(RA 1989)
(Reaffirmation of ANSI/ASHRAE 96-1980)

# ASHRAE™ STANDARD

AN AMERICAN NATIONAL STANDARD

# METHODS OF TESTING TO DETERMINE THE THERMAL PERFORMANCE OF UNGLAZED FLAT-PLATE LIQUID-TYPE SOLAR COLLECTORS

Reaffirmed by the ASHRAE Standards Committee January 28, 1989, by the ASHRAE Board of Directors, February 2, 1989 and by the American National Standards Institute's Board of Standards Review, August 24, 1989.

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**information purposes only.**

## FOREWORD

This Standard describes tests for determining the thermal performance of unglazed collectors used in low temperature applications such as heating of swimming pools and with heat pumps. Glazed and/or concentrating collectors used in these same applications are intended to be tested for thermal performance in accordance with ASHRAE Standard 93-1986.

It should be recognized that the thermal performance of a single collector may not be indicative of the performance of a collector array consisting of a number of modules of the same collector.

The 1980 Standard was recommended for reaffirmation with minor editorial changes by the Standards Committee on June 28, 1987. Since the ASHRAE Journal intent-to-reaffirm notice elicited no negative comments, the Board of Directors approved the reaffirmation with minor editorial changes on February 2, 1989.

## 1.0 PURPOSE

**1.1** The purpose of this Standard is to provide test methods for determining the thermal performance of unglazed flat-plate liquid-type solar energy collector modules (hereinafter called solar collectors) which heat a liquid for low temperature applications.

## 2.0 SCOPE

**2.1 Application.** This Standard applies to unglazed flat-plate liquid-type solar collectors to be used in low temperature applications and in which a liquid enters the collector through a single inlet and leaves the collector through a single outlet.

**2.1.1** Collectors containing more than one inlet and more than one outlet may be tested according to this Standard provided that the external piping can be connected so as to provide effectively a single inlet and a single outlet.

**2.1.2** Collectors, other than unglazed flat-plate liquid-type, which are intended for low temperature applications should be tested in accordance with ASHRAE Standard 93-1986 modified in accordance with the requirements of Section 8.3 of this Standard.

**2.2 Outdoor and Indoor Testing.** This Standard contains methods for conducting tests outdoors under natural solar irradiation and for conducting tests indoors under simulated solar irradiation.

**2.3 Test Methods and Calculation Procedures.** This Standard provides test methods and calculations procedures for determining steady-state and quasi-steady-state thermal performance, and angular response characteristics of the solar collectors.

## NOMENCLATURE

a,b = constants used in incident angle modifier equation, dimensionless
$A_a$ = transparent frontal area or aperture area for a flat-
$A_g$ = gross collector area, m² (ft²)
$b_o$ = constant used in incident angle modifier equation, dimensionless
$c_p$ = specific heat of the transfer fluid, J/(kg · °C) [Btu/ (lb · °F)]
$F_R$ = solar collector heat removal factor, dimensionless
$I_{DN}$ = direct normal solar irradiation, W/m² [Btu/(h · ft²)]
$I_d$ = diffuse solar irradiation incident upon the aperture plane of collector, W/m² [Btu/(h · ft²)]
$I_{sc}$ = solar constant, 1353 W/m² [429.2 Btu/(h · ft²)]
$I_t$ = total solar irradiation incident upon the aperture plane of collector, W/m² [Btu/(h · ft²)]
$K_{\alpha\tau}$ = incident angle modifier, dimensionless
LST = local standard time, decimal hours
LSTM = local standard time meridian, deg
AST = apparent solar time, decimal hours
$\dot{m}$ = mass flow rate of the transfer fluid, kg/s (lb/h)
$P_{th}$ = theoretical power required to move the transfer fluid through the collector, W (hp)
$\Delta p$ = pressure drop across the collector, Pa (lb/in.²)
$q_u$ = rate of useful energy extraction from the collector, W(Btu/h)
$t_a$ = ambient air temperature, °C (°F)
$t_{f,e}$ = temperature of the transfer fluid leaving the collector, °C (°F)
$t_{f,i}$ = temperature of the transfer fluid entering the collector, °C (°F)
$t_p$ = average temperature of the absorber surface for a flat-plate collector, °C (°F)
$\Delta t$ = temperature difference, °C (°F)
$U_L$ = solar collector heat transfer loss coefficient, W/(m² · °C) [Btu/(h · ft² · °F)]
w = density, kg/m³ (lb/ft³)
$\alpha$ = absorptance of the collector absorber surface for solar radiation, dimensionless
$\theta$ = angle of incidence between direct solar rays and the normal to the collector surface or to the aperture, deg
$\eta_g$ = collector efficiency based on gross collector area, %
$\lambda$ = wavelength, μm
$\tau$ = transmittance of the solar collector cover plate, dimensionless (if no cover plate is used, $\tau$ = 1.0)
$(\tau\alpha)_e$ = effective transmittance-absorptance product, dimensionless
$(\tau\alpha)_{e,n}$ = effective transmittance-absorptance product at normal incidence, dimensionless
$T_1,T_2$ = time at the beginning and end of a test period, decimal hours

## 3.0 DEFINITIONS

***absorber:*** that part of the solar collector which receives the incident radiant energy and transforms it into thermal energy. It may possess a surface through which energy is transmitted to the transfer liquid; however, the transfer liquid itself can be the absorber.

***absorber area:*** the total heat transfer area through which the absorbed solar irradiation heats the transfer liquid or of the absorber media if both transfer liquid and solid surfaces jointly perform the absorbing function.

***air mass:*** the ratio of the mass of atmosphere in the actual earth-sun path to the mass which would exist if the sun were directly overhead at sea level.

***angle of incidence:*** the angle between the direct solar beam and the normal to the aperture plane.

***aperture area:*** the maximum projected area of a solar collector through which the unconcentrated solar radiant energy is admitted.