

FLORIDA SOLAR



ENERGY CENTER[®]

FSEC STANDARD

Test Methods and Minimum Standards for Certifying Solar Thermal Collectors

FSEC Standard 102-10

January 2010

1679 Clearlake Road, Cocoa, FL 32922-5703 • Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu



A Research Institute of the University of Central Florida

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3.0 Definitions

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 solid surface through which energy is transmitted to the transfer fluid; however, the transfer fluid itself could be the absorber in certain configurations.

Ambient Air: Ambient air is the air in the vicinity of the solar collector being tested.

Aperture Area: Maximum projected area through which the unconcentrated solar radiation enters a collector.

Certification: Designation that specific products are in compliance with FSEC standards.

Collector Enclosure: The structural frame which supports the components of the collector and protects internal components from the environment.

Concentrating Collector: A solar collector which uses reflectors, lenses or other optical elements to concentrate the radiant energy passing through the aperture 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.

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

Corrosion: The deterioration of a substance or its properties caused by a chemical or electrochemical reaction with its environment.

Cover Plate: The cover plate is the material or materials covering the 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.

Crazing: Formation of minute surface cracks.

Deformation: An alteration of shape by pressure or stress.

Delamination: Separation into constituent layers.

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

Gross Collector Area: The maximum projected area of the complete collector module, including integral mounting means, excluding connecting fluid pipeworks. Gross area includes all area inside the outer perimeter of the collector.

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 a specified reference collector area (gross or transparent) during the measuring period, under quasi steady state conditions.

Integrity of Construction: Those physical and mechanical properties of the solar collector, which 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 (Btu/hr-ft²).

Model: A unit of solar equipment that is distinguishable from other units by a specified size, set of materials, construction and performance. A change in any of these basic characteristics constitutes a new model.

Outgassing: The generation of vapors by materials, usually during exposure to elevated temperature and/or reduced pressure.

Pitting: The process by which localized material loss is caused in materials or components by erosion, corrosion or chemical decomposition.

Pyranometer: A radiometer used to measure the total solar radiation (direct, diffuse, and reflected) 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.

Reflector or Reflective Surface: A surface intended for the primary function of reflecting radiant energy.

Site Dependent Collector: A collector intended to be assembled only at the site of its installation. This may be because parts of the building (e.g., rafters, insulation) are part of the collector or because the size of the collector makes delivery impractical.

Solar Collector: A solar collector is a device designed to absorb incident solar radiation, to convert it to thermal energy, and to transfer energy to a fluid in contact with it.

Solar Energy: The photon energy originating from the sun's radiation primarily encountered in the wavelength region from 0.3 to 3.0 micrometers.

Standard: A document, which specifies the performance, durability or safety requirements for a product.

Time Constant: The time constant is the time required for the fluid leaving a solar collector to attain 63.2 percent of its steady state value following a step change in insolation or inlet fluid temperature.

Transfer Fluid: The transfer fluid is a medium such as air, water, or other fluid which passes through or in contact with the solar collector and carries the thermal energy away from the collector.

5.0 Test Methods for Solar Collectors

Collector testing shall be performed in the following sequence:

- a. Random selection
- b. Receiving inspection.
- c. Static pressure test.
- d. Thirty-day exposure test.
 1. Thermal shock/water spray test.
 2. Thermal shock/cold fill test.
- e. Static pressure test.
- f. Collector time constant determination test.
- g. Thermal performance test.
- h. Incident angle modifier test.
- i. Pressure Drop Test
- j. Disassembly and final inspection.

The same serial-numbered collector must go through the above test sequence in the exact order specified.

5.1 Random Selection

Solar collectors being submitted for certification testing must be randomly selected. The manufacturer will make available, from existing stock at the manufacturing facility or at the manufacturer's distribution location, five production unit collectors of the model to be tested from which one will be selected for testing. The manufacturer will then have the selected collector shipped to FSEC.

5.2 Receiving Inspection

Upon receiving a collector for testing, the test laboratory shall inspect and document the condition of the collector using ISO 9806-2, Appendix A.14 "Final inspection results". (See Section 6.6 for details.)

5.3 Static Pressure Test

A static pressure test shall be conducted prior to exposure testing.

5.3.1 Types of Collectors

- a. Street pressure solar collectors - collectors which, by virtue of their installation in a municipal water system, will be directly subjected to variations in street water pressure and hot water tank pressure.
- b. Low pressure service hot water (SHW) and swimming pool solar collectors - collectors which, by virtue of their installation will not have a direct fluid interchange with an auxiliary heater or street pressure. (Heat transfer from such SHW collectors to the service water system would be accomplished by the use of an appropriate heat exchanger.)
- c. Hybrid and alternate fluid solar collectors - collectors which, by virtue of design, are not intended to have a direct fluid connection to a SHW system. Such units may or may not be designed to accept street pressure.

5.3.2 Basis of Test Pressure

- a. The test pressure shall be 1,100 kPa gauge (160 psig) for street pressure collectors, based on:
 1. Two times the allowable street pressure 550 kPa gauge (80 psig) in a dwelling.
 2. The test pressure exceeding the required P-T valve relief setting on approved hot water tanks, which is 1,030 kPa gauge (150 psig).
- b. Collectors specified for a positive operating pressure less than street pressure, 550 kPa gauge (80 psig), shall be pressure-tested at 1.5 times the manufacturer's rated operating gauge pressure, but at a minimum of 170 kPa gauge (25 psig).
- c. Collectors specified for operating pressures greater than 550 kPa gauge (80 psig) shall be pressure-tested at 1.5 times the manufacturer's rated operating gauge pressure or 1,100 kPa gauge (160 psig), whichever is less.
- d. Collectors specified for operation at atmosphere pressure or below shall be pressure-tested at the discretion of the test manager, but at no greater than 170 kPa gauge (25 psig).
- e. Determination of test pressure shall be based on required application documentation supplied with the collector.

5.3.3 Method of Testing

Either hydrostatic or pneumatic pressure sources may be used on liquid filled collectors. Pneumatic pressure sources shall be used for air collectors.

5.3.3.1 Liquid Collectors

a. A pressure gauge shall be attached to read pressure at the collector, the collector shall be completely filled with fluid between 5⁰C (41⁰F) and 30⁰C (86⁰F), and the exit port shall be closed off. The ambient temperature shall be between 5⁰C (41⁰F) and 30⁰C (86⁰F).

b. Hydraulic pressure will be applied via the inlet port until the gauge indicates the test pressure.

c. After a stable test pressure has been reached, the exit port shall be closed and the pressure will be monitored for 10 minutes.

d. If the pressure drops by more than 10% from the starting test pressure the collector shall be deemed to have failed the test.

5.3.3.2 Air Collectors

a. A pressure tap of pipe or tubing shall be sealed onto the exit port of the test specimen and connected to a manometer which can be read directly to 2.5 Pa (0.01 inch water column) or to a pressure gauge of equivalent accuracy. An air volume meter accurate to within 14.0 liters (± 0.5 cubic feet) shall be placed in the air supply system between the supply source and the collector.

b. Apply pressure via the inlet port of 125 Pa (0.5 inch water column) and monitor the pressure for one hour. The volume of air added or removed in order to maintain the required pressure shall be documented.

5.4 Exposure Test

The purpose of this test is to verify the integrity of construction after at least 30 days of exposure to adverse conditions.

5.4.1 Method of Testing

a. The collector unit shall be tested under worst case conditions. The collector shall be dry. Units which use a sealed container or loop charged with a refrigerant, other phase change material or fluid, shall be tested with a normal charge of the material (according to manufacturer specifications).

b. Exposure conditions shall consist of 30 days of cumulative exposure to a minimum daily incident solar radiation flux of 17 MJ/m²·day (1,500 Btu/ft²·day) as measured in the plane of the collector aperture.

c. Data recorded and reported during exposure testing shall include integrated daily solar radiation data. A regularly scheduled weekly visual inspection shall also be made, and a record of changes in the physical appearance of the collector shall be kept.

5.5 Thermal Shock/Water Spray Test

The external thermal shock test shall be performed as specified in ISO 9806-2, Section 8, Class B. Two external shock tests shall be performed. Measurement of the absorber temperature is not required. Any collector whose integrity is permanently compromised by this test such that it obviously will not be able to perform later, is deemed to have failed the test.

5.6 Thermal Shock/Cold Fill Test for Liquid Collector

The internal thermal shock test shall be performed as specified in ISO 9806-2, Section 9, Class B. Any collector whose integrity is permanently compromised by this test such that it obviously will not be able to perform later, is deemed to have failed the test.

5.7 Static Pressure Test

A static pressure test following the provisions of Section 5.3 shall be conducted after exposure and prior to thermal performance testing.

5.8 Collector Time Constant

A time constant test shall be conducted to determine the time required for the outlet fluid temperature to attain 63.2 percent of its steady state value following a step change in the input. This test is used to determine the time period over which temperature and irradiance data are integrated to obtain the computed efficiency values for the thermal performance test. The test method used will conform to the method described in ISO 9806-1, Section 10 for glazed and ISO 9806-3, Section 10 for unglazed collectors, and ASHRAE 93 for air-heating collectors.

5.9 Thermal Performance Test

A thermal performance test shall be conducted on those collectors that have passed the requirements of Sections 5.1-5.7 and for which the collector time constant has been determined. The thermal performance test determines "instantaneous" efficiency of the solar collector over a wide range of operating temperatures. Efficiency is defined as the ratio of collected energy to the total available energy falling upon the entire collector area. Collected energy is determined by the product of fluid mass flow, specific heat and integrated temperature gain across the collector. Available energy is determined by the

integrated solar irradiance. Four data points are taken at each of four different inlet fluid temperatures. For unglazed collectors, the inlet fluid temperatures include test temperatures below and above ambient air temperature. Glazed collectors are normally tested over a range of inlet fluid temperatures from near ambient to approximately 70°C (126°F) above ambient temperature.

5.9.1 Testing Method

5.9.1.1 Liquid Heating

Testing Method - The test method used for glazed collectors shall conform to ISO 9806-1. The test method used for unglazed collectors shall conform to ISO 9806-3.

All collectors must be tested at or below the flow rate recommended by the appropriate part of ISO 9806 with the exception that the test on an unglazed collector may be conducted at a flow rate up to 0.07 kg/s·m² (0.1 gpm/ft²).

Any deviations from these standards shall be delineated in all FSEC publication of the test and certification results.

5.9.1.2 Air Heating

Testing Method – The test used for air heating collectors shall be conducted in accordance with ASHRAE 93-86.

5.10 Collector Incident Angle Modifier Determination

The thermal performance curve for a collector is determined when the insolation incident on 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 shall 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 incident angle. The test method used shall conform to ISO 9806-1 for glazed, or ISO 9806-3 for unglazed collectors, or ASHRAE 93-86 for air-heating collectors.

Biaxial incident angle modifiers are required on collectors which are non-symmetrical in their response to irradiance as solar altitude and azimuth change.

5.11 Pressure Drop Test

The pressure drop across the collector using a heat transfer fluid shall be measured at sufficiently small flow rate intervals to accurately describe the flow rate characteristics from minimum through maximum design flow rates, and shall include the ISO recommended flow rate. This testing shall be done in accordance with ISO 9806-1 for glazed or 9806-3 for unglazed collectors.

5.12 Disassembly and Final Inspection

After exposure and performance testing, the collector shall be disassembled and causes or conditions that may lead to impairment of function or abnormally short collector life shall be identified. The major components and subassemblies of the collector as defined in Section 6.6 shall be visually inspected and their condition reported in accordance with the chart listed therein. In addition, the following measurements or observations shall be made:

- a. Enclosure
 - 1) Depth of the collector enclosure
 - 2) Enclosure side material
 - 3) Enclosure back material
 - 4) Frame fastening methods (pop rivets, screws, etc.)
 - 5) Dry Weight
 - 6) Fluid Capacity

- b. Glazing
 - 1) Number of covers
 - 2) Glazing thickness
 - 3) Glazing dimensions (width or diameter and length)
 - 4) Surface characteristics (clear, textured)

- c. Insulation (flat plate: back and sides; tubular: header and tubes)
 - 1) Type of insulation
 - 2) Thickness

- d. Caulking, sealants, gasket materials
 - 1) List all used in collector (i.e., glazing gasket, inlet/out tube gaskets, etc.)

- e. Absorber
 - 1) Materials (plate/fin and tube)
 - 2) Absorber dimensions (width or diameter and length)
 - 3) Length of flow path through riser tube (n/a for heat pipes)
 - 4) Number of riser tubes (or serpentine passes)
 - 5) Riser tube to header connection method (if able to discern)
 - 6) Flow pattern
 - 7) Spacing between riser tubes (between center to center of risers or heat pipes)
 - 8) Glazing to absorber air space thickness
 - 9) Riser tube OD
 - 10) Riser tube ID
 - 11) Header OD
 - 12) Header ID

- 13) Test Pressure
- 14) Absorber Coating
- 15) Plate or fin thickness
- 16) Bond between riser and fin/plate (mechanical, solder, weld-ultrasonic, laser)
- 17) Bond width

6.0 Collector Standards

The following criteria represent the requirements for durability in collector design and construction in order to qualify for certification.

6.1 Cover Plate

All flat cover plates must be of a non-shattering or tempered type.

6.2 Condensation

The collector shall be designed to prevent condensate buildup. The use of desiccants to control condensation will be permitted. The test report shall note any unusual condensate buildup.

6.3 Pressure Test Results

6.3.1 Liquid Collector Test Results

After testing, collectors shall be considered passable if:

- a. A loss of pressure greater than that specified in 5.3.3.1 does not occur.
- b. There is no evidence of fluid leakage.
- c. There is no evidence of permanent fluid path deterioration (swelling, stretching, etc.)

6.3.2 Air Collector Test Results

After testing, collectors shall be considered passable if there is no evidence of permanent fluid path deterioration (swelling, stretching, etc.).

6.4 Thermal Shock/Water Spray Test Results

The collector structure and performance shall not be degraded by moisture penetration. There shall be no cracking, warping or buckling of the cover plate.

6.5 Exposure Test Results

The test will be terminated if it is apparent without collector disassembly that the unit no longer meets the requirements of Section 6.6.

6.6 Disassembly and Final Inspection

After completing the test sequence outlined in Section 5.0, the collector shall be disassembled and subassemblies visually inspected and their condition noted. The format specified in ISO 9806-2, Appendix A.14, "Final inspection results," shall be used to report observed conditions. Listed below are the items covered.

<u>Collector component</u>	<u>Potential problem</u>
a. Collector box/fasteners	Cracking/warping/corrosion/rain prevention
b. Mountings/structure	Strength/safety
c. Seals/gaskets	Cracking/adhesion/elasticity
d. Cover/reflector	Cracking/crazing/buckling/delamination/ warping/outgassing
e. Absorber coating	Cracking/crazing/blistering
Absorber tubes and headers	Deformation/corrosion/leakage/loss of bonding
Absorber mountings	Deformation/corrosion
f. Insulation	Water retention/outgassing/degradation

Conditions that, in the judgment of FSEC, may lead to abnormally short collector life will be justification for denying certification.

These conditions are:

- a. Severe deformation* of the absorber.
- b. Severe deformation* of the fluid flow passages.
- c. Loss of bonding between fluid flow passages and absorber plate.
- d. Leakage from fluid flow passages or connections.
- e. Loss of mounting integrity.
- f. Severe corrosion* or other deterioration caused by chemical action.
- g. Crazing, cracking, blistering or flaking of the absorber coating or reflective surfaces.
- h. Excessive retention of water anywhere in the collector.
- i. Swelling, severe outgassing or other detrimental changes in the collector insulation which could adversely affect collector performance.
- j. Cracking, loss of elasticity, or loss of adhesion of gaskets and sealants.
- k. Leakage or damage to hoses used inside the collector enclosure, or leakage from mechanical connections.
- l. Cracking, crazing, permanent warping or buckling of the cover plate.
- m. Cracking or warping of the collector enclosure materials.

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