

ANSI/ASAE S423.1 MAR2014

Thermal Performance Testing of Open-Loop Solar Ambient Air Heaters with Defined Inlet and Outlet Conditions



**American Society of
Agricultural and Biological Engineers**

STANDARD

ASABE is a professional and technical organization, of members worldwide, who are dedicated to advancement of engineering applicable to agricultural, food, and biological systems. ASABE Standards are consensus documents developed and adopted by the American Society of Agricultural and Biological Engineers to meet standardization needs within the scope of the Society; principally agricultural field equipment, farmstead equipment, structures, soil and water resource management, turf and landscape equipment, forest engineering, food and process engineering, electric power applications, plant and animal environment, and waste management.

NOTE: ASABE Standards, Engineering Practices, and Data are informational and advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. The ASABE assumes no responsibility for results attributable to the application of ASABE Standards, Engineering Practices, and Data. Conformity does not ensure compliance with applicable ordinances, laws and regulations. Prospective users are responsible for protecting themselves against liability for infringement of patents.

ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as "ASAE", regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as "ASABE".

Standards designated as "ANSI" are American National Standards as are all ISO adoptions published by ASABE. Adoption as an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by ASABE.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

CAUTION NOTICE: ASABE and ANSI standards may be revised or withdrawn at any time. Additionally, procedures of ASABE require that action be taken periodically to reaffirm, revise, or withdraw each standard.

Copyright American Society of Agricultural and Biological Engineers. All rights reserved.

ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, phone 269-429-0300, fax 269-429-3852, hq@asabe.org

Thermal Performance Testing of Open-Looped Solar Ambient Air Heaters with Defined Inlet and Outlet Conditions

Developed by the ASAE Solar Energy Committee; approved by the ASAE Structures and Environment Division Standards Committee; adopted by ASAE December 1991; approved as an American National Standard February 1993; reaffirmed by ASAE December 1996; reaffirmed by ANSI March 1998; reaffirmed by ASAE December 2001, January 2007, reaffirmed by ANSI January 2007; reaffirmed by ASABE and ANSI February 2012; revised March 2014; revision approved by ANSI April 2014.

Keywords: Heaters, Solar, Testing

1 Purpose and Scope

1.1 The purpose of this Standard is to provide a method for testing the thermal efficiency of open-looped solar air heaters which are used exclusively for heating ambient air. The test data should provide a basis for computing technical performance and for comparing efficiency of collectors of different design and/or construction. Examples of use of solar ambient air heaters are preheating of ventilation air, heating make-up air for all types of environmental control systems, and heating of air to dry agricultural products without recirculation.

1.2 This test procedure simplifies the testing equipment needs, procedures and computations as compared to the currently recognized methods, for example, ANSI/ASHRAE Standard 93-2010, Method of Testing to Determine the Thermal Performance of Solar Collectors.

1.3 The scope of this Standard is restricted to collectors which have a fixed orientation and slope during the test and are used exclusively for heating ambient air with defined inlet and outlet conditions.

1.4 This Standard provides the method for using a 6 h continuous test consisting of twenty-four 15 min test periods.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies unless noted. For undated references, the latest approved edition of the referenced document (including any amendments) applies.

2.1 ANSI/ASHRAE 93-2010, Method of Testing to Determine the Thermal Performance of Solar Collectors

2.2 ASAE D271.2 APR1979 (R2010), Psychometric Data

3 Definitions

3.1 collector aperture area (A_a): The maximum projected area of the solar collector through which the solar radiation is admitted, m^2 (ft^2). The area does not include partitions between collectors, framing and insulation.

3.2 surface Azimuth Angle (γ): Fixed solar collectors situated in the northern hemisphere are normally oriented due south. In this case, the surface azimuth angle is equal to zero. If the solar collector is oriented east or west of this direction then specify the solar surface azimuth angle.

3.3 collector slope (β): The collector slope is the angle between the plane of the collector absorber and a horizontal surface, in degrees. A common slope for fixed collectors is equal to the latitude of the collector location.

3.4 continuous data: Data taking is considered continuous if the instrument measures and records data once each minute or more frequently.

3.5 daily efficiency (η_d): The collected energy of the collector for the test day divided by the total solar energy incident on the gross collector area for the same test day, dimensionless. This equation is given below.

$$\eta_d(\%) = \frac{\text{actual useful energy collected (kWh)}}{\text{solar energy intercepted by the collector (kWh)}} \times 100$$

3.6 other efficiency calculations (η_x): The collector efficiency is calculated for a given test period. The efficiency is the ratio of the collected energy from the collector per test period divided by the total solar energy incident on the gross collector area for the same test period (also dimensionless). Efficiency for short time periods (such as one test period, see paragraph 3.13) shall not be used as an efficiency value unless the collector has quasi-steady state heat flow as indicated by constant efficiency ($\pm 1\%$) for 4 continuous test periods.

3.7 useful energy collected (Q_u): The amount of energy collected by the solar air heater per unit of time shall be computed from the specific heat of air flowing through the measuring device multiplied by the mass flow rate of air and by the temperature rise of the air from entrance to exit of the collector, kW (Btu/hr). This is given in the equation below.

$$Q_u = m_f C_p (t_{f,o} - t_{f,i})$$

where:

Q_u = useful energy collected, kW (Btu/h)

m_f = mass flow rate of air, kg/s (lb/hr)

C_p = specific heat of air, kJ/kg °C (Btu/lb °F)

$t_{f,o}$ = average outlet air temperature, °C (°F)

$t_{f,i}$ = average inlet air temperature, °C (°F)

3.8 mass flow rate (m_f): The mass flow rate of air entering ($m_{f,i}$) and exiting ($m_{f,o}$) the solar collector, kg/s (lb/s). This is also given in the equation below.

$$m_f = \rho v A$$

where:

ρ = density of air, kg/m³ (lb/ft³)

v = average air velocity, m/s (ft/s)

A = cross sectional area, m² (ft²)

Mass flow of air is estimated from measuring the air velocity and the cross sectional areas. The density is calculated from the ideal gas equation shown in section 7.1.1 and corrected for temperature and pressure and humidity ratio.