Table B.2.7(a)
F2735—2023	Standard Specification for Plastic Insert Fittings for SDR9 Cross-linked Polyethylene (PEX) and Polyethylene of Raised Temperature (PE-RT) Tubing	Table B.2.6(b), Table B.2.7(b)
F2769—2024	Polyethylene of Raised Temperature (PE-RT) Plastic Hot and Cold-Water Tubing and Distribution Systems	Table B.2.6(a), Table B.2.6(a)

AWWA

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235

Standard reference number	Title	Referenced in code section number
C110/A21.10—2021	Standard for Ductile Iron & Gray Iron Fittings	Table B.2.6(b), Table B.2.7(b)
C115/A21.15—2020	Flanged Ductile-Iron Pipe With Ductile-Iron or Gray-Iron Threaded Flanges	Table B.2.6(a), Table B.2.7(a)
C151/A21.51—2023	Ductile-Iron Pipe, Centrifugally Cast	Table B.2.6(a), Table B.2.7(a)
C153/A21.53—2019	Standard for Ductile-Iron Compact Fittings for Water Service	Table B.2.6(b), Table B.2.7(b)
C500—2019	Metal-Seated Gate Valves for Water Supply Service	Table B.2.9
C504—2023	Rubber-Seated Butterfly Valves	Table B.2.9
C507—2023	Ball Valves, 6 In. Through 60 In. (150 mm Through 1,500 mm)	Table B.2.9

CSA

Canadian Standards Association
8501 East Pleasant Valley
Cleveland, OH 44131-5516

Standard reference number	Title	Referenced in code section number
B125.3—2018	Plumbing fittings	304.4.4, Table B.2.9, D.4.4
B137.1—2023	Polyethylene (PE) Pipe, Tubing and Fittings for Cold Water Pressure Services	301.9.2, Table 301.9.4, Table B.2.6(b)
B137.2—2023	Polyvinylchloride (PVC) Injection-moulded Gasketed Fittings for Pressure Applications	Table B.2.6(b)
B137.3—2023	Rigid Poly (Vinyl Chloride) (PVC) Pipe for Pressure Applications	Table B.2.6(b)
B137.5—2023	Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications	Table B.2.6(a), Table B.2.6(b)
B137.6—2023	Chlorinated Polyvinylchloride (CPVC) Pipe, Tubing, and Fittings for Hot- and Cold-Water Distribution Systems	Table B.2.6(a), Table B.2.6(b)
B137.9—2023	Polyethylene/Aluminum/Polyethylene (PE-AL-PE) Composite Pressure-Pipe Systems	Table B.2.7(a), Table B.2.6(b), Table B.2.7(a)
B137.10—2023	Crosslinked Polyethylene/Aluminum/Crosslinked Polyethylene (PEX-AL-PEX) composite Pressure-Pipe Systems	Table B.2.6(a), Table B.2.6(b), Table B.2.7(a)
B137.11—2023	Polypropylene (PP-R) Pipe and Fittings for Pressure Applications	Table B.2.6(a), Table B.2.6(b)
C22.1—2024	Canadian Electrical Code, Part I	303.2.3
C22.2, No. 108—2014(2024)	Liquid Pumps	304.7, Table 304.10
E60730-1—2015	Automatic electrical controls – Part 1: General requirements	Table 304.10

IAPMO

IAPMO Group
4755 E. Philadelphia Street
Ontario, CA 91761

Standard reference number	Title	Referenced in code section number
Z1157—2014(R2019)	Ball Valves	Table B.2.9

ICC

International Code Council, Inc.
500 New Jersey Ave, NW
6th Floor
Washington, DC 20001

Standard reference number	Title	Referenced in code section number
ICC 901/SRCC 100—2020	Solar Thermal Collectors	304.2.1, A2.1, A3.0, A7.4.1, C101.1
ICC 903/SRCC 500—2024	Solar Tanks	304.2, 304.3.1, 304.6, 403.2.6, 502.2
IBC—24	International Building Code®	503.2, A1.2, B.1.1
IFC—24	International Fire Code®	503.2, B.1.7
IMC—24	International Mechanical Code	301.0, 304.4, 304.4.1, 304.5, 304.8, 503.2, B.1.4, B.2.10.1
IRC—24	International Residential Code	301.0, 304.4, 304.4.1, 304.5, 304.8, 503.2, B.1.1
IPC—24	International Plumbing Code	301.0, 304.4, 304.4.1, 304.5, 304.8, 503.2, B.1.1, B.1.4, B.2.4, B.2.5

IEC

International Electrotechnical Commission
3, rue de Varembé, PO Box 131, CH-1211
Geneva 20, Switzerland

Standard reference number	Title	Referenced in code section number
IEC 60529—1989	Degrees of protection provided by enclosures (IP Code)	D.6.2

ISO

International Organization for Standardization
ISO Central Secretariat
1 ch, de la Voie-Creuse, Case Postale 56
CH-1211 Geneva 20, Switzerland

Standard reference number	Title	Referenced in code section number
ISO 9488-1999	Solar Energy – Vocabulary	201.4, 403.4, C.5.1
ISO 9806-2017	Solar energy — Solar thermal collectors — Test methods	403.2.1, 403.2.2, 403.2.3, 403.2.4, 403.2.5, 403.2.7, 403.2.8, 403.2.9, 403.3.2, 502.2, A2.1, A5.3, Table A5.3, A5.3.1, A.6.1, A.6.4, C.4.4.2, C.6.1.1
ISO 10380—2012	Pipework—Corrugated Metal Hoses and Hose Assemblies	Table B.2.7(a)

ISO 21469—2006	Safety of machinery — Lubricants with incidental product contact — Hygiene requirements	303.2

MSS

Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
127 Park Street, NE
Vienna, VA 22180-4602

Standard reference number	Title	Referenced in code section number
SP-67—2022	Butterfly Valves	Table B.4.2

NFPA

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471

Standard reference number	Title	Referenced in code section number
70—2023	National Electrical Code	304.10.1, 304.10.2, 304.10.3, 503.2, B.4.1, B.4.2

NSF

NSF International
789 N. Dixboro
Ann Arbor, MI 48105

Standard reference number	Title	Referenced in code section number
NSF HT1	Heat transfer fluids - Incidental contact	303.2
NSF 61—2023	Drinking Water System Components—Health Effects	B.2.5.8, B.2.8.4
NSF 359—2022	Valves for Crosslinked Polyethylene (PEX) Water Distribution Tubing Systems	B.2.9
NSF 372—2022	Drinking Water System Components—Lead Content	B.2.5.8

UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062-2096

Standard reference number	Title	Referenced in code section number
94—2024	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances	D.5.2
174—2004	Household Electric Storage Tank Water Heaters—with revisions through October 2021	Table 304.2, 304.3.1, D.6.2
499—2014	Electric Heating Appliances—with revisions through February 2017	Table 304.2
723—2018	Test for Surface Burning Characteristics of Building Materials	304.5.2, D.2.3, D.3.1, D.5.2
726—1995	Oil-Fired Boiler Assemblies—with revisions through October 2013	Table 304.2
732—2018	Oil-Fired Storage Tank Water Heaters—with revisions through August 2018	Table 304.2, 304.3.1
746B—2024	Polymeric Materials - Long Term Property Evaluations	D.3.1

778—2014	Standard for Motor-Operated Water Pumps	Table 304.10, 304.7
795—2016	Commercial-Industrial Gas Heating Equipment – with revisions through 2020	Table 304.2
834—2004	Heating, Water Supply, and Power Boilers - Electric—with revisions through July 2019	Table 304.2
873—2012	Standard for Safety Temperature-Indicating and Regulating Equipment	Table 304.10
969—2023	Marking and Labeling Systems	D.7
1030—2015	Standard for Sheathed Heating Elements	Table 304.10
1453—2016	Electric Booster and Commercial Storage Tank Water Heaters—with revisions through May 2018	Table 304.2, 304.3.1
1703—2002	Standard for Flat-Plate Photovoltaic Modules and Panels—with Revisions through November 2014	303.2.2.2, Table 304.10, 403.2.8
1741—2010	Standard for Inverters, Converters, Controllers and Interconnection System Equipment Use with Distributed Energy Resources	Table 304.10
1977—2022	Component Connectors for Use in Data, Signal, Control and Power Applications	Table 304.10
2523—2009	Oil-Fired Storage Tank Water Heaters—with revisions through March 2018	Table 304.2
3703—2015	Standard for Solar Trackers—with revisions through April 2020	Table 304.10
60335-2-40—2022	Household and Similar Electrical Appliances - Safety - Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers	Table 304.2, 304.3.1
61730—2023	Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction	Table 304.10, 403.2.8
60730-1—2024	Automatic Electrical Controls for Household and Similar Use - Part 1: General Requirements	Table 304.10

APPENDIX A

SOLAR UNIFORM ENERGY FACTOR PROCEDURE FOR SOLAR WATER HEATING SYSTEMS

This appendix is informative and is not part of the standard.

A.1 INTRODUCTION: The US Department of Energy sets uniform test methods for measuring the energy consumption of water heaters in 10 CFR 430, Subpart B, Appendix E, *Uniform Test Method for Measuring the Energy Consumption of Water Heaters* ("DOE Test Procedure"). It produces two performance values, First-Hour Rating or Maximum GPM and Uniform Energy Factor (UEF), utilizing the data collected during the prescribed tests. The DOE Test Procedure addresses water heaters utilizing electricity, natural gas, propane and fuel oil sources. The UEF values resulting from the DOE Test Procedure permit the performance of water heaters utilizing different fuels and heating technologies to be compared on a consistent basis.

A.1.1 The current DOE Test Procedure does not address water heaters utilizing solar energy. Therefore, this document details the additional specifications required to produce a UEF value for solar water heaters, permitting the direct comparison of the performance of water heaters utilizing solar energy with other water heating fuels and technologies.

A.1.2 This specification defines the conditions, assumptions, methodologies and metrics for the determination of Uniform Energy Factor for water heaters directly utilizing solar energy. It does not establish minimum safety and durability requirements, addressed by the ICC 900/SRCC 300 standard, that are referenced by the *International Building Code* (IBC).

A.1.3 Performance ratings derived in accordance with this specification are intended to provide an indicator of relative system performance under consistent installation and operating conditions. They are not intended to accurately predict actual performance, which will vary with installation, load, weather and operating conditions.

A.2 REFERENCES: This specification shall augment the information provided in 10 CFR 430, Subpart B, Appendix E, *Uniform Test Method for Measuring the Energy Consumption of Water Heaters* (79 FR 40542; July 11, 2014) ("DOE Test Procedure").

A.2.1 The following standards are also referenced in this specification:

ICC 900/SRCC 300, Solar Thermal System Standard

ICC 901/SRCC 100, Solar Thermal Collector Standard

ISO 9806—2017, Solar energy—Solar Thermal Collectors – Test Methods

A.2.2 Where a conflict or difference between the DOE Test Procedure exists, this specification shall prevail.

A.3 DEFINITIONS: Terms associated with solar water heaters shall be as defined in ICC 901/SRCC 100, *Solar Thermal Collectors* and ICC 900/SRCC 300, *Solar Thermal Systems*.

A.4 SCOPE: Solar Uniform Energy Factor ratings apply to water heating systems utilizing solar energy as a source of energy in conjunction with a fueled auxiliary energy source to heat water to meet a hot water load. Auxiliary water heaters used as part of a solar water heating system shall be fueled by natural gas, propane, fuel oil or electricity.

A.4.1 Solar water heating systems that do not incorporate an auxiliary heat source are outside the scope of this specification. Since they rely exclusively on solar radiation, their Uniform Energy Factor will always be infinite. Such solar water heaters may be unable to meet the hot water load, depending on local weather conditions.

A.5 APPROACH: Uniform Energy Factor ratings for solar water heaters may be determined either by means of laboratory testing or computer modeling as established in this specification.

A.5.1 Additional Test Requirements. The current DOE Test Procedure assumes the test subject to be a unitary device installed within conditioned space, drawing from a constant and limitless energy source (e.g., gas, fuel oil or electricity). Solar water heaters, by definition, include a solar collector or module that is directly exposed to solar radiation outdoors and is often separated from a storage tank and/or auxiliary water heater located indoors. Because of these differences, several assumptions made by the DOE Test Procedure must be addressed to permit the consistent rating of solar water heaters, as listed in Table A.5.1.

TABLE A.5.1
VARIATIONS FROM DOE TEST PROCEDURE ASSUMPTIONS

DOE 10 CFR 430, SUBPART B, APPENDIX E	SOLAR WATER HEATERS
Constant and infinite energy supply	Time-dependent energy supply based on solar time and its relationship to the hot water draws.
Unitary equipment	Distributed equipment connected by piping (in some cases).
Insensitive to orientation	System performance is a function of collector tilt and orientation and vertical distance from collector to tanks.
Installation in controlled space	One or more components installed outdoors (e.g., solar collector/module). Tank may be installed indoors or outdoors.
Fixed efficiency	Efficiency varies with irradiance, weather, season and time of day.

A.5.2 Computer Simulation. Software and routines used to determine UEF ratings in accordance with this specification shall be validated against measured laboratory data.

A.5.3 Laboratory Testing. In addition to the measurements prescribed in the DOE Test Procedure, the additional measurements listed in Table A.5.3 shall be made during the period of any testing incorporating solar as an energy source, as applicable for the type of collector used in the system. Instrumentation type, configuration and accuracy shall comply with the requirements of ISO 9806. All other instrumentation prescribed in the DOE Test Procedure shall comply with Section 3, *Instrumentation* of the DOE Test Procedure.

TABLE A.5.3
ADDITIONAL MEASUREMENTS FOR SOLAR WATER HEATERS

ITEM MEASURED	PROCEDURE & SENSORS	NOTES
Outdoor ambient air speed (u)	ISO 9806, Section 21.5	Measured in the vicinity and in the plane of the solar collector.
Hemispherical irradiance (G)	ISO 9806, Section 21.1.1	Usually measured using a pyranometer.
Long-wave irradiance (E_L)	ISO 9806, 21.2	Necessary for certain types of solar thermal collectors. Usually measured using a pyrgeometer.
Outdoor ambient air temperature (T_a)	ISO 9806, Section 21.3.4	Measured in the vicinity of the collector.

A.5.3.1 Solar Simulators. Where testing is conducted in an indoor solar simulator, the setup, sensors, accuracy and operation of the test equipment shall comply with ISO 9806.

A.6 INSTALLATION: Unlike the water heaters addressed in the DOE Test Procedure, solar water heaters must be installed in whole or in part outdoors and are sensitive to orientation. Therefore, the requirements for installation in this specification have been expanded to accommodate exterior components and systems as given below. The solar water heater shall comply with all other requirements in the DOE Test Procedure, Section 4, *Installation.*

A.6.1 Solar collectors and modules shall be installed in accordance with manufacturer's instructions and utilizing mounting hardware specified by the manufacturer. When subject to system testing, collector backing shall be utilized in accordance with ISO 9806, Section 20, and the collector shall be oriented to achieve the incidence angles indicated in Table 7.4 of this standard.

A.6.2 Solar water heating system components designed for installation indoors shall be subject to an ambient temperature of 67.5°F (19.7°C) for computer modeling. Where the system is subject to testing, ambient indoor air temperature shall be controlled as specified in the DOE Test Procedure.

A.6.3 The length of the piping between separable collector(s) and tank(s) shall be 25 feet (6.75 m) in each direction, with a vertical head from the solar loop pump to the top of the collector(s) of 16 feet (4.9 m). The piping type and insulation shall be as specified by the manufacturer.

A.6.4 For laboratory testing, a wind generator shall be used to produce the airspeed conditions required in this specification and shall be configured as specified in ISO 9806.

A.6.5 Supply water temperature, outlet water temperature, set point temperature, supply water pressure and any fuel supplies shall be configured as specified in the DOE Test Procedure, Section 2, *Test Conditions.*

A.7 SOLAR WATER HEATER TEST PROCEDURES.

A.7.1 Operational Mode Selection. Operational modes shall be selected in accordance with the DOE Test Procedure, Section 5.1.

A.7.2 Solar Water Heater Preparation.

A.7.2.1 Determination of Storage Tank Volume. Storage volume shall be determined in accordance with the DOE Test Procedure, Section 5.2.1, with the following exceptions for solar water heaters:

A.7.2.1.1 Where the system includes multiple storage tanks, all storage shall be included in the storage volume determination.

A.7.2.1.2 Except for integrated collector storage (ICS) collectors, the volume enclosed within the solar collector shall not be included in the storage volume determination.

A.7.2.1.3 The volume enclosed in piping between solar collectors and tanks shall not be included in the storage volume determination.

A.7.2.2 Setting the Outlet Discharge Temperature. Outlet discharge temperature shall be set in accordance with the DOE Test Procedure, Section 5.2.2, with the following exception:

A.7.2.2.1 When tested in a laboratory, solar water heaters shall be operated, exposed to the solar irradiance and weather conditions described in this specification for 24 hours before setting the outlet discharge temperature, in accordance with the DOE Test Procedure, Section 5.2.2.

A.7.2.2 Power Input Determination. When tested in a laboratory, the power input for auxiliary water heaters utilizing natural gas, propane or fuel oil, shall be determined in accordance with the DOE Test Procedure, Section 5.2.3.

A.7.2.3 Soak-In Period for Solar Water Heaters. Solar water heaters shall be operated for at least 24 hours while exposed to the solar irradiance and weather conditions described in this specification and connected to any other power source, to achieve the nominal temperature setpoint. During this time, no hot water draws shall be conducted.

A.7.3 Delivery Capacity Tests.

A.7.3.1 Maximum GPM Rating Test for Flow-Activated Water Heaters. Maximum GPM rating testing per Section 5.3.2 of the DOE Test Procedure is not required for solar water heaters incorporating flow-activated water heaters.

A.7.3.2 First-Hour Rating Test. First-hour rating testing in accordance with Section 5.3.3 of the DOE Test Procedure is not required for solar water heaters incorporating storage-type water heaters.

A.7.4 24-Hour Simulated Use Test.

TABLE A.7.4
24- HOUR TEST WEATHER AND IRRADIANCE PROFILES

HOUR	INCIDENCE ANGLE*	OUTDOOR TEMP.		WIND**	SOLAR RADIATION		
		Ambient Air	Sky		Beam	Diffuse	Ground Diffuse
	(degrees)	(°C)		(m/s)	(kJ/m²)		
0	–	18.0	8.2	1.34	0	0	0
1	–	17.4	7.7	1.34	0	0	0
2	–	17.2	7.5	1.34	0	0	0
3	–	17.2	7.5	1.34	0	0	0

4	–	17.4	7.7	1.34	0	0	0
5	–	18.0	8.1	1.34	0	0	0
6	90.0	18.7	8.8	1.34	0	0	0
7	75.1	19.6	9.6	1.34	126	241	6
8	60.1	20.6	10.5	1.34	671	465	11
9	45.1	21.6	11.4	1.34	1158	658	15
10	30.2	22.6	12.3	1.34	1538	806	18
11	15.4	23.5	13.1	1.34	1781	899	21
12	3.3	24.3	13.8	1.34	1865	930	21
13	15.2	24.8	14.2	1.34	1781	899	21
14	30.0	25.1	14.5	1.34	1538	806	18
15	44.9	25.1	14.5	1.34	1158	658	15
16	59.8	24.8	14.2	1.34	671	465	11
17	74.8	24.3	13.8	1.34	126	241	6
18	90.0	23.6	13.1	1.34	0	0	0
19	–	22.7	12.3	1.34	0	0	0
20	–	21.7	11.4	1.34	0	0	0
21	–	20.6	10.5	1.34	0	0	0
22	–	19.6	9.6	1.34	0	0	0
23	–	18.7	8.8	1.34	0	0	0
24	–	18.0	8.2	1.34	0	0	0

** Incidence angle indicates the angle of the solar radiation incident on the tilted surface of the solar collector or module.*
***Wind speed is assumed to be constant and omnidirectional, in the transverse direction parallel to the plane of the collector or module as established in ISO 9806 for solar thermal performance testing.*

A.7.4.1 Selection of Draw Pattern. Solar water heaters shall be tested or modeled using a draw pattern that is dependent on the total area of all solar thermal collectors or all photovoltaic modules supplying energy to heat water in the system. For solar thermal water heaters, the gross area of each solar thermal collector shall be determined in accordance with ICC 901/SRCC 100 and added to obtain the total gross area to be used in Table 7.4.1(a) to select the draw pattern. For photovoltaic water heaters, the total area of all photovoltaic modules in Table A.7.4.1(b) shall be used to select the draw pattern to be used.

TABLE A.7.4.1(a)
DRAW PATTERN TO BE USED BASED ON TOTAL GROSS SOLAR THERMAL COLLECTOR AREA

TOTAL SOLAR THERMAL COLLECTOR OR MODULE GROSS AREA GREATER THAN OR EQUAL TO:	… AND TOTAL GROSS AREA LESS THAN:	DRAW PATTERN TO BE USED IN SIMULATED-USE TEST OR MODELING
0 square feet	24 square feet	Very-Small-Usage (DOE Test Procedure Table III.1)
24 square feet	38 square feet	Low-Usage (DOE Test Procedure Table III.2)
38 square feet	64 square feet	Medium-Usage (DOE Test Procedure Table III.3)

64 square feet	No upper limit	High-Usage (DOE Test Procedure Table III.4)

TABLE A.7.4.1(b)
DRAW PATTERN TO BE USED BASED ON TOTAL GROSS PHOTOVOLTAIC MODULE AREA

TOTAL PHOTOVOLTAIC MODULE GROSS AREA GREATER THAN OR EQUAL TO:	... AND TOTAL GROSS AREA LESS THAN:	DRAW PATTERN TO BE USED IN SIMULATED-USE TEST OR MODELING
0 square feet	84 square feet	Very-Small-Usage (DOE Test Procedure Table III.1)
84 square feet	133 square feet	Low-Usage (DOE Test Procedure Table III.2)
133 square feet	224 square feet	Medium-Usage (DOE Test Procedure Table III.3)
224 square feet	No upper limit	High-Usage (DOE Test Procedure Table III.4)

A.7.4.2 24-Hour Rating Test. The 24-Hour Simulated Use Test shall be conducted for solar water heaters in accordance with the requirements of the DOE Test Procedure, Section 5.4.2 or 5.4.3, as applicable, with the exceptions below:

A.7.4.2.1 The solar collectors or modules and any other components installed outdoors shall be subjected to the irradiance and weather profile described in Table A.7.4. Hour 0:00 in the applicable draw profile established by the DOE Test Procedure shall correspond to a solar time of 07:00 a.m. in the weather profile in Table A.7.4.

A.7.4.2.2 Solar angles should be based on a latitude of 29.5 degrees and with a collector slope of 25.6 degrees at the center of the time zone based on the autumnal equinox.

A.7.4.2.3 The soak-in period described above shall be completed immediately prior to the start of the 24-Hour Test. The test shall begin at the solar time of 0:00 a.m. with the first draw occurring at 07:00 a.m. The other prescribed draws shall occur using the same 7-hour offset between the solar time and the draw time scales.

A.7.4.2.4 The incidence angle of the solar irradiance on fixed solar collectors or modules shall be as described in Table A.7.4. If the solar water heater incorporates a tracking mechanism designed to actively alter the orientation of the solar collector or module, it shall be operated during testing or modeling. In that case, the incident angle of the solar radiation shall be set by the solar tracker, rather than Table A.7.4.

A.8 COMPUTATIONS.

A.8.1 General.

A.8.1.1 The properties of water and glycol fluids for all modeling and computations shall be as given in Table A.8.1.1

TABLE A.8.1.1
FLUID PROPERTIES

FLUID PROPERTY	WATER	GLYCOL
Density (ρ)	8.28 lb_m/gal	8.38 lb_m/gal
Specific heat (C_p)	1.0 BTU/lb_m °F	0.8957 BTU/lb_m °F
Coefficient of thermal expansion (α)	0.0003 /°F	0.0005 /°F
Absolute (dynamic) viscosity (μ)	1.0692 lb_m/ft • h	3.6286 lb_m/ft • h
Thermal conductivity (κ)	0.2377 BTU/h • ft • °F	0.208 BTU/h • ft • °F

A.8.1.2 Measurements for irradiance, ambient air temperature at the collector and wind speed are conducted in order to confirm compliance with the specification established for irradiance and weather shown above and are not included in rating calculations.

A.8.1.3 Modeling of the 24-Hour Test allows the UEF to be readily calculated for each of the draw patterns established in the DOE Test Procedure. While only the determination of the UEF for the draw profile determined by solar collector or module area is required, the UEF at the other draw patterns may be determined. Where this is done, the UEF associated with the draw pattern prescribed by Table 7.4.1(a) or (b) shall be clearly identified as such and are the only results suitable for comparison with UEF values for other water heater types.

APPENDIX B

INSTALLATION CRITERIA FOR SOLAR THERMAL SYSTEMS

This appendix is normative and is part of the standard. It provides basic installation requirements for solar domestic water heating systems for use when no applicable local codes are available. It should not supersede local codes. It should only be used in conjunction with solar thermal systems compliant with the ICC 900/SRCC 300 standard.

B.1 General. Solar thermal systems complying with ICC 900/SRCC 300 shall be installed in accordance with the requirements with this section.

B.1.1 Building penetrations. Penetrations of the building through which piping or wiring is passed shall not reduce or impair the function of the enclosure. Penetrations through walls or other surfaces shall not allow intrusion by insects and vermin. Required roof penetrations shall be made in accordance with the *International Building Code* or *International Residential Code*. Where penetrations are required in structural members to accommodate passage of solar components, such modified structural members shall comply with the plumbing code and mechanical code adopted by the authority having jurisdiction or, in the absence of such code, the *International Plumbing Code* or *International Residential Code*. Penetrations of floor/ceiling assemblies and assemblies required to have a fire-resistance rating shall be protected in accordance with the *International Building Code* or *International Residential Code,* as applicable.

B.1.2 Component placement. Components of a solar thermal system that, during operating conditions, will increase or decrease humidity, temperature or thermal radiation beyond acceptable levels for building materials, shall be identified in the installation, operation and maintenance manuals with required clearances to prevent such effects. The location of components used in the solar thermal system design shall facilitate installation, startup, operation, shutdown and maintenance of the system. Water heating equipment shall not be installed in a location where subject to mechanical damage unless protected by *approved* barriers.

B.1.3 Building access. The design and installation of systems shall not impair egress of the building occupants. The installed location of solar components shall not impair access needed to maintain and protect the building or site.

B.1.4 System service access. Access to components of the system that require periodic examination, adjustment, service or maintenance shall be provided in accordance with the plumbing code and/or mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Plumbing Code* and/or *International Mechanical Code,* as applicable.

B.1.5 Occupant protection. System subassemblies and components that are exposed to the public and are maintained at elevated temperatures shall be insulated to maintain exposed surface temperatures below 120°F (49°C) during operation, or they shall be isolated.

B.1.6 Protection from thermal deterioration. Building materials adjacent to solar equipment shall not be exposed to elevated temperatures that could accelerate their deterioration.

B.1.7 Heat transfer fluid removal. Where fluid is automatically discharged in systems using a *toxic heat transfer fluid,* a means shall be provided for the catchment and removal of these fluids in accordance with *Title 15 of the Federal Hazardous Substances Act,* Chapter 60 of the *International Fire Code* and the requirements of the local jurisdiction.

B1.8 Supports. Tanks shall be supported on a firm base capable of withstanding the weight of the tank when filled to capacity. Where earthquake loads are applicable, supports designed to withstand the applicable seismic loads shall be installed on all auxiliary water heaters and solar tanks. Piping shall be supported in accordance with the plumbing code adopted by the authority having jurisdiction and the piping and fitting manufacturers' instructions. Hangers or supports for insulated pipes and components shall be designed to not compress or damage the insulation material. Hangers shall not cause galvanic corrosion of the hanger or the pipe. Solar thermal collectors shall be supported as required in Section B.3. Thermal expansion tanks shall not be supported by the piping that connects to such pipes.

B.1.9 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 design temperature range.

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

B.2 Plumbing installation

B.2.1 Auxiliary water heater and solar tank installation. Auxiliary water heaters and solar tanks shall be installed in accordance with their manufacturers' installation instructions and local codes. Interconnection of the *auxiliary heating equipment* and solar tanks to the solar energy system shall be made in a manner that will not result in temperatures or pressures beyond design specifications in the auxiliary heating equipment or bypassing of safety devices in the auxiliary heating equipment.

B.2.1.1 Required pan. Where an auxiliary water heater or solar tank is installed in a location where water leakage from the tank will cause damage, the tank shall be installed in a galvanized steel pan having a material thickness of not less than 0.0236 inch (0.6010 mm) (No. 24 gage), or other pans approved for such use. The pan shall be not less than 1$^1/_2$ inches (38 mm) in depth and shall be of sufficient size and shape to receive all dripping or condensate from the tank or water heater. The pan shall be drained by an indirect waste pipe having a diameter of not less than $^3/_4$ inch (19 mm). Piping for safety pan drains shall be of those materials listed in Table 301.9.2 or Table 301.9.3. The pan drain shall extend full-size and terminate over a suitably located indirect waste receptor or floor drain or extend to the exterior of the building and terminate not less than 6 inches (152 mm) and not more than 24 inches (610 mm) above the adjacent ground surface.

B.2.1.2 Cold water line valve.

Cold water branch lines from the main water supply line to the solar thermal system shall be provided with a valve, located near the equipment and serving only the solar thermal system. The valve shall not interfere or cause a disruption of the cold-water supply to the remainder of the cold water system. The valve shall be provided with access on the same floor level as the water heater served.

B.2.1.3 Relief valve.

Storage water heaters and solar tanks operating above atmospheric pressure shall be provided with an approved, self-closing (levered) pressure relief valve and temperature relief valve or combination thereof. The relief valve shall conform to ANSI Z21.22/CSA 4.4.

B.2.1.4 Elevation of ignition source. Equipment and appliances having an ignition source shall be elevated such that the source of ignition is not less than 18 inches (457 mm) above the floor in hazardous locations and public garages, private garages, repair garages, motor fuel-dispensing facilities and parking garages.

B.2.3 Relief valve installation. Solar energy system components containing pressurized fluids shall be protected against pressures and temperatures exceeding design limitations with a pressure and temperature relief valve. Each section of the system in which excessive pressures can develop shall have a relief device located so that a section cannot be isolated from a relief device. Safety and safety relief valves shall be listed and labeled and shall have a minimum rated capacity for the equipment or appliances served.

Exception: Solar energy system collector loops containing pressurized fluids and separated from a domestic water source by an approved heat exchanger, shall be protected against pressures exceeding design limitations with a pressure relief valve.

B.2.4 Discharge pipes. Safety and relief valve discharge pipes shall be of rigid pipe that is approved for the temperature of the system. The discharge pipe shall be the same diameter as the safety or relief valve outlet. Safety and relief valves shall not discharge so as to be a hazard, a potential cause of damage or otherwise a nuisance. Relief valves in partially filled collector loops capable of producing steam shall be discharged to the outside of the structure. Where a relief valve discharges inside a structure or to the drainage system, the installation shall conform to the plumbing code adopted by the authority having jurisdiction or, in the absence of such code, the *International Plumbing Code*. Where a solar thermal system component requiring a relief valve is located outside the structure, the termination shall be not more than 6 inches (152 mm) above a splash block, a secured surface material or catchment method to prevent damage.

B.2.5 Pipe installation. Piping, with its associated fittings and joints, shall be installed in accordance with the plumbing code adopted by the authority having jurisdiction and the piping and fitting manufacturers' instructions. In the absence of such code, piping shall be installed in accordance with the *International Plumbing Code.* Where the piping is designed to drain by means of gravity, it shall be installed and supported to continuously maintain the system manufacturer's prescribed slope.

B.2.6 Potable piping and fitting standards. Pipe used to convey potable water in solar thermal systems shall comply with at least one of the standards listed in Table B.2.6(a). Fittings installed on potable piping shall conform to the respective pipe standards or to the standards listed in Table B.2.6(b).

B.2.7 Non-potable piping and fitting standards. Pipe used to convey non-potable fluids in *solar thermal systems* shall comply with at least one of the standards listed in Table B.2.7(a). Fittings installed on non-potable piping shall conform to the respective pipe standards or to the standards listed in Table B.2.7(b).

TABLE B.2.6(a)
POTABLE WATER PIPING & TUBING

MATERIAL	STANDARD
Brass pipe	ASTM B43
Chlorinated polyvinyl chloride (CPVC) plastic pipe and tubing	ASTM D2846; ASTM F441; ASTM F442; CSA B137.6
Copper or copper-alloy pipe	ASTM B42; ASTM B302
Copper or copper-alloy tubing (Type K, WK, L, WL, M or WM)	ASTM B75; ASTM B88; ASTM B251; ASTM B447
Cross-linked polyethylene (PEX) plastic tubing	ASTM F876; ASTM F877; CSA B137.5
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pipe	ASTM F1281; ASTM F2262; CSA B137.10M
Cross-linked polyethylene/aluminum/high-density polyethylene (PEX-AL-HDPE)	ASTM F1986
Ductile iron pipe	AWWA C151/A21.51; AWWA C115/A21.15
Galvanized steel pipe	ASTM A53
Polyethylene/aluminum/polyethylene (PE-AL-PE) composite pipe	ASTM F1282
Polyethylene of raised temperature (PE-RT) plastic tubing	ASTM F2769
Polypropylene (PP) plastic pipe or tubing	ASTM F2389; CSA B137.11
Polyvinyl chloride (PVC)	ASTM D1785; ASTM D2241
Stainless steel pipe (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel pipe (Type 316/316L)	ASTM A312; ASTM A778

TABLE B.2.6(b)
POTABLE PIPING & TUBING FITTINGS

MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic	ASTM D2468
Cast-iron	ASME B16.4; ASME B16.12
Chlorinated polyvinyl chloride (CPVC) plastic	ASSE 1061; ASTM D2846; ASTM F437; ASTM F438; ASTM F 439; CSA B137.6
Copper or copper alloy	ASSE 1061; ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29
Cross-linked polyethylene/aluminum/high-density polyethylene (PEX-AL-HDPE)	ASTM F1986
Fittings for cross-linked polyethylene (PEX) plastic tubing	ASSE 1061; ASTM F877; ASTM F1807; ASTM F1960; ASTM F2080; ASTM F2098; ASTM F2159; ASTM F2434; ASTM F2735; CSA B137.5

Fittings for polyethylene of raised temperature (PE-RT) plastic tubing	ASTM F1807; ASTM F2098; ASTM F2159; ASTM F2735
Gray iron and ductile iron	AWWA C110/A21.10; AWWA C153/A21.53
Insert fittings for polyethylene/aluminum/polyethylene (PE-AL-PE) and cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX)	ASTM F1974; ASTM F1281; ASTM F1282; CSA B137.9; CSA B137.10M
Malleable iron	ASME B16.3
Metal (brass) insert fittings for polyethylene/aluminum/polyethylene (PE-AL-PE) and cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX)	ASTM F1974
Polyethylene (PE) plastic pipe	ASTM D2609; ASTM D2683; ASTM D3261; ASTM F1055; CSA B137.1
Polypropylene (PP) plastic pipe or tubing	ASTM F2389; CSA B137.11
Polyvinyl chloride (PVC) plastic	ASTM D2464; ASTM D2466; ASTM D2467; CSA B137.2; CSA B137.3
Stainless steel (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel (Type 316/316L)	ASTM A312; ASTM A778
Steel	ASME B16.9; ASME B16.11; ASME B16.28

TABLE B.2.7(a)
NONPOTABLE WATER PIPING & TUBING

MATERIAL	STANDARD
Acrylonitrile butadiene styrene (ABS) plastic pipe	ASTM D1527; ASTM D2282
Brass pipe	ASTM B43
Brass tubing	ASTM B135
Copper or copper-alloy pipe	ASTM B42; ASTM B302
Copper or copper-alloy tube (Type K, L or M)	ASTM B75; ASTM B88; ASTM B251
Chlorinated polyvinyl chloride (CPVC) plastic pipe	ASTM D2846; ASTM F441; ASTM F442
Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX-AL-PEX) pressure pipe	ASTM F1281; CSA B137.10
Cross-linked polyethylene (PEX) tubing	ASTM F876; ASTM F877
Ductile iron pipe	AWWA C151/A21.51; AWWA C115/A21.15
Flexible stainless-steel pipe	ASME A112.18.6/CSA B125.6; ISO 10380
EPDM hoses	ASTM D3568-03
Polyethylene/aluminum/polyethylene (PE-AL-PE) pressure pipe	ASTM F1282; CSA B137.9
Polyethylene (PE) pipe, tubing and fittings (for ground source heat pump loop systems)	ASTM D2513; ASTM D3035; ASTM D2683; ASTM F1055; ASTM D2837; ASTM D3350; ASTM D1693
Polypropylene (PP) plastic pipe	ASTM F2389
Polyvinyl chloride (PVC) plastic pipe	ASTM D1785; ASTM D2241

Raised temperature polyethylene (PE-RT)	ASTM F2623; ASTM F2769
Steel pipe	ASTM A53; ASTM A106
Steel tubing	ASTM A254
Stainless steel pipe (Type 304/304L)	ASTM A312; ASTM A778
Stainless steel pipe (Type 316/316L)	ASTM A312; ASTM A778

TABLE B.2.7(b)
NONPOTABLE PIPING & TUBING FITTINGS

MATERIAL	STANDARD
Brass	ASTM F1974
Bronze	ASME B16.24
Copper and copper alloys	ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29
Ductile iron and gray iron	ANSI/AWWA C110/A21.10
Ductile iron	ANSI/AWWA C153/A21.53
Gray iron	ASTM A126
Malleable iron	ASME B16.3
PEX fittings	ASTM F877; ASTM F1807; ASTM F2159
Plastic	ASTM D2466; ASTM D2467; ASTM D2468; ASTM F438; ASTM F439; ASTM F877; ASTM F2389; ASTM F2735
Steel	ASME B16.5; ASME B16.9; ASME B16.11; ASME B16.28; ASTM A420

B.2.5.8 Joints. Joints between pipe and fittings shall comply with the requirements in this section, as applicable for the piping type and materials. Filler materials and flux used in joints in contact with potable water shall comply with NSF 61 and NSF 372. Joints shall be selected and installed to withstand the full range of local pressures, temperatures and fluids within the system and outside environment.

B.2.8.1 Mechanical joints. Mechanical joints for ABS plastic, CPVC plastic, PVC plastic, steel, copper, copper-alloy pipe and fittings shall be made with an approved elastomeric seal. For ABS and PVC plastic, the seal shall comply with ASTM D3139. Mechanical joints for PEX plastic, PEX-AL-PEX piping, and PE-AL-PE piping shall be made between pipe and fittings marked for connection.

B.2.8.2 Threaded joints. Threads in threaded joints shall conform to ASME B1.20.1. Where ABS plastic pipe is to be threaded, the pipe shall have a wall thickness of not less than Schedule 80. Approved thread lubricant or tape shall be applied on the male threads of threaded joints.

B.2.8.3 Brazed joints. Brazed joints between copper or copper-allow pipe and fittings shall use a filler metal conforming to AWS A5.8.

B.2.8.4 Solder joints. Solder joints between copper or copper-allow pipe and fittings shall be made in conformance with ASTM B828. Flux used for soldered joints shall conform to ASTM B813. The solder shall conform to ASTM B32. Where the joint is exposed to potable water, the solder and flux shall be lead-free and comply with NSF 61.

B.2.8.5 Welded joints. Welded joints for copper and copper alloy pipe shall be welded with an approved filler metal. Welded joints for stainless steel pipe shall use an approved filler metal as referenced in ASTM A312.

B.2.8.6 Grooved and shouldered mechanical joints. Grooved and shouldered mechanical joints for copper and copper-alloy tubing, PEX plastic piping, and stainless-steel pipe shall comply with ASTM F1476.

B.2.8.7 Flared joints. Flared joints for PEX plastic pipe, copper and copper alloy tubing, shall be made by a tool designed for the operation.

B.2.8.8 Press-connect joints. Press-connect joints shall be pressed with a tool certified by the manufacturer.

B.2.8.9 Push-fit joints. Push-fit joints shall comply with ASSE 1061 and shall be installed in accordance with the manufacturer's instructions with pipe materials approved for use with the fitting.

B.2.8.10 Solvent cement joints. Solvent cement joints shall be made in accordance with ASTM D2235 for ABS pipe and fittings, ASTM D2855 or ASTM F3328 for CPVC pipe and fittings, and ASTM D2855 for PVC pipe and fittings.

B.2.8.11 Heat-fusion joints. Heat fusion joints for polyethylene plastic and fittings shall comply with ASTM D2657. Heat fusion joints for and polypropylene plastic pipe shall comply with ASTM F2389.

B.2.8.12 Joints between different materials. Joints between different piping materials shall be made with a mechanical joint of the compression or mechanical-sealing type or shall be made in accordance with Section B.2.8.12.1, B.2.8.12.2, or B.2.8.12.3 installed in accordance with the manufacturer's instructions.

B.2.8.12.1 Copper or copper-alloy tubing to galvanized steel pipe. Joints between copper pipe or tubing and galvanized steel pipe shall be made with a copper-alloy or dielectric fitting or a dielectric union conforming to ASSE 1079. The copper tubing shall be soldered to the fitting in an approved manner, and the fitting shall be screwed to the threaded pipe

B.2.8.12.2 Plastic pipe or tubing to other piping material. Joints between different types of plastic pipe or between plastic pipe and other piping material shall be made with approved adapters or transition fittings.

B.2.8.12.3 Stainless steel. Joints between stainless steel and different piping materials shall be made with a mechanical joint of the compression or mechanical sealing type or a dielectric fitting or a dielectric union conforming to ASSE 1079.

B2.9 Valves.

B.2.9.1 Shutoff and diverter valves. Shutoff and diverter valves installed in the solar thermal system shall conform to one of the standards listed in Table B.2.9.

TABLE B.2.9
SHUTOFF & DIVERTER VALVE STANDARDS

MATERIAL	STANDARD
Chlorinated polyvinyl chloride (CPVC) plastic	ASME A112.4.14; ASME A112.18.1/CSA B125.1; ASTM F1970; CSA B125.3; IAPMO Z1157; MSS SP-122
Copper or copper alloy	ASME A112.4.14; ASME A112.18.1/CSA B125.1; ASME B16.34; CSA B125.3; IAPMO Z1157; MSS SP-67; MSS SP-80; MSS SP-110; MSS SP-139
Cross-linked polyethylene (PEX) plastic	ASME A112.4.14; ASME A112.18.1/CSA B125.1; CSA B125.3; IAPMO Z1157; NSF 359
Gray iron and ductile iron	AWWA C500; AWWA C504; AWWA C507; IAPMO Z1157; MSS SP-67; MSS SP-70; MSS SP-71; MSS SP-72; MSS SP-78
Polypropylene (PP) plastic	ASME A112.4.14; ASTM F2389; IAPMO Z1157
Polyvinyl chloride (PVC) plastic	ASME A112.4.14; ASTM F1970; IAPMO Z1157; MSS SP-122
Stainless steel (Type 304/304L)	ASME A112.4.14; IAPMO Z1157
Stainless steel (Type 316/316L)	ASME A112.4.14; IAPMO Z1157

B.2.10 Expansion tank sizing and installation. Where expansion tanks are used to provide thermal expansion control, expansion tanks used in a collector loop shall be sized to allow for compensation of pressure and volume increase caused by accumulation of thermal energy during operating, stagnation, and no-flow conditions. Thermal expansion tank components shall be compatible with the heat transfer fluid and rated for the fluid temperature and pressure at design conditions.

B.2.10.1 Expansion tank sizing. The expansion tank volume shall be based on all of the following:

1. Total system volume shall be calculated for as-built conditions.
2. Calculation of total volume that can evaporate and turn to steam, including collectors and associated piping experiencing similar conditions for the heat transfer fluid contained therein.
3. Static pressure height calculated from the highest point in the collector loop to the location of the pressure relief device.
4. An additional 10-percent safety factor shall be used.
5. If the calculated size is greater than a readily available expansion tank, then the next greater size shall be specified.
6. Expansion tanks used in single-phase systems shall be sized in accordance with the mechanical code adopted by the authority having jurisdiction, or in the absence of such code, the *International Mechanical Code*.

B.3 Collector and roof-mounted equipment installation. Solar thermal collectors and other associated roof-mounted equipment in solar thermal systems shall be installed in accordance with this section.

B.3.1 Water damage. Collectors and supports shall be installed in such a manner that water flowing off the collector surface will not damage the building or cause erosion of the roof beyond design specifications.

B.3.2 Roof load. Neither wind loading, including uplift, nor the additional weight of filled collectors and tanks shall exceed the live or dead load ratings of the building, roof, roof anchorage, foundation or soil. Collector supports shall not impose stresses on the collectors beyond design specifications. The design load shall be as specified by the codes in force at the installation site and shall include an additional load for snow accumulation for applicable locations.

B.3.3 Expansion and contraction of supports. Structural supports shall be selected and installed in such a manner that thermal expansion of the collector and piping will not cause damage to the collector structural frame or the building.

B.3.4 Rain and snow build-up. The location, orientation, and position of collectors relative to nearby objects and surfaces shall be such that water run-off from the collector surface is not impeded and excessive build-up of snow on lower portions of the collector glazing is not permitted to occur.

B.3.5 Orientation maintenance. Collectors shall be installed on a mount capable of maintaining the orientation (i.e. tilt and azimuth angles) to design conditions.

B.3.6 Shading of collectors. The location and orientation of collectors shall be such that they are not shaded by external obstructions or each other more than the specified period allowed in the design.

B.4 Electrical installation. Electrical devices and wiring installed with the system shall be installed in accordance with the requirements of this section.

B.4.1 Wiring. Electrical wiring over 24 volts connected to systems or system components 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.

B.4.2 Electrical components. Electrically powered components over 24 volts installed as part of systems shall be listed and labeled to standards referenced by NFPA 70. Electrical components shall be installed and used in accordance with the component manufacturer's instructions and any conditions of listing.

B.4.3 Sensors. Control sensors and the means for transmitting sensor outputs to control devices shall be protected from environmental influence such as wind, moisture, temperature, ultraviolet radiation, and other factors that have the potential to adversely affect accuracy.

APPENDIX C

Performance Test Methods for Passive Solar Thermal Collectors with Internal Storage

This appendix is normative and is part of the standard.

C.1 Purpose. The performance tests established in this document are used to generate specific thermal performance test data to calibrate computer models for the performance rating of certain solar thermal collectors with integral storage. These include Integral Collector Storage (ICS) and Thermosiphon Systems (TS) types. This method does not include qualification tests for topics such as internal pressure, internal or external thermal shock, mechanical loading, and impact resistance which are addressed in the ICC 901/SRCC 100 and ICC 900/SRCC 300 standards.

C.2 Scope. The test methods apply to direct Integral Collector Storage (ICS) solar thermal collectors and Thermosiphon Systems (TS) with a minimum of 5 gallons (18.7 l) of storage capacity and designed to heat liquid fluids. The test methods are prescribed for outdoor testing only, and therefore are not to be conducted in a solar simulator.

C.3 Nomenclature.

ε: Hemispherical solar emittance

E_L: Longwave irradiance ($\lambda > 3$ µm), as measured by a pyrgeometer.

G_{sc}: Solar constant

K_T: Sky clearness index.

M_{drawn}: Mass of test fluid withdrawn from the collector during a test.

Q_{del}: Energy delivered from the fluid in the test article, measured by a purge test process.

σ: Stefan-Boltzmann constant (5.669 x 10^{-8} W/m^{2}K^4)

T_a: Ambient air temperature in the vicinity of the test article, either indoors or outdoors.

T_{del}: Temperature of the water delivered at the outlet of the test article.

T_{in}: Inlet temperature of the fluid entering the test article.

$T_{initial}$: Temperature of the fluid in a test article at the beginning of a test.

T_{low}: Initial temperature of the fluid in a test article at the beginning of a low-temperature test.

θ_z = Solar zenith angle on a horizontal plane

T_{high}: Initial temperature of the fluid in a test article at the beginning of a high-temperature test.

T_{max}: Recommended maximum temperature of the fluid enclosed in the ICS collector as specified by the manufacturer.

T_o: Outlet temperature of the fluid exiting the test article.

T_{sky}: Atmospheric or equivalent sky radiation temperature in units of absolute temperature (°K or °R).

t: Elapsed time in seconds.

C.4 Tests.

C.4.1 Tests Required. Direct ICS collectors and TS systems shall be tested for thermal performance using the procedures proscribed below. Tests must be completed in the order given in Table C.4.1.

TABLE C.4.1 TEST REQUIREMENTS FOR ICS AND TS

TEST NAME	TEST METHOD SECTION	TEST LOCATION	SYSTEM TYPE	
			DIRECT ICS	TS

Initial Inspection	5.1	-	X	X
Capacitance	5.2	Indoors	O	O
Heat Loss Test	5.3	Indoors		X
Night-Time Decay Loss	5.4	Outdoors	X	
Low-Temperature, Clear Warm-Up	5.5.2	Outdoors	X	X
High-Temperature, Stratified Warm-Up*	5.5.4	Outdoors	O	O
High-Temperature, Cloudy Warm-Up	5.5.3	Outdoors	X	X
Final Inspection	5.6	-	X	X

* Note: If the unit contains an integral heater, then an additional stratified warmup series of tests must be performed.

C.4.2 Setup

C.4.2.1 Fixture. Tests are to be performed on a test article installed without a separate auxiliary water heater. If the test article includes a supplemental, integral heater, it shall be included and setup as described below. Fluid conditioning shall be provided with sufficient capacity to maintain a constant inlet temperature to the collector for the duration of the charge and purge periods. Components that incorporate a self-draining mechanism shall be plumbed with a physical head of 4.88 m (16.0 ft). Unions may be used to facilitate the installation and removal of components. An appropriately rated pressure and temperature relief valve on the test article shall be installed in a location specified by the manufacturer.

C.4.2.2 Collector mounting. For outdoor tests, mount and fix the test sample with the collecting surface facing the equator. The tilt for the collector during the warm-up tests shall be normal to the sun at solar noon +/- 4° on the day of the test, unless this contradicts the manufacturers recommended tilt. In this case, the recommended tilt that will come closest to meeting the above requirement shall be used. Any piping integral to the collector and tank system should use the manufacturers provided materials and layout, except where modifications are required for measurements.

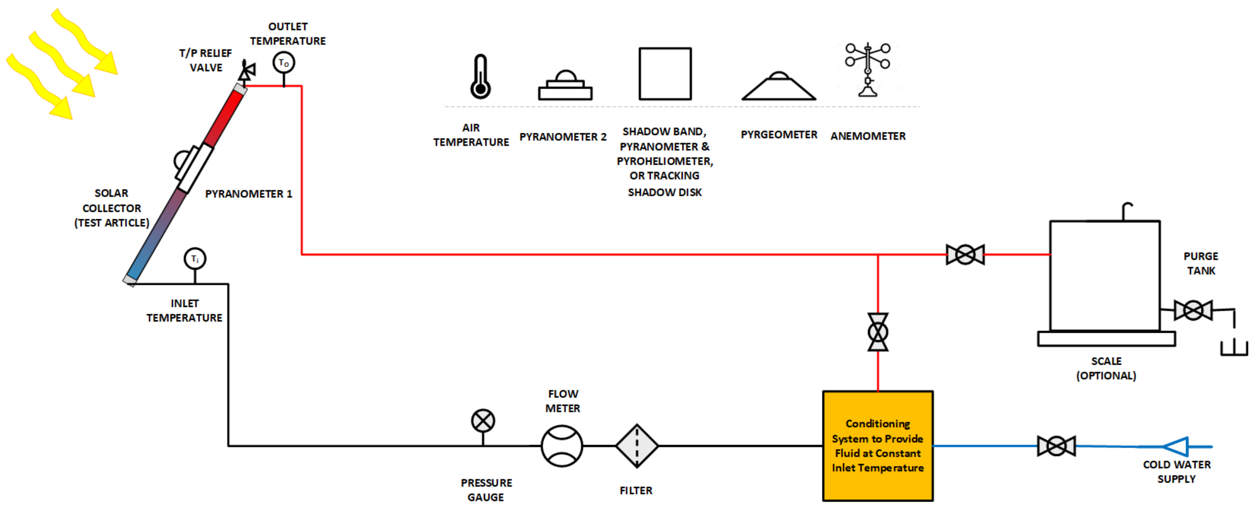

FIGURE 4.2 TEST SETUP

C.4.2.3 Collector cover. A cover, used during testing to isolate a collector from solar radiation, shall be constructed from foil-faced insulation board with a minimum thickness of 40 mm (1.6 inches). The cover shall extend a minimum of 80 mm (3.1 inches) beyond the gross horizontal collector aperture area and cover any vertically exposed optical components. The exposed side of the cover shall be backed with non-conductive material for structural rigidity and weather resistance (e.g., plywood or plastic sheeting) as necessary.

C.4.2.4 Test fluid. Testing shall be conducted using water supplied to the system, connected as specified by the manufacturer. Where the test article includes a closed indirect solar loop connected to a heat exchanger, the fluid shall be per the manufacturer's specifications. Indirect solar loops shall be filled in accordance with the manufacturer's installation instructions.

C.4.2.5 Operating conditions. Performance testing shall not be performed in excess of the manufacturer's design operating conditions. The flow rate to be used for testing shall be specified by the manufacturer and shall be the same for all tests. If the test article includes an integral supplemental heating device, then it shall be tested with and without the heater in operation.

The setpoint of the supplemental heater shall be 50°C (122°F). The supply pressure of the test fluid shall be maintained between 275 kPa (40 psi) and the maximum allowable pressure specified by the collector manufacturer.

C.4.3 Instrumentation and Measurements

C.4.3.1 Data collection. The numerical and physical data specified below shall be collected during testing of the collectors. The timing of the draw, purge and irradiation start and stop times shall be recorded. Data regarding the test site shall be recorded, including site elevation, longitude, latitude, and test sample orientation. The following parameters shall be collected for each test, as applicable:

1. Time, both local and solar, and date and numerical day of year (*n*).
2. Fluid inlet temperature (°C).
3. Fluid outlet temperature (°C).
4. Ambient air temperature (°C).
5. Fluid flow rate (kg/hr).
6. Wind velocity (m/s) for outdoor tests.
7. Supplemental heater energy consumption (kJ/hr), as applicable.
8. Solar irradiance (kJ/(hr m^2)).
   a. Hemispherical irradiance in the plane of the aperture of the collector (G) using a pyranometer mounted in the plane of the collector.
   b. Global irradiance on an unshaded horizontal surface near the collector (G_h) using a pyranometer.
   c. Horizontal diffuse irradiance (G_{dh}) using a shadow band, pyranometer and pyroheliometer, or tracking shadow disk.
9. Longwave irradiance on an unshaded horizontal surface near the collector (W/m^2) using a pyrgeometer (E_{Lh}). This is only required for ICS collectors.

C.4.3.2 Instrumentation accuracy. Instrumentation used to conduct thermal performance testing of collectors containing storage shall comply with the accuracy requirements in the table below. Solar radiation measurements shall be performed using devices that meet the standards of the World Meteorological Organization for a first class pyranometer or pyrheliometer.

TABLE 4.3.2 INSTRUMENTATION ACCURACIES

VALUE TO BE MEASURED	ACCURACY (±)	
	SI Units	IP Units
Fluid Temperature	0.1°C	0.2°F
Fluid Temperature Difference	0.05 K	0.09 R
Ambient Air Temperature	0.5 K	0.09 R
Mass	1%	
Fossil Fuel Usage	1%	
Electric Energy Usage	1%	
Wind Speed	Uncertainty <0.5 m/s	
Liquid Mass Flow Rate	1% measured mass value	

C.4.3.3 Sampling interval. Unless otherwise indicated, all data shall be sampled with a maximum of a fifteen-second-time step. All data must be reported in fixed time steps that do not vary during the duration of the test.

C.4.3.4 Fluid temperature measurement. The measurement of the fluid temperature within the collector may be accomplished either indirectly or directly, depending on the collector's design. Direct measurement of the real-time fluid temperature within the test article by means of distributed temperature sensors installed inside the test article (using a sensor "tree") may provide the most accurate results but is not always possible. Where indirect measurement is necessary, the fluid temperature in the collector shall be determined by means of analysis of the inlet and outlet fluid temperature throughout the prescribed tests. In these cases, care should be taken to address false values due to conduction and thermal lag when ascribing the collector storage temperatures. Regardless of the approach taken, inlet and outlet fluid temperature shall be measured during all tests.

If the direct, real-time temperature of the fluid within the test article is measured, it shall be measured by means of a minimum of three evenly spaced temperature measurement sensors inside the test article. One of the temperature sensors must be positioned at the vertical midpoint of each of the test article, as installed. The sensors should be installed through one of the following openings:

- Anodic device opening
- Relief valve opening
- Hot water outlet.

If installed through the relief valve opening or the hot water outlet, a tee fitting or outlet piping must be installed as close as possible to its original location. If the relief valve temperature sensor is relocated and it no longer extends into the test article itself, a substitute relief valve that has a sensing element that can reach into the test article must be installed. If the hot water outlet includes a heat trap, it shall be installed on top of the tee fitting. Any added fittings must be covered with thermal insulation having an R value of 0.7 -1.4 (m^2°C)/W (4 - 8 (hr ft^2°F)/Btu). As much as possible, temperature sensors should be positioned away from any heating elements, anodic protection devices, tank walls and any other internal structures.

C.4.3.5 Ambient air temperature measurement. Ambient air temperature measurements to be conducted for indoor or outdoor testing shall be made using a temperature sensor at the vertical mid-point of the test article, and approximately 610 mm (24 in.) from the surface. The sensor shall be shielded against radiation and shall not obscure solar irradiance on the plane of the collector.

C.4.3.6 Drawn fluid measurement. Measurements of the fluid mass drawn shall be made by collecting the fluid in a tank situated on a scale or by measuring the real-time mass or volumetric fluid flowrate during the purge process.

C.4.3.7 Supplemental heater energy measurement. Measurements of the supplemental heater energy consumption should use the nominal input voltage (electric) and/or supply flow and pressure (gas) specified by the manufacturer. Where this is not practical, the lab should note the deviation.

C.4.4 General Testing Processes. Several testing processes are used in more than one test method and are defined below. They are referenced by the test methods in Section C.5.

C.4.4.1 Charging process. Charging is prescribed before some tests to pre-heat the entire test article to a uniform initial temperature to establish an isothermal condition and should be conducted outdoors. This is accomplished by fully mixing the test fluid contained within the test article immediately prior to exposing it to solar radiation. Charging may occur at any rate up to manufacturer's recommended maximum flow rate. The flow rate used shall be recorded.

The procedure for charging is as follows:

a. Heat the fluid in the test article to $T_{initial}$ as specified by the test.

b. Prepare the collector. Where a supplemental heater is not installed, the following charging method shall be used:
   1. Initial temperature ($T_{initial}$) close to or higher than the ambient temperature: Uncover solar collectors during the charging period (about 10 minutes prior to exposure start).
   2. Initial temperature ($T_{initial}$) lower than the ambient temperature: Cover solar collectors during the charging period.

   If the test article includes an integral supplemental heater, cover the solar collectors and set the controller of the supplemental heater per Section 4.2.5. Then energize the heater for a minimum 60 minutes before checking the conditions in Step c.

c. Continue until one of the following two conditions is met for a 10-minute period or the dwell time. The dwell time is the time required for the fluid leaving the test article (T_o) to attain 63.2% of its steady state value following a step change in inlet fluid temperature (T_i).

$$|T_i - T_o| = 0.2°K \ \ (0.4°R)$$

or

$$\frac{\partial |T_i - T_o|}{\partial t} = 0.05°K\ (0.09°R)$$

C.4.4.2 Purge process. Where purging of a test article is prescribed in a test, it shall be conducted as described below. The objective of a purge process is to remove and quantify the energy content of the fluid (Q_{del}) in the test article at a specific point in time.

a) Use the bypass loop to pre-condition the inlet water to the specified purge temperature before introducing water to the test article. Unless otherwise specified, the purge temperature to be used is the same temperature as the initial temperature ($T_{initial}$) specified by the test (e.g., T_{low} or T_{high}).

b) Purge the energy in the test article by circulating water through it at the purge temperature at a flow rate of 0.125 to 0.189 l/s (2-3 GPM). Conduct real time measurement of the following parameters. Note that measurements of the parameters should be taken at the highest possible frequency to maximize accuracy.
   a. Temperature of the fluid introduced into the collector (T_i).
   b. Temperature of the fluid displaced/purged from the collector (T_o) through the outlet during the purge process.
   c. Ambient air temperature in the vicinity of the test article (T_a).
   d. Volumetric or mass flowrate of the fluid ($\dot{V}\ or\ \dot{m}$).
   e. Time (t) from the start of the purge process.

c) The purge flow and measurements shall continue until one of the following two conditions is met for a minimum of 10 minutes:

$$|T_i - T_o| = 0.2°K\ (0.4°R)$$

or

$$\frac{\partial |T_i - T_o|}{\partial t} = 0.05°K\ (0.09°R)$$

d) After the purge process is completed, calculate the delivered energy in the fluid (Q_{del}) from the time-dependent dataset using one of the following equations, depending on whether mass or volumetric flowrate was measured. Values for density and specific heat of the test fluid as a function of temperature shall be determined in accordance with ISO 9806, Annex C.

$$Q_{del} = \int \rho(T)Cp(T)\dot{V}(t)(T_o(t) - T_i(t))dt$$

or

$$Q_{del} = \int Cp(T)\dot{m}(t)(T_o(t) - T_i(t))dt$$

C.5.0 Test Methods

C.5.1 Initial Inspection. The test article shall be inspected prior to installation and testing and any evidence of damage shall be recorded. A detailed initial inspection of the test article shall document the following:

1. Gross collector dimensions, length, width, and depth.
2. Enclosed fluid volume.
3. Empty weight.
4. Materials of construction.
5. Photographic record of all test articles.
6. Test article serial number and/or date of manufacture.

The gross area of the test article shall be determined as defined in ISO 9488 based on measurements conducted during the initial inspection.

C.5.2 Capacitance Test.

C.5.2.1 Test method. Where thermal capacitance is to be measured, the following test method shall be used. The Capacitance Test is to be performed indoors, where the ambient temperature is maintained between 18.3 and 21.1°C (65.0 and 70.0°F). Any source of heating, including resistance heaters and/or solar radiation, must be shut off or blocked for the duration of the test. Parameters 1-5 listed in Section C.4.3.1 shall be measured during the charge and purge periods. The ambient air temperature shall be measured during the entire test.

1. Charge test article with fluid with an initial temperature of 55-60°C ($T_{initial}$) per Section C.4.4.1.
2. Immediately purge the energy in the test article with water with an inlet temperature (T_i) equal to the ambient air temperature in the vicinity of the test article (T_a) per Section C.4.4.2.

C.5.2.2 Analysis method. Calculate the thermal capacitance of the test article using the Q_{del} value derived from the purge process at the end of the capacitance test.

$$C = \frac{Q_{del}}{\bar{T}_{col,0} - \bar{T}_{col,final}}$$

C.5.3 Heat Loss Test.

C.5.3.1 Test method. During this test, the test article is filled and heated to an initial temperature and allowed to cool during a loss period. The data collected is then used to determine the heat loss coefficient (UA). The Heat Loss Test is to be performed indoors, where the ambient temperature is maintained between 18.3 and 21.1°C (65.0 and 70.0°F). Any source of heating, including resistance heaters, ambient infrared radiation, and/or solar radiation, must be shut off or blocked for the duration of the test.

Heat and fully mix the fluid in the test article with fluid to an initial temperature of 55 to 60 °C ($T_{initial}$) at any rate up to the manufacturer's recommended maximum flow rate.

If the test article includes an integral supplemental heater, cover the solar collectors and set the controller of the supplemental heater per Section C.4.2.5. Then energize the heater for a minimum 60 minutes.

Continue until one of the following two conditions is met for a 10-minute period:

$$|T_i - T_o| = 0.2°K\ (0.4°R)$$

or

$$\frac{\partial |T_i - T_o|}{\partial t} = 0.05°K\ (0.09°R)$$

1. Allow the test article to cool, losing heat to the ambient air. Continue all temperature measurements during the loss period.

2. Purge the energy remaining in the test article with fluid at an inlet temperature equal to the ambient temperature ($T_{in} = T_a$) per Section C.4.4.2 when the temperature following condition is met:

$$\frac{1}{3}\left(\bar{T}_{col,0} - T_a\right) \leq \left(\bar{T}_{col} - T_a\right) \leq \frac{2}{3}\left(\bar{T}_{col,0} - T_a\right)$$

If $\bar{T}_{col}$ cannot be monitored directly using internal sensors per Section C.4.3.4, the average temperature of the fluid in the test article shall be determined using the purge process. In this case, the loss period for Step 2 must be estimated with a subsequent confirmation that the temperature criteria above has been met. If not, the test must be repeated with a different estimated loss period until the temperature criteria is satisfied.

C.5.3.2 Analysis method. Two calculation methods are available to determine the heat loss coefficient of the test article (UA) using the data from the heat loss test. The appropriate method should be determined based on the measured ambient temperature variation and the sensor configuration.

C.5.3.2.1 Real-Time numerical loss calculation. If one of the following conditions are met, the real-time numerical loss calculation method can be used:

1) The variation in the ambient temperature (T_a) during the test period is >10% of the difference between the initial average test article fluid and environment temperature ($\bar{T}_{col,0} - \bar{T}_{env}$) during the test, or
2) The test article is not fully mixed due to varying or large insulation levels.

The calculation shall be conducted by numerically solving for UA using the following equation:

$$Q_{loss} = (Q_0 - Q_{del}) = \sum UA\,(\bar{T}_{col} - T_a)\Delta t$$

C.5.3.2.2 Ideal exponential temperature decay loss calculation. If the variation in the ambient temperature (T_a) measured during the test ≤10% of the difference between the initial average test article fluid and environment temperature ($\bar{T}_{col,0} - \bar{T}_{env}$) during the test, the ideal exponential temperature decay calculation method can be used to determine UA.

$$UA = \frac{C}{t} ln\left[\frac{(\bar{T}_{col,0} - \bar{T}_a)}{(\bar{T}_{col,final} - \bar{T}_a)}\right]$$

Where:

$$\bar{T}_{col,final} = \bar{T}_{col,purge} + \frac{Q_{del}}{C}$$

C.5.4 Night-Time Decay Test.

C.5.4.1 Test method. Perform the heat loss test on the test article installed outdoors and with the solar thermal collector uncovered. If installed, supplemental heaters must be shut off for the duration of the test. The test shall be conducted on two different nights, starting 60 minutes after dusk and ending 60 minutes before dawn. One test shall be conducted when the average outdoor sky temperature is at least 10°K below the average ambient temperature at the start of the test. A second test shall be conducted when the average outdoor sky temperature is within 2°K of the average ambient temperature at the start of the test. The sky temperature shall be determined indirectly by measuring longwave irradiance using a pyrgeometer.

C.5.4.2 Analysis method. The outdoor sky temperature shall be calculated using the following equation.

$$E_L = \varepsilon\sigma T_{sky}^4$$

Where measured emissivity (ε) is not available, a value of 1.0 shall be assumed. T_{sky} shall be reported in units of °K.

C.5.5 Warm-Up Test.

C.5.5.1 General. Two types of warm-up tests, Low-Temperature, Clear and High-Temperature, Cloudy, are to be conducted, with two full days of testing each. In general, the Low-Temperature Tests are designed to provide the "high performance" case when the test is run under cool temperatures and clear conditions. The High-Temperature Tests are designed to give the "low performance" case when the test is run at "high" temperatures and cloudy conditions.

For each test, the initial temperature to be used as the target isothermal condition must be selected. The low temperature (T_{low}) used for the Low-Temperature Warm-Up Test, must be selected such that the high temperature (T_{high}) for the High Temperature Warm-Up Test is 30°K (54°F) higher. T_{low} should be set as close to the expected ambient air temperature (T_a) as possible (typically 20°C (68°F)), and $T_{high}=T_{low}+30$°K (54°F). T_{high} shall not exceed T_{max} as specified by the manufacturer prior to testing.

The same T_{low} value must be used for each day of Low-Temperature testing, and the same T_{high} value must be used for each day of High-Temperature testing.

The clearness index, K_T, is used to classify the sky conditions for both the Low-Temperature and High-Temperature Warm-up Tests:

$$K_T = \frac{G_h}{G_{sc}\left(1 + 0.033\cos\left(\frac{2\pi n}{365}\right)\right)\cos(\theta)}$$

where:

n = Numerical day of the year when the testing is conducted, ranging from 1 on January 1 to 365 on December 31

G_{sc} = 1367 W/m^2, solar constant.

G_h = Horizontal total radiation measured on a horizontal plane

θ_z = Solar zenith angle on a horizontal plane

C.5.5.2 Low-Temperature warm-up test. This test is to be performed on a minimum of two clear days ($\overline{K}_T > 0.65$) averaged over the whole warm-up period but excluding charge and purge processes and assumes an isothermal starting condition at T_{low}.

a) Charge the test article with an initial temperature, $T_{initial} = T_{low}$ per Section C.4.4.1
b) Expose the solar thermal collectors to solar radiation until a cumulative solar exposure of 13,000 kJ/m^2 (12,322 Btu/ft^2) is reached and the average fluid temperature is at least 5°K (9°F) greater than the initial low temperature (T_{low}).
c) At the conclusion of the irradiation period, cover the solar thermal collectors and purge the gathered energy from the test article with water at an inlet temperature $T_{in} = T_{low}$ per Section C.4.4.2.

C.5.5.3 High-Temperature warm-up test. This test is to be performed on two cloudy days ($\overline{K}_T < 0.65$) averaged over the whole warm-up period but excluding charge and purge processes). The test assumes an isothermal starting condition at T_{high}.

a) Charge the test article to an initial temperature $T_{initial} = T_{high}$ per Section C.4.4.1.
b) Expose the solar thermal collectors to solar radiation until a cumulative solar exposure of 13,000 kJ/m^2 (12,322 Btu/ft^2) is reached and the average fluid temperature is at least 5°K (9°F) greater than the initial high tank temperature (T_{high}).
c) At the conclusion of the irradiation period, cover the solar thermal collectors and purge the gathered energy from the test article with water at an inlet temperature $T_{in} = T_{high}$ per Section C.4.4.2.

C.5.5.4 High-Temperature stratified warm-up test. This test is applicable to devices incorporating an integral supplemental heater. It shall be performed on two cloudy days ($\overline{K}_T < 0.65$) averaged over the entire warm-up period but excluding charge and purge processes). The test is to be performed on two cloudy days ($K_T < 0.65$ averaged over the entire warm-up period) with the heater enabled. The test assumes an isothermal starting condition at T_{high}.

a) Charge the test article to an initial temperature $T_{initial} = T_{high}$ per Section C.4.4.1.
b) Expose the solar thermal collectors to solar radiation until a cumulative solar exposure of 13,000 kJ/m^2 (12,322 Btu/ft^2) is reached and the average fluid temperature is at least 5°K (9°F) greater than the initial high tank temperature (T_{high}).
c) At the conclusion of the irradiation period, cover the solar thermal collectors and purge the gathered energy from the test article with water at an inlet temperature $T_{in} = T_{high}$ per Section C.4.4.2.

C.5.5.5 Analysis method. Each completed Warm-Up Test yields a time-dependent dataset consisting of the measurements listed in Section C.4.3.1. The goal of the tests is to gather approximately 13,000 kJ/m^2 (1145 Btu/ft^2) of radiation for all tests (cloudy test length shall be adjusted to not exceed this value) to equalize relative experimental errors and to equally weight the various conditions.

C.5.6 Final Inspection. The test article shall be inspected after the completion of all testing. Any damage, or degradation of the test article shall be documented. The test article may be disassembled to facilitate the inspection if necessary. Any condensation or water retained within the collector's enclosure or leakage shall be photographed and documented.

C.6.0 Analysis and Reporting

Test data acquired through the test methods described in Section C.5 shall be analyzed and reported as described in this section.

C.6.1 Data Processing. Data from performance testing shall be processed in accordance with this section.

C.6.1.1 Fluid properties. The fluid density and specific heat shall be calculated as a function of average fluid temperature in accordance with ISO 9806, Annex C for each time step in the datasets.

C.6.1.2 Datasets. The complete resulting dataset consisting of all measured parameters shall be provided for each test. Provided templates shall be used to group the data into a consistent format for each test.

C.6.2 Test Report.

C.6.2.1 Results. The following results shall be calculated and reported for each test in the units shown in Table C.6.2.1.

TABLE C.6.2.1 REPORTING PARAMETERS

TEST METHOD	VALUE	UNITS
Initial Inspection	Gross Dimensions (L, W, D)	mm
	Gross Area	m^2
	Fluid Capacity	L
	Empty Weight	kg
	Maximum Design Temperature (T_{max})	°C
Capacitance	Capacitance (C)	J/°K
Heat-Loss Test	Heat Loss (UA)	kJ/(h°C)
	Averaged dataset per Section 6.1.2	
Night-Time Decay Loss	Average Outdoor Sky Temperature ($\bar{T}_{sky}$)	°K
	Emissivity (ε)	-
	Heat Loss (UA)	kJ/(h°C)
	Averaged dataset per Section 6.1.2	
Warm-Up Tests	Average Clearness Index ($\bar{K}_T$)	-
	Initial Temperature ($T_{initial,}$ i.e., T_{low} or T_{high})	°C
	Cumulative Solar Exposure	kJ/m^2
	Final average fluid temperature in the test article ($\bar{T}_{col}$)	°C
	Supplemental heater (if applicable) energy consumption	kJ
	Purge Energy (Q_{del})	kJ
	Averaged dataset per Section 6.1.2	

C.6.2.2 Additional documentation. The following additional documentation shall be provided in the test report:

1. Instrumentation model numbers.
2. Photographs of test equipment and fixtures.
3. Photograph of the test article as installed in the test fixture.
4. Maximum temperature, maximum pressure and test flow rate prescribed by the manufacturer prior to the test.

APPENDIX D

LISTING CRITERIA FOR FACTORY-BUILT SUBASSEMBLIES FOR SOLAR THERMAL SYSTEMS

This appendix is normative and is part of the standard. It provides criteria for the listing and labeling of factory-built subassemblies of components used for solar thermal systems, including those known as pump stations. Separate listing and labeling of these subassemblies, is an option in the standard but is not required.

D.1 Purpose. This appendix sets minimum criteria for the design and construction of factory-built sub-assemblies of hydraulic components within solar thermal systems. The appendix allows for the listing and labeling of these sub-assemblies to the requirements of the ICC 900/SRCC 300 apart from the balance of the solar thermal system.

D.2 Scope. This appendix applies to factory-built sub-assemblies of components intended for use in solar thermal systems, intended to facilitate the assembly and operation of complete solar thermal systems. Sub-assemblies may consist of but are not limited to the following components: circulating pumps, fill ports, fill valves, isolation valves, pressure gauges, temperature gauges, check valves, pressure relief valves, temperature relief valves, thermostatic mixing valves, isolation valves, drain valves, expansion tanks and controllers. Sub-assemblies containing a circulating pump assembled with at least one other component are known as "pump stations."

D.3 General. Solar thermal system subassemblies shall comply with the applicable sections of the standard, along with the requirements below for separate listing and labeling.

D.3.1 Materials. Materials used in subassemblies shall comply with Section 302. Materials in direct contact with potable water shall comply with NSF 61 and NSF 372 and shall have a weighted average lead content of 0.25 percent or less.

D.3.2 Insulation. Thermal insulation incorporated into subassemblies shall not directly contact live electrical parts. Polymeric foam insulation used within pump stations shall have a maximum flame spread index of 25 when tested per UL 723 or ASTM E84 or be enclosed in a metal enclosure. Foam shall be tested per UL 746B and be rated for the maximum operating temperature of the subassembly.

D.4 Design. Components and devices used in subassemblies shall be listed and labeled by recognized third-party listing agencies to the referenced standards. The subassemblies shall comply with the applicable design requirements in Section 301.

D.4.1 Piping and fittings. Piping and fittings incorporated into pump stations shall comply with one or more of the pipe and fitting standards in Section Appendix B.

D.4.2 Connections. Inlets to and outlets from subassemblies shall be made with fittings or pipe stub-outs with complying with Appendix B. Pipe stub-outs shall be cut square, reamed and deburred.

D.4.3 Valves. Valves incorporated into subassemblies shall be listed and labeled by a recognized third-party listing agency in accordance with the requirements of Section 304.4. Isolation valves shall be provided at the inlet and outlet of the subassembly, instead of individual components, as required in Section 304.4.4

D.4.4 Thermostatic mixing valve. Thermostatic mixing valves incorporated into pump stations shall be listed and labeled to ASSE 1017 or CSA B125.3 and shall be accessible for adjustment and service.

D.4.5 Expansion tanks. Expansion tanks incorporated into pump stations shall comply with Appendix B. Expansion tanks shall not be supported by the piping and shall be accessible for charging and service.

D.4.6 Heat exchangers. Heat exchangers incorporated into pump stations shall comply with Section 304.6.

D.4.7 Pumps. Circulation pumps in subassemblies shall comply with 304.7.

D.4.8 Controls and sensors. Controls and sensors incorporated into subassemblies shall comply with Section 304.9.

D.4.9 Electrical systems. Electrical systems and wiring in subassemblies shall comply with Section 304.10.

D.5 Construction

D.5.1 Joints. Piping and components shall be assembled by means of joints complying with Appendix B as applicable for the pipe and fitting types and materials.

D.5.2 Enclosure. Where pump stations include an enclosure, it shall be removable or permit access to the pump station components for maintenance or repair. Enclosures shall be constructed of corrosion-resistant, non-combustible materials. Polymeric materials used in the enclosure shall have a minimum HB flammability classification when tested per UL 94. Enclosures with a surface area greater than 10 square feet shall also have a maximum flame spread index of 200 when tested per UL 723 or ASTM E84.

D.5.3 Supports or brackets. Subassemblies shall be provided with rigid brackets or floor stands to allow for free-standing, wall or tank-mounted installation. Brackets, mounts and supports shall fully support the filled weight of the subassembly without deformation. Subassemblies shall not be supported by means of the connected piping alone. Brackets, mounts and supports shall be constructed from non-corrosive and materials or protected from corrosion or galvanic corrosion with contacting dissimilar materials.

D.5.4 Fill and drain ports. Fill and drain ports incorporated into subassemblies shall be listed for the intended use and shall be provided with caps.

D.5.5 Gauges. Pressure, temperature, flow and combination gauges shall be rated for the full range of design operating conditions at the point of installation.

D.6 Tests. The following tests shall be performed on each subassembly, as applicable.

D.6.1 Hydrostatic pressure test. Hydrostatic pressure testing of subassemblies shall be conducted in accordance with the following procedure at a test pressure 150% of the maximum design pressure. Where the subassembly is designed to be connected to a pressurized domestic water supply, the test pressure shall be no less than 160 psi (1110 kPa).

1. The pressure gauge shall be attached to the exit port of the subassembly and the outlet shall be sealed.

2. The supply side shall be filled with unheated water.

4. Hydraulic pressure shall be applied to the inlet port until the gauge indicates the test pressure has been reached.

5. The inlet pressure port shall be closed, and the pressure monitored for 15 minutes.

6. The final pressure shall be recorded. The pump station shall be determined to have passed the test where there is no observable pressure change or leakage observed.

D.6.2 Rain penetration (outdoor use). Where subassemblies are designed for installation outdoors, they shall be tested per the rain test method in UL 174 or have a minimum rating of IPX4 as specified in IEC 60529 or NEMA 3R as specified in NEMA 250. After water spray testing, there shall be no evidence of water ingress that impacts the safety or performance of the subassembly.

D.7 Labeling and Marking. Subassemblies shall be marked and/or labeled with the information listed in this section. The information shall be provided in a clearly readable size and format. Markings shall be stamped, molded, etched, or engraved on the exterior of the product, or using labels affixed to the product. Marks and labels shall comply with permanence requirements set forth in UL 969. Marks and labels shall be in a location visible after the subassembly is installed.

D.7.1 Control and indicator labeling. Warning lights, switches and controls in subassemblies shall be clearly identified.

D.7.2 Product labeling. Product marks and/or labels shall include the following minimum information as applicable:

1. Manufacturer name and/or trademark
2. Model name and/or number.
3. Certification number and third-party certification agency.
4. Maximum working pressure(s).
5. Port locations. Where both heat transfer fluids and potable water are supplied to the subassembly, the respective ports shall be clearly identified.
6. Compatible fluids.
7. Heat exchanger type (single-wall, double-wall), as applicable.

8. Electrical rating in volts and amperes or watts, indicating alternating current (AC) or direct current (DC), frequency and number of phases (where applicable).

D.8 Manuals. Subassemblies shall be supplied with manuals addressing the installation, operation, and maintenance and installation of the product. The following minimum information must be provided:

1. Manufacturer's name and address.
2. Model name and/or number.
3. Maximum working pressure.
4. Maximum and minimum recommended operating temperature.
5. Dry weight.
6. Compatible heat transfer fluids.
7. Heat exchanger type (single-wall, double-wall) as applicable.
8. Inlet and outlet port sizes and types, identifying the fluids to be connected to each and specifically noting any approved for use with potable water.
9. Electrical rating in volts and amperes or watts, indicating alternating current (AC) or direct current (DC), frequency and number of phases (where applicable).
10. Outer dimensions.
11. Manufacturer's approved mounting hardware and instructions for mounting of the subassembly in each approved orientation.
12. Approved installation locations: indoors, outdoors-protected, outdoors-unprotected.
13. Warning against health and safety hazards that could arise in the operation and maintenance of the subassembly and full description of the precautions that must be taken to avoid these hazards.
14. Directions for transport, storage, and handling.