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Standard Practice for Generating All-Day Thermal Performance Data for Solar Collectors[1]

This standard is issued under the fixed designation E 904; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a means of generating all-day thermal performance data for flat-plate collectors, concentrating collectors, and tracking collectors.

1.2 The values stated in SI units are to be regarded as the standard. The values given in the parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 772 Terminology Relating to Solar Energy Conversion[2]

2.2 *ASHRAE Standards:*

93-86 Methods of Testing to Determine the Thermal Performance of Solar Collectors

96-80 Methods of Testing to Determine the Thermal Performance of Unglazed Flat-Plate Liquid-Type Solar Collectors[3]

3. Terminology

3.1 *Definitions:*

3.1.1 Terms from Terminology E 772 and solar nomenclature documents under ballot, are listed for convenience.

3.1.2 For definitions of other terms used in this practice, refer to Terminology E 772.

3.1.3 *area, aperture, n—of a solar thermal collector,* maximum projected area through which the unconcentrated solar radiant energy is admitted, measured in square metres (m^2) (square feet (ft^2)).

NOTE 1—For concentrating collectors, the gross aperature area includes any area of the reflector or refractor shaded by the receiver and its supports and including gaps between reflector segments within a collector module. Net aperture excludes any shaded area or gaps between reflector segments and is sometimes called effective aperture area.

(E 772)

3.1.4 *heat transfer fluid, n—in solar energy systems, (1)* liquid or gas that passes through the solar collector and carries the absorbed thermal energy away from the collector. *(2)* any fluid that is used to transfer thermal energy between subsystems in solar energy systems. **(E 772)**

3.1.5 *non-operational mode exposure, n*—condition that exists when the collector has been filled, then purged of heat transfer fluid (if a liquid) and capped (but not sealed) to prevent introduction of foreign substances, mounted on a test rack, and exposed to solar radiation. **(E 772)**

3.1.6 *stagnation conditions, n*—conditions (that is, temperature and pressure) existing when an energy system has attained a quasi-steady state after the flow of heat transfer fluid has stopped, but the absorber continues to receive significant solar irradiance. **(E 772)**

3.1.7 *tilt angle, n—in solar energy applications,* angle between the horizontal and the plane of the detector (collector, photovoltaic array, instrument) surface. **(E 772)**

3.1.8 *time constant, n*—time required for the temperature change in the fluid leaving a solar collector to attain 63.2 % of its equilibrium value following a step change in the solar irradiance or inlet fluid temperature.

NOTE 2—The step change involved should be thoroughly described in the procedure.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *useful energy (removed), n*—time integral of the product of mass flow rate, specific heat, and temperature difference across the collector when the outlet temperature is greater than the inlet temperature.

4. Summary of Practice

4.1 The solar collector is mounted in accordance with the manufacturer's instructions. A constant flow rate and inlet temperature, and the transfer fluid, is preselected and specified. The temperature, fluid flow rate, irradiance, and wind parameters are recorded throughout the daylight hours. Data are collected at 1-min intervals or more frequently, and the average values are reported for each 5-min interval of the test day. All-day thermal performance is determined from the summation of energy outputs for all intervals of the test day.

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[1] This practice is under the jurisdiction of ASTM Committee E-44 on Solar, Geothermal, and other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.05 on Solar Heating and Cooling Subsystems and Systems.

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[2] *Annual Book of ASTM Standards*, Vol 12.02.

[3] Available from the American Society of Heating, Refrigeration, and Air-conditioning Engineers, Inc. (ASHRAE), Publications Sales Department, 1791 Tullie Circle, N.E. Atlanta, GA 30329; or American National Standards Institute, 11 W. 42nd St., 13th Flr., New York, NY 10036, for the ANSI standard.

5. Significance and Use

5.1 This practice may be employed for a relative determination of the useful energy collected by different solar collectors tested side-by-side under the same operating and environmental parameters, in the same location, and on the same test day. Variations in inlet temperature and transfer fluid flow rate should be minimized for best results.

5.2 *Limitations:* Caution should be exercised when comparing the all-day thermal performance data for collectors tested by this practice to the performance of other collectors not tested at the same time and the same location, or with the same test conditions. The data collected by this practice represent the behavior of the tested collectors only under the conditions occurring on the day of test and at the specific inlet temperature and fluid flow rate employed during the test.

5.2.1 In the case of low-temperature collectors (operating below 100°C (212°F)), consideration must be given to the relationship of inlet temperature to ambient temperature when analyzing or interpreting the test data.

5.3 Data collected in this test have not been shown to provide the overall comparison of collectors or collector concepts that would be required to support a nationally accepted rating or certification program.

6. Preconditioning

6.1 Prior to starting the all-day thermal performance test in accordance with this practice, the solar collectors shall be preconditioned. Preconditioning shall consist of stagnation conditions in a nonoperational mode and in a dry (or drained) condition for a minimum of three days. The minimum radiant exposure measured in the plane of the collector during preconditioning shall be 17 mJ/m^2·day (1500 Btu/ft^2·day).

NOTE 3—If the preconditioning procedure of 6.1 can be expected to cause either structural or material failure, the procedure should be deleted or modified to a method agreeable to the client to preclude thermally induced problems prior to performance testing.

7. Procedures and Computations

7.1 *General*:

7.1.1 *Mounting*—Mount the solar collectors in accordance with the manufacturer's instructions at a tilt and azimuth that is commensurate with the end-use application, if known. Otherwise, for non-tracking collectors, the tilt shall be that of the local latitude minus the seasonal declination angle and the azimuth shall be 180° (true south).

7.1.1.1 If the test is intended to compare collector types for which an array of two or more will be used in normal applications, then test a collector assembly consisting of two or more collectors of each type, together with any required external manifolding. Include a description of the manifolding in the report, giving the pipe length, diameter, and material and the insulation type and thickness used. It shall be stated whether collectors were joined in series or parallel.

7.1.2 *Time constant*—Determine the collector time constant at the mass flow rate utilized in this test method and in accordance with ASHRAE 93-86.

7.2 *Test Conditions*:

7.2.1 *Exposure Conditions*—Precondition the solar collectors in accordance with Section 6.

7.2.2 *Operating Conditions*—Pump the specified transfer fluid through the collectors at a constant preselected mass flow rate and inlet temperature specified by the manufacturer. The selected flow rate should be the projected flow rate for the anticipated end-use application, and the inlet temperature should be selected to provide the anticipated end-use temperature. Maintain the inlet temperatures within ± 0.5°C (± 1°F) during each 5-min measurement interval and within ± 2.5°C (± 5°F) during the test day. Maintain the flow rate within ± 1.0 % during each 5-min measurement interval. Variations in inlet temperature and mass flow rate should be minimized for best test results.

7.2.3 *Measurements*:

7.2.3.1 *Temperature and Flow Rate Measurements*—Make temperature and flow rate measurements in accordance with ASHRAE 93 or ASHRAE 96 where applicable. Mount inlet and outlet temperature sensors at the location where the heat transfer fluid first enters the collector assembly and leaves the collector assembly, respectively. Average the transfer fluid temperature measurements and the flow rate measurement over the 5-min test interval and record.

7.2.3.2 *Solar Radiation Measurements*—Make solar radiation measurements in accordance with ASHRAE 93 and record at 1-min intervals. More frequent intervals or continuous recording are permissible. Average the readings over each 5-min interval and report the averages.

7.2.3.3 *Area Measurements*—Measure both gross and aperture areas and report for each collector tested.

7.2.4 *Recorded Data*:

7.2.4.1 Record ambient temperature, collector inlet and outlet temperatures, mass flow rate, solar irradiance (measured in the plane of the collector), and wind data beginning at local sunrise and terminating at local sunset plus three collector time constants.

7.2.4.2 Record solar radiation over the sunrise-to-sunset test day including those measurement intervals during which the collector does not produce useful energy.

NOTE 4—As defined in this practice, the collector can operate during a measurement interval of the test day in such a manner that useful energy is not generated. In actual system operation, flow to the collector would normally be shut off during these intervals.

8. Calculation

8.1 *Energy Collected*:

8.1.1 *Useful Energy Rate*—Calculate the useful rate of energy collection, q_u, in W(Btu/h), as follows:

$$q_u = mC_p\Delta T \quad (1)$$

where:

m = mass flow rate, kg/s (lb/h),
C_p = specific heat of transfer fluid, J/(kg·°C), (Btu/lb·°F)
ΔT = difference between outlet temperature, T_o, and inlet temperature, T_i, ΔT has the value zero when $T_o \leq T_i$·°C, (°F)

8.1.2 *Useful Energy in the Data Interval*—Calculate the useful energy collected during the i^{th} 5-min data interval, in J(Btu), as follows:

$$Q_i = \int_{t_i}^{t_i + 5\text{ min}} mC_p\Delta T dt \quad (2)$$