Summary of Substantive Changes
between the 2014 and the 2015 editions of
SRCC Standard 100, Minimum Standards for Solar Thermal Collectors

Presented to the IAPMO Standards Review Committee on October 16, 2017

General: The changes to this standard will likely have an impact on currently listed products. The significant changes are:

- Added specification of ASTM C1048 for tempered glass and the requirement for perpendicular impact for non-flat, non-tempered glass (see Section 302).
- Clarified the pressure test performance requirements (see Section 304).
- Clarified the Thermal Shock /Cold fill performance requirements (see Section 305).
- Added reference to ISO 9806 Section 18 for the final inspection requirements (see Section 306).
- Clarified the requirements of concentrating and non-concentrating solar collectors (see Section 307).
- Clarified the means of identifying the method testing and the testing sequence for the collector type (see Section 401.2).
- Added a method and process to use for selection of collectors to be tested (see Section 401.3).
- Added requirements for documentation of the baseline inspection (see Section 401.4).
- Added requirements for addressing factory-sealed containers and active mechanisms and an exception for collectors in which heat transfer fluid is continuously flowing for protection (see Section 401.8).
- Changed the test procedure for the thermal performance test (see Section 401.14).
- Added specific requirements for determination of the incident angle modifier for concentrating collectors (see Section 401.15).
- Added an inspection criterion for penetration (see Table 306.1)
- Added requirements for liquid heating collectors protected by controls and non-separable storage (see Table 401.2)
- Added the required accuracies for the instrumentation use in the tests of Section 401.14.2 (see Table 401.14.2.1.4)

Chapter 1, Application and Administration: Former Sections 1.0 Purpose, 2.0 Scope, and 4.0 Referenced Standards, were combined under Chapter 1 as follows:

SECTION 101 GENERAL
~~1.0~~ 101.1 Purpose.
SECTION 102 SCOPE
~~2.0~~ 102.1 Scope.
SECTION 103 REFERENCED DOCUMENTS
~~4.0~~ 103.1 Referenced Standards documents.

Chapter 2, Definitions: Definitions were added for a number of terms and existing definitions were revised as follows:

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 referenced standards shall have ordinarily accepted meanings as the context implies. Where a definition does not appear herein, informative reference is made to ISO 9488.

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

SECTION 202 DEFINED TERMS

ABSORBER: ~~The absorber is~~ That part of the solar collector that receives the incident solar radiation and transforms it into thermal energy. It usually is a solar surface through which energy is transmitted to the transfer fluid; however, the transfer fluid itself could be the absorber in certain configurations.

ABSORBER AREA. The maximum area in which concentrated or unconcentrated solar radiation is admitted and converted to heat or power. Absorber area does not include portions of the absorber/receiver where light is permanently screened and thermal barriers are in place.

ACTIVE CONTROLS. Control and actuator systems where external power and a computational device are used for operation and safety control purposes.

AMBIENT AIR: ~~Ambient air is~~ The ~~outdoor~~ air in the vicinity of the solar collector ~~being tested~~.

APERTURE AREA. The maximum area projected on a plane perpendicular to the optical normal through which the unconcentrated solar radiant energy is captured. In a concentrating collector, the following areas are excluded:

1) *any area of the reflector or refractor permanently shaded by collector elements that are opaque, such as a secondary reflector or receiver;*
2) *structural elements such as supports;*
3) *gaps between reflector segments within the collector module.*

*AVAILABLE ENERGY**:** ~~Is determined by~~ The time integrated solar irradiance.*

*COLLECTED ENERGY**:** ~~Is~~ The product of the fluid mass, specific heat and integrated temperatures gain across the collector.*

COLLECTOR ENCLOSURE: The structural frame ~~which~~ that supports the components of the collector and protects internal components from the environment.

COMBINED ASSEMBLY. A solar collector with one or more subcomponents that are not physically attached within a common structure or assembly at the point of manufacture, but are assembled in the field. Once assembled, collector modules shall not vary in geometry and performance from design specifications. A combined assembly would generally be comprised of subcomponents, each with individual nameplates and serial numbers, and might be shipped from separate facilities and manufacturers to a common location for final assembly. A building-integrated collector that requires specific shared external components for normal operation is an example of a combined assembly.

COMPLETE ASSEMBLY. A solar collector designed and constructed as a permanent, single unit. Complete assemblies cannot be physically separated for normal operation and would generally carry a single nameplate and serial number. A single parabolic trough with mounted receiver and tracking frame is an example of a complete assembly.

CONCENTRATING PHOTOVOLTAIC. A solar collector that uses optical elements, such as lenses or mirrors, to concentrate sunlight onto solar photovoltaic cells to generate electrical energy.

CONCENTRATING THERMAL COLLECTOR: A solar collector ~~which~~ that uses ~~reflectors, lenses or other~~ optical elements to concentrate ~~the radiant energy passing through the aperture~~ solar energy onto an absorber ~~which has a surface area smaller than the aperture. Some collectors using concentrating elements also fit the definition of a flat-plate collector. Thus, this document treats non-concentrating flat plate collectors, concentrating flat-plate collectors, and concentrating tracking collectors~~ Concentrating collectors include flat plate and tubular collectors with mirrors.

CONCENTRATION: The direction of a quantity of solar insolation greater than normal incident insolation onto a solar collector absorber surface.

CONCENTRATOR: The concentrator is that part of the concentrating collector which directs the incident solar radiation onto the absorber.

COVER PLATE: The ~~cover plate is the~~ material or materials covering the absorber. ~~aperture and most directly exposed to the solar radiation.~~ These materials generally are used to reduce the heat loss from the absorber to the surroundings and to protect the absorber. In some collector designs, materials in the shape of a tube serve as a cover plate by enclosing the absorber (see "Transparent Cover").

CRAZING: Formation of minute surface cracks.

DEGRADATION: ~~Is defined as that~~ Leading to significant permanent loss of collector performance ~~and/~~or leading to elevated risk of danger to life, limb or product. "Repeated exposure" is defined as a minimum total of 1000 hours/year at stagnation conditions during the design life

Modes of degradation ~~shall~~ include, but are not limited to:

Outgassing from coatings or insulation that result~~s~~ in harmful deposits or significant structural failure or significant reduction in insulation value.

Structural weakening with permanent failure, melting, charring, ignition~~, etc.~~ of wooden or polymer components exposed to temperatures greater than documented limits

Release of undesirable compounds from the wall of the fluid passageway into the heat transfer fluid.

DELAMINATION: Separation into constituent layers, as in one layer of material separating from another.

DISTORTION. A change witnessed or measured during testing that suggests a change to the functional dimensional integrity of a product raising safety, reliability or performance concerns.

DISTRIBUTED ASSEMBLY. A solar collector using subcomponents that are not physically attached to each other or a common structure. When fully assembled, the geometry of the assembly can vary from module to module due to customization of design or installation. Distributed assemblies have the potential to be scaled by subcomponent count and collector geometry without changes to actual subcomponent specifications. An example of a distributed assembly would be a central receiver design where layout or count of heliostats can vary while the central receiver and individual heliostat module designs and specifications remain fixed.

DRY COLLECTORS. Collectors where heat transfer fluid is not shared with other external components as part of a heat transfer loop.

FAIL-SAFE. An operating condition of a collector where collector protection functions will continue under all collector and system failure modes.

FLAT-PLATE COLLECTOR: A ~~flat-plate~~ solar collector ~~is normally a solar collector (~~either liquid or air~~)~~ in which the surface absorbing the incident radiation is essentially flat and employs no concentration. ~~However,~~ In this ~~document~~ standard the term refers to all collectors designed to perform satisfactorily with all parts of the collector in fixed positions.

FLUID: A ~~fluid is defined as a~~ substance that can flow and does not maintain a fixed shape. Gases and liquids are considered to be fluids.

GLAZED. A typed of solar collector with a cover over the absorber plate.

GROSS ~~COLLECTOR~~ AREA: The maximum projected area of the complete module, including integral mounting means.

HAIL. Precipitation in the form of small balls or lumps, usually consisting of concentric layers of clear ice and compact snow.

~~Heat Pipe: A heat transfer device that combines the principles of both thermal conductivity and phase change.~~

~~Innovative Equipment: Solar equipment which, due to its design, cannot be evaluated fairly and adequately by the test methods described in this document.~~

HEAT TRANSFER FLUID. Air, water, or other fluid that is used to transfer thermal energy between collectors and other components in a system.

ICS. Acronym for solar collectors in which the solar energy collection function is integrated with storage of the heated fluid, thus: Integral Collector Storage collector. In this type of collector the collection and storage functions cannot be separated for testing or operation.

INCIDENT ANGLE MODIFIER (IAM). The measurement of changes in collector efficiency as a function of the angle at which light enters the aperture.

INSTANTANEOUS EFFICIENCY: ~~The instantaneous efficiency of a solar collector is defined as~~ The amount of energy removed by the transfer fluid over a given measuring period divided by the total incident solar radiation onto the gross collector area during the measuring period.

INTEGRITY OF CONSTRUCTION: Those physical and mechanical properties of the solar collector ~~which~~ that collectively are responsible for the overall thermal performance and physical structure of the solar collector.

IRRADIANCE: ~~Irradiance is~~ The rate of solar radiation received by a unit surface area in unit time~~.~~ ~~in W/m^2~~ Irradiance is expressed in Btu per hour square feet. (Btu/hr ft^2) W/m^2.

IRRADIANCE, BEAM. Irradiance, on a defined plane, originating from a narrow solid angle centered on a solar disk.

IRRADIANCE, DIFFUSE. Scattered irradiance, on a defined plane, originating from outside the solar disk.

IRRADIANCE, GLOBAL. Hemispherical irradiance on a horizontal surface.

IRRADIANCE, HEMISPHERICAL. The sum of direct and diffuse irradiance.

"NO-FLOW" CONDITION: ~~The~~ A condition ~~that result when the heat transfer fluid does not flow through the collector array due to shut-down or malfunction and the collector is exposed to the amount of solar radiation that it would receive under normal operating conditions~~ where thermal energy is not transferred from the collector by means of heat transfer fluid flow.

NON-CONCENTRATING SOLAR THERMAL COLLECTOR: A solar collector ~~receives incident solar radiation at~~ without optical elements that redirect incident solar radiation onto an integral flat absorber ~~and transforms it into thermal energy. The transfer from solar energy to heat energy occurs at the absorber surface and heat energy is transmitted to a transfer fluid; however, the transfer fluid itself could be the absorber in certain configurations~~.

NORMAL SOLAR ANGLE, GEOMETRIC. An imaginary line perpendicular to the surface of an optical medium. The word normal is used in the mathematical sense, meaning perpendicular.

OPTICAL NORMAL SOLAR ANGLE. The angle at which the sun is perpendicular to each axis of the solar collector optical plane, as determined by the manufacturer. The aperture optical plane can be characterized as an invisible datum plane that can be orthogonal to or have any symmetrical relationship to the aperture, reflecting elements, heat collecting apparatus, or the solar collector frame. An optical based definition of the normal solar angle is necessary when the collector is geometrically asymmetrical or has a tailored and nonsymmetrical solar response.

OUTGASSING: The generation of vapors by solar collector components or construction materials usually occurring during periods of solar collector exposure to elevated temperatures ~~and/~~or reduced pressure.

PASSIVE. An operating condition of a solar concentrating collector where human or mechanical intervention is not required for operation as intended.

PASSIVE CONTROLS. Control and actuation systems where external energy source is not required and computational device is not used.

POWER. The amount of energy produced over time, expressed as watts or Btu per hour.

PYRANOMETER: A radiometer used to measure the total ~~solar radiation (direct, diffuse, and reflected)~~ hemispherical irradiance incident on a surface ~~per unit time per unit area~~.

~~Rated Performance: The solar equipment thermal output characteristics determined by tests specified in this document.~~

SITE DEPENDENT COLLECTORS: A collector intended to be assembled only at the site of its application. This may be because parts of the building (e.g., rafters, insulation) are part of the collector or because the fully assembled size of the collector or other construction characteristics makes delivery in operational form impractical.

SOLAR ENERGY: ~~The~~ Energy originating from the sun's radiation primarily encountered in the wavelength region from 0.3 to 3.0 micrometers.

SOLAR THERMAL COLLECTOR: A ~~solar thermal collector is a~~ device designed to absorb ~~incident~~ solar radiation ~~to convert it to thermal energy,~~ and to transfer the thermal energy so produced to a fluid ~~coming in contact with~~ passing through it. ~~The materials and dimensions of the cover (if any) and the absorber must be specified. A solar collector must contribute net gain and be able to have its solar energy conversion efficiency characterized by recognized thermal performance equations.~~

STAGNATION. The solar collector temperature at which the energy gain is balanced by the heat loss.

STANDARD: A document ~~which~~ that specifies the performance, durability, or safety requirements of a product.

THERMAL EFFICIENCY: ~~Is~~ The ratio of ~~collected~~ thermal energy removed from a collector to the available solar energy falling upon the collector area.

~~THERMAL PERFORMANCE CURVE: For a collector is determined when the insolation incident to the collector is within 30 degrees of normal to the aperture of the collector. To predict collector performance over a wide range of conditions, tests will be conducted to determine the collector incident angle modifier. This is used to modify the efficiency curve (determined within 30 degrees of normal incidence) to account for changes in performance as a function of the sun's incidence angle.~~

TIME CONSTANT: The time ~~constant is the time~~ required for the fluid leaving a solar collector to attain 63.2% of its steady state value following a step change in ~~insolation~~ solar radiation or inlet fluid temperature.

TRANSFER FLUID: ~~The transfer fluid is~~ A medium such as air, water, or other fluid ~~which~~ that passes through or comes in contact with ~~the~~ a system component, such as the solar collector~~,~~ and carries the thermal energy ~~away from the collector~~ to another component.

TRANSPARENT COVER. Radiation-transmitting material covering the absorber.

~~TRANSPARENT FRONTAL AREA: The transparent frontal area is the projected area of that part of the collector designed to transmit incident solar energy to the interior of the collector.~~

TRANSPIRED. A type of solar collector in which fluid is drawn through holes in the absorber plate rather than flowing through tubes or across the absorber plate.

UNGLAZED. A type of solar collector without a cover over the absorber plate.

WET COLLECTOR. A concentrating collector where thermal subcomponents share a common heat transfer fluid with and are part of a fluid circuit with external components.

Chapter 3, General Requirements:

Section 302, Cover: Added specification of ASTM C1048 for tempered glass and the requirement for perpendicular impact for non-flat, non-tempered glass as follows:

302.1 General. Collector covers shall comply with Sections 302.1.1 through 302.1.2.
~~*5.18 Impact Resistance Test*~~ *302.1.1 Tempered glass.* Where the outer cover is *flat, and* constructed of *tempered* glass, t*he glass shall be tempered in accordance with ASTM C1048 or equivalent.* Testing in accordance with this section shall not be required when tempered glass is used.
~~*5.18 Impact Resistance Test*~~ *302.1.2 Nonglass and nontempered glass.* The outer cover of ~~*one*~~ *the* test specimen shall be tested in accordance with ISO 9806, Section 17, ~~*with the exception that the test must be conducted in accordance with*~~ Method 2 using steel balls.
Where the outer cover is ~~*constructed of tempered glass, testing shall not be required*~~ *not flat, the impact shall be perpendicular to the curvature. The optical elements of the collector shall withstand impacts without adverse effect on operation or performance.*

Section 304, Pressure Test Requirements: Clarified the pressure test performance requirements as follows:
304.1 General. Pressure test results shall comply with Sections 304.1.1 through 304.1.2.
~~*6.2*~~ *304.1.1 Liquid. A collector, after testing, shall be considered to be passable if* ~~*it meets the requirements stated in Section 6.4 of ISO 9806.*~~*: 1) a loss of pressure greater than that specified in ISO 9806, Section 6.4 does not occur; 2) there is no evidence of fluid leakage; 3) there is no evidence of fluid path deterioration, including but not limited to swelling and stretching.*
304.1.2 Air. A collector, after testing, shall be considered to be passable if there is no evidence of permanent fluid path deterioration, including but not limited to swelling and stretching.

Section 305, Thermal Shock Results: Clarified the Thermal Shock /Cold fill performance requirements as follows:
~~*6.3*~~ *305.2 Thermal shock/Water spray. The collector structure and performance shall not be degraded by moisture penetration. There shall not be cracking, crazing, warping or buckling of the cover* ~~*or the absorber*~~ *plate.*
305.3 Thermal shock/Cold fill. The collector's fluid pathway shall not leak. The absorber shall not be permanently distorted such that performance is degraded.

Section 306, Disassembly and Final Inspection: Added reference to ISO 9806 Section 18 for Final inspection requirements as follows:
~~*6.4*~~ *306.1 General. After completing the test sequence outlined in Section* ~~*401*~~ *5.0, the collector shall be disassembled,* ~~*its*~~ *and subassemblies visually inspected, and their condition noted as specified in ISO 9806, Section 18, to determine final collector condition and actual or potential points of failure that can lead to impairment of function or abnormally short collector life. The format specified in ISO 9806, Annex A.15, "Final inspection results," shall be used to report conditions observed.* ~~*Listed below are the items covered.*~~ *Components and inspection criteria shall be in accordance with Table 306.1.1.*
Test specimens and their components shall ~~*not*~~ *exhibit no conditions capable of producing premature failure, including but not limited to the items listed in Table 306.1.2.*

Section 307, Protection of Materials: Clarified the requirements of concentrating and non-concentrating solar collectors as follows:

~~6.5~~ 307.1 Nonconcentrating solar collectors. Materials used in the construction of nonconcentrating solar collectors shall ~~be capable of withstanding no~~ withstand not less than 1000 hours per year at stagnation temperature without significant degradation over the design life. Stagnation temperature shall be determined in accordance with ISO 9806, Section 10.

307.2 Concentrating solar collectors. Materials used in the construction of concentrating solar collectors shall withstand the maximum temperature to which the solar collector is tested in accordance with Sections 307.2.1 and 307.2.2.

~~5.4~~ 307.2.1 No controls employed. If controls are not employed, ~~the~~ collector stagnation temperature shall be determined in accordance with ISO 9806, Section 10.

307.2.2 Controls employed. If controls are employed, collector stagnation temperature shall be determined in accordance with manufacturer's stated maximum operating temperature.

~~6.6~~ 307.3 Photovoltaic collectors. When a photovoltaic module is incorporated into the ~~solar~~ collector design, the photovoltaic module shall be ~~certified~~ listed and labeled to UL 1703.

Exception: The photovoltaic module portion of a photovoltaic-thermal collector shall comply with UL 1703.

Chapter 4, Test Methods:

Section 401.2, Testing Requirements: Clarified the method of testing and determination of the testing sequence as follows:

~~5.0~~ 401.2 Testing requirements. Table ~~1~~ 401.2 specifies ~~which~~ the tests ~~are to be~~ that shall be conducted on each type of solar collector. An "X" in the table indicates the test shall be conducted. An "O" indicates the test shall be conducted but can be conducted on either collector if two collectors are used to complete testing requirements. ~~All tests shall be conducted in accordance with ISO 9806:2013.~~ The testing sequence is determined by identifying the type of collector, identifying the method of testing to be used, and then following the requirements in Table 401.2 and Sections 401.2.1 and 401.2.2.

401.2.1 Methods for conducting tests. There are two methods for conducting the test. Table 401.2 demonstrates the appropriate requirements for each type of collector and each method as follows:

1. (Indicated in the table as "1") When all of the tests are conducted on a single collector, the testing requirements for each type of collector are designated with the column heading "1."

2. ~~(Indicated in the table as "2Q" and "2P")~~ When two collectors are tested, ~~with~~ one ~~of them being~~ shall be subjected to the qualification tests, designated in column heading of "2Q," ~~one of them being subjected~~ and ~~one of them being~~ the other shall be subjected to the performance tests, designated in column heading of "2P."

401.2.2 Testing sequence. The test sequence shall follow the order ~~in which the tests are~~ as listed in Table 401.2. ~~with the following exceptions:~~

Exceptions:

1. *The following tests can be conducted in any sequence relative to each other: thermal capacity and time constant, thermal performance, incident angle modifier and pressure drop.*
2. *The following tests can be conducted in any sequence relative to each other: high-temperature resistance, exposure, ~~stagnation temperature,~~ external thermal shock, and internal thermal shock.*
3. *All solar collectors containing heat pipes shall be subjected to the exposure test in accordance with ~~Subclause 11 of ISO 9806~~ Section 401.7 before the thermal performance test is conducted. The same serial-numbered collector shall be subjected to the exposure test and then to the thermal performance test.*

Section 401.3, Test Specimen Selection: Added a method and process to use for selection of collectors to be tested as follows:

~~5.1~~ 401.3 Test specimen selection. *Collectors to be tested shall be selected at random for testing and shall be tested ~~as received from the manufacturer~~ in accordance with Sections 401.3.1 through 401.3.2.*
401.3.1 Selection method. Random selection of test collectors shall be accomplished through a personal visit by the laboratory, certification body, or authority having jurisdiction or selection from photographs of the collectors in stock. The selected collectors, or collector components, shall be affixed with nonremovable serial-numbered labels.
401.3.2 Selection process. Collectors shall be randomly selected from a group of at least five collectors. Where final assembly of the collector components occurs only at the installation site, each of the components shall be randomly selected from a group of at least five components. The collector's final assembly geometry shall not change from its design specification.

Exceptions:

1. *Large collectors greater than 4.6 m^2 (50 ft^2) shall be randomly selected from a group of at least two collectors where either:*
   1.1. Transport in a fully constructed condition is impractical; or
   1.2. Collectors are not inventoried in a fully constructed condition.
2. *If the collector design to be tested is always built for a specific installation, the collector is to be tested in-situ without random selection.*
3. *For distributed assembly solar concentrating collectors where the subcomponents are not physically connected to each other, the manufacturer shall specify the geometric parameters and configuration of all subcomponents and the total collector.*
   3.1. Parameters shall include orientation, distance, height, and angle of all solar collector subcomponents in relation to each other and the installation site, including the quantity of each.
   3.2. The manufacturer's specifications shall include minimum and maximum values for each geometric parameter defining the configuration's final assembly with minimum-and maximum-operating specifications.
   3.3. The configuration(s) to be tested shall fall within these specified ranges, representing operating conditions closest to the minimum and maximum allowed. The most rigorous test conditions applicable shall be used.

Section 401.4, Baseline Inspection: Added requirements for documentation of the baseline inspection as follows:
~~5.2~~ 401.4 Baseline inspection. The collectors shall be tested as received from the manufacturer when assembled per manufacturer's documentation. Test specimens shall be inspected prior to testing and any visible damage or assembly flaws shall be recorded. Documentation shall include photographs of the collector or its constituent parts, as received, showing all visible surfaces. Any abnormalities shall be noted and photographed in detail.

Section 401.8, Thermal Shock Tests: Added requirements for addressing factory-sealed containers and active mechanisms and an exception for collectors in which heat transfer fluid is continuously flowing for protection as follows:

~~5.6 EXTERNAL THERMAL SHOCK/WATER SPRAY TEST~~

401.8 Thermal shock tests. All collectors shall comply with Sections 401.8.1 through 401.8.7.

401.8.1 Outdoor testing option. ~~Where~~ When testing is conducted outdoors, ~~one external~~ each shock shall be performed on ~~each of two different days of the exposure test~~ a different day.

401.8.2 Indoor testing option. ~~Where~~ When testing is conducted indoors under a solar simulator, ~~the second test may be performed on the same day as the first test~~ it is permissible to conduct multiple shock tests on the same day ~~as the first test~~ provided ~~that~~ the collector ~~has cooled~~ is allowed to cool to ambient air temperature ~~before the second test is begun~~ between shock tests.

401.8.3 Factory-sealed containers. When the solar collector design incorporates one or more factory-sealed containers charged with a refrigerant, other fluid, or phase change material, these containers shall not be removed for these tests.

401.8.4 Active mechanisms. If the collector assembly has active mechanisms that are intended to be functional during operation, those mechanisms shall be operational during testing.

…

401.8.6 External thermal shock/water spray test. ~~The~~ Two external thermal shock tests ~~shall be conducted in accordance with~~ performed as specified in ISO 9806, Section 12, ~~under~~ using a minimum of ~~climate~~ Class B conditions.

~~5.7~~ 401.8.7 Internal thermal shock/cold fill test. ~~The~~ Two internal thermal shock tests shall be performed as specified in ISO 9806, Section 13, ~~under~~ using a minimum of ~~climate~~ Class B conditions. All parts of the solar collector assembly that are not factory sealed shall be subjected to this test. ~~Where testing is conducted outdoors, one Internal shock shall be performed on each of two different days of the exposure test. Where testing is conducted indoors under a solar simulator, the second test may be performed on the same day as the first test provided that the collector has cooled to ambient air temperature before the second test is begun. If this test is conducted indoors under a solar simulator, it may be performed on the same day as one or both of the external thermal shock tests, provided that the collector has cooled to ambient air temperature before this test is begun.~~

~~A collector shall be considered to have failed the test when the test specimen experiences permanent distortion, damage or degradation of performance.~~

Exception: This test is not applicable to collectors in which heat transfer fluid is continuously flowing for protection purposes. In such cases, control(s) used to manage a no-flow condition shall be validated to be functional in such a way that any failure can be detected. Control functions that have been verified shall be described and reported with the test results.

Section 401.14, Thermal Performance Test: Changed the test procedure for the thermal performance test as follows:

~~5.13~~ 401.14 Thermal performance test. ~~The thermal performance test determines "instantaneous" efficiency of the solar collector over its normal range of operating temperatures.~~ The thermal performance ~~test~~ testing of solar thermal collectors shall be ~~conducted in accordance with Section 24 of ISO 9806~~ performed as specified in Section 401.14.1 or 401.14.2.

401.14.1 Collectors containing no internal storage. The thermal performance test on collectors that do not contain internal storage shall be performed as specified in ISO 9806, Section 20.

401.14.2 Collectors containing storage. Additional testing shall be required for collectors containing storage because the mass of the storage precludes measurement of instantaneous efficiency. Such collectors include both integral collector storage designs and thermosiphon designs where the collection function cannot be separated from the storage function for testing. Such collectors shall be subjected to the applicable tests described in Sections 401.14.2.1 through 401.14.2.2.

401.14.2.1 General testing procedures. Test objects shall be mounted in a manner that is similar to the intended usage. This requirement includes the use of such devices as reflectors and roof support structures. The hydraulic, thermal and optical characteristics shall be reproduced during the test.

401.14.2.1.1 Testing with fluid other than water. Where testing with a fluid other than water, fluid composition tests shall be performed to ensure that the specified fluid composition exists. At a minimum, a hygrometer test or its equivalent shall be performed and checked with the fluid specification before proceeding with the test.

401.14.2.1.2 Pre-heating heat exchanger. In any collector with a heat exchanger containing more than 2.5 percent by volume of the storage vessel volume, the heat exchanger shall be preheated to the same temperature as the rest of the collector for all tests. This heat exchanger shall not be directly purged at the end of the test. The energy within it shall be purged in the normal operating fashion.

401.14.2.1.3 Manufacturer's recommended operating conditions. Performance testing shall not be performed in excess of manufacturer's recommended operating conditions. Adjustment of test operating conditions is permissible to conform to the intent of the test.

401.14.2.1.4 Required instrumentation accuracy and resolution. Table 401.14.2.1.4 indicates the required assurances for the instrumentation used in the tests required in Section 401.14.2. The radiation measurements shall be performed with devices that meet the standards of the World Meteorological Organization for a first-class pyranometer or pyrheliometer. The data resolution shall be not lower than the stated accuracy. The test lab shall ensure that data is checked for any offsets immediately prior to and at the conclusion of the test. Offsets shall be applied to the processed data and noted in the test report.

401.14.2.1.5 Minimum data time step. Data shall be sampled at a maximum interval of 15 seconds. This data shall be averaged and reported at a maximum rate of 5 minutes for long-term tests having a duration longer than 1 day, or 0.5 minute for short term tests. Because of the interaction with the transient system simulation software, which uses a fixed time step, data for all collected channels shall be reported in fixed time steps. Note that any test using an energy purge shall be measured with the highest data resolution available at the laboratory.

401.14.2.1.6 Instrument calibration. Calibration of instrumentation used in the testing setup shall be traceable to a national standard and be performed at least annually.

401.14.2.1.7 Required experimental data. The data specified in Sections 401.14.2.1.7.1 through 401.14.2.1.7.3 are required.

401.14.2.1.7.1 Required numerical data. The minimum real time data to be collected for the tests shall consist of the following in metric units. Data channels shall be reported on a regular time interval. Channels not used in a particular test shall be populated with a value not found elsewhere in the data for that channel. The test lab shall review for and address any missing or erroneous data. This data reduction shall occur prior to submission for modeling.

401.14.2.1.7.1.1 Data gaps or corrections. Gaps or corrections for critical data shall not last longer than 10 minutes during non-purge periods. During purge periods, critical data shall not be missing or erroneous. The missing or adjusted data shall be filled in using proxy measurements or interpolation to existing data and highlighted in the data set and noted in the test report.

401.14.2.1.7.1.2 Log requirements. A log indicating the timing of the draw, purge, and irradiation start and stop times shall be included. Other data including site elevation, longitude, latitude, and test sample orientation shall be supplied. Any data sets that do not meet these minimum requirements shall be excluded from the analysis. Required data includes:

1. Data collection time, both local and solar, and date and day of year (dd-mm-yyyy)
2. Inlet temperature(s) (°C)
3. Outlet temperature(s) (°C)
4. Ambient temperature (i.e., "Outside," if applicable) (°C)
5. Environmental temperature (i.e., "Inside," if applicable) (°C)
6. Flow rate(s) (kg/hr)
7. Fluid heat capacities(s) (kJ/kg-°C)
8. Wind velocity (m/s)
9. Auxiliary energy usage, if applicable (kJ)
10. Radiation measurements (kJ/m2)
    a. Total surface
    b. Total horizontal
    c. Horizontal diffuse
    d. Horizontal infrared, integral collector storage and unglazed collectors only

401.14.2.1.7.2 Required physical data. Easily accessible significant characteristics of the component or collector shall be measured and reported in consistent sets of units, including:

1. Diameters, lengths and widths, internal and external.
2. Lengths, internal and external, and spacing of tubes and fins.
3. Heights, internal and external, minimum and maximum water levels shall be denoted.
4. Thickness, such as insulation, tank shell, tank vessel, and fins.
5. Volumes at ambient air temperature of the tank and any integral heat exchangers.
6. A diagram indicating geometry including vessel, shell, and any protrusions such as heat exchangers and plumbing connections.
7. Materials used for vessel, including insulation, shell, tank liner, and heat exchangers.
8. Piping lengths and orientations.
9. Slope of components.

401.14.2.1.7.3 Additional required documentation. The following documentation shall be provided:

1. Equipment model number(s);
2. Description of the test method(s) and any deviations from the standard method; and
3. Photographs of any applicable equipment.

401.14.2.1.8 Laboratory process. The testing and analytical work shall consist of these steps:

1. The test lab shall determine physical parameters from the tests.
2. The test lab shall collect extended test data from warm up tests.
3. The test lab shall prepare the data in the format requested by the certification body.
4. The certification body shall create a model using transient system simulation software.

401.14.2.1.9 Data processing methods. These tests shall provide data for computer modeling of collectors or collector components, or both. The method of modeling shall depend upon the test and available transient system simulation software models. The certification body will provide direction for new and innovative collector tests that are not explicitly covered in this test method.

401.14.2.1.9.1 Use of real-time data. The calculation of temperature-dependent densities and heat capacities shall be performed using real-time data by the test lab. Data reduction shall include the filtering out of any erroneous data. The delivered energy value shall be used where matching net delivered energy with the transient system simulation software. It is permissible to not adjust this value if the simulation software accounts for energy changes caused by different starting and ending temperatures and losses from the collector during the purge period.

401.14.2.1.9.2 Data consistency. All data shall be consistent with the test conditions. When the pyranometer and pyrheliometer are not covered by the collector cover, the visual radiation shall be set to zero and the sky infrared radiation shall be adjusted to an equivalent sky radiation to account for the covering of the collector during the purge period. Any adjustments shall be noted in the test report.

401.14.2.1.9.3 Processing for component model calibration using transient system simulation software. Upon receipt of the processed data, the certification body shall create a series of computer models using transient system simulation software. One model shall be created for each test. This model is called the "audit" model.

Each of the audit models is then fit to the test data as indicated in Items 1 through 4:

1. Collector heat loss shall be determined as follows:
   1.1. When both capacitance and heat loss tests are performed, the results from the heat loss test and capacitance tests shall be iterated upon until a final value of collector loss rate is determined.
   The loss value shall be used directly in the model. No other explicit fit is required at this point.
   1.2. When only the heat loss test is performed, the results are used to calibrate a transient system simulation software computer model. The loss value shall be used directly in the model. No other explicit fit is required at this point.
2. Parameters for heat exchangers integral to a collector shall be used directly in the model. No other explicit calibration is required at this point. The calibration is done by minimizing the chi-squared value for all data sets.
3. The data from each of the individual data points in the warm-up tests shall be used to calibrate a transient system simulation software computer model using the $F_R\tau\alpha$ and F_RU_L isothermal initial conditions. A calibration routine shall be used to compare the

observed net, solar or auxiliary energy deliveries to the observed data points (one per test). The calibration is done by minimizing the chi-squared (x^2) value for all data sets.

For integral collector storage collectors, the $F_R U_L$ adjustment is actually a UA_{loss} adjustment since there is no measure ed value for $F_R U_L$. (Note that the ICS nighttime loss test shall be calibrated as part of the data set.) The net result of this process is two points ($F_R \tau\alpha$ and $F_R U_L$) that are used in the transient system simulation software model.

4. When the collector is initially stratified due to the presence of an auxiliary heater, a separate set of tests and calibrations shall be completed. This is required when a heater is located within the storage vessel of a thermosiphon collector.

401.14.2.2 Specific testing procedures. Collectors containing internal storage shall be tested using the procedures described in ISO 9459-4, Annex C, with the following clarifications:

1. During the collector purge described in ISO 9459-4, Section B.2, a bypass loop shall be used to precondition the inlet water to the specified temperature before introducing water to the test article. Unless otherwise specified, the purge temperature shall be the same temperature as the charge temperature in order to minimize internal energy change in the collector.
2. During the heat loss test described in ISO 9459-4, Section B.4.1, any source of heating, including resistance heaters and/or solar radiation, shall be shut off or blocked. All pumps shall be shut off for the duration of the test.
3. During the heat loss test described in ISO 9459-4, Section B.4.1, when internal temperature probes are used, the test shall continue until both of the following are satisfied:
   3.1. The collector temperature drops at least 3°C.
   3.2. The differential between the average collector temperature and the average environmental temperature changes by at least 3°C.
4. During the warm-up tests described in ISO 9459- 4, Section C.3, the temperature in the collector at the beginning of a low-temperature test shall be close to ambient temperature.
5. During the warm-up tests described in ISO 9459- 4, Section C.3, wind at a speed between 1 and 3m/s shall be required when testing collectors with integral storage tanks or unglazed collectors, or both.

Section 401.15, Collector Incident Angle Modifier: Added specific requirements for determination of the incident angle modifier for concentrating collectors as follows:

~~5.14~~ 401.15 Collector incident angle modifier. The incident angle modifiers of the collector shall be determined for each test specimen in accordance with ISO 9806, Section 27. Biaxial incident angle modifiers are required on collectors that are nonsymmetrical in their response to irradiance as solar altitude and azimuth change. Data shall be taken in each of the two perpendicular planes that characterize the collector geometry.

401.15.1 Concentrating collectors. Concentrating solar collector testing shall include all operational conditions in which the collector is designed to operate. Incident angle modifiers shall be found for the maximum acceptance angle and all intermediate angles as needed to properly characterize the optical behavior of the collector. Unless the manufacturer stipulates otherwise, the maximum acceptance angle to be tested shall be at least 60 degrees.

401.15.1.1 Biaxial incident and single angle modifiers testing. Biaxial incident angle modifiers testing and reporting shall be conducted on all nontracking concentrating collectors as covered by this standard and any single axis tracking collector where reflectors and/or receivers move independently of each other.

401.15.1.2 Drawings. The manufacturer shall submit a drawing showing the optical normal, transverse plane and longitudinal plane.

Table 306.1.1, Component Inspection Criteria: The text of former Section 6.4 was converted into a table and an inspection criterion for penetration was added to the requirement for Collector box/fasteners.

Table 401.2, Solar Collector Test Requirements: Formerly Table 1, Requirements for Liquid Heating Collectors; Protected by Controls, and Non-separable Storage, were added and a row for Thermal Performance was included.

Table 401.14.2.1.4, Instrumentation Accuracies: New Table, specifies the required accuracy for the instrumentation used in the tests required in Section 401.14.2.