

IAPMO/ANSI S1001.4-2015

Energy Production Rating of Solar Heating Collectors



American National Standard

Approval of an American National Standard requires verification by the American National Standards Institute (ANSI) that the requirements for due process, consensus, and other criteria for approval have been met by the standards developer.

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.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether he has approved the standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards.

ANSI does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of ANSI. Requests for interpretations should be addressed to the secretariat or sponsor whose name appears on the title page of this Standard.

This American National Standard may be revised or withdrawn at any time. ANSI procedures require that action be taken periodically to reaffirm, revise, or withdraw this Standard. Purchasers of American National Standards may receive current information on all standards by calling or writing ANSI.

Published by

International Association of Plumbing and Mechanical Officials (IAPMO)

5001 East Philadelphia Street, Ontario, California, 91761

1-800-854-2766 • 1-909-472-4100

Visit the IAPMO Online Store at: www.IAPMOstore.org

Visit the IAPMO Standards website at: www.IAPMOstandards.org

Copyright © 2013-2015 by

International Association of Plumbing and Mechanical Officials (IAPMO)

All rights reserved.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission of the publisher.

Printed in the United States of America

Contents

Preface

IAPMO Solar Standards Committee

IAPMO S1001 Technical Subcommittee

- 1** **Scope**
- 2** **Reference Publications**
- 3** **Definitions and Abbreviations**
 - 3.1 Definitions
 - 3.2 Abbreviations
- 4** **Collector Testing**
 - 4.1 Performance Testing
 - 4.2 Test Report Data
- 5** **Rating Days**
 - 5.1 General
 - 5.2 Total Daily Solar Irradiation
- 6** **Heating Categories**
 - 6.1 General
 - 6.2 Alternative Procedure Based on Mean Temperature Differential
- 7** **Incidence Angle Effects**
 - 7.1 Angle Effects
 - 7.2 Fixed Plane
 - 7.3 Isotropic and Biaxial Angle Effects
- 8** **Calculation Procedures — Glazed Collectors**
 - 8.1 Efficiency Equation for Glazed Collectors
 - 8.1.1 General
 - 8.1.2 Coefficients
 - 8.2 Incidence Angle Modifier — Isotropic
 - 8.2.1 General
 - 8.2.2 Incidence Angle Modifier — Isotropic Interpolation
 - 8.3 Effective Solar Irradiance Calculation — Isotropic
 - 8.3.1 General
 - 8.3.2 Effective Direct (Beam) Solar Irradiance
 - 8.3.3 Effective Diffuse Solar Irradiance
 - 8.4 Incidence Angle Modifier — Biaxial
 - 8.4.1 General
 - 8.4.2 Incidence Angle Modifier — Biaxial Interpolation

- 8.5 Effective Solar Irradiance Calculation — Biaxial
 - 8.5.1 General
 - 8.5.2 Effective Direct (Beam) Solar Irradiance
 - 8.5.3 Effective Diffuse Solar Irradiance
- 8.6 Daily Thermal Energy Generation
 - 8.6.1 Calculation
 - 8.6.2 Thermal Energy Output
 - 8.6.3 Equation Simplification
 - 8.6.4 Heating Categories
 - 8.6.5 Output Values
- 9 Calculation Procedures — Unglazed Collectors**
 - 9.1 Efficiency Equation for Unglazed Collectors
 - 9.1.1 General
 - 9.1.2 Coefficients
 - 9.1.3 Air Speed
 - 9.2 Incidence Angle Modifier — Unglazed Collectors
 - 9.2.1 General
 - 9.2.2 Incidence Angle Modifier — Isotropic Interpolation for Unglazed Collectors
 - 9.3 Effective Solar Irradiance Calculation
 - 9.3.1 General
 - 9.3.2 Effective Direct (Beam) Solar Irradiance
 - 9.3.3 Effective Diffuse Solar Irradiance
 - 9.4 Net (Solar and Non-Solar) Irradiance Calculation
 - 9.4.1 General
 - 9.4.2 Collector Energy Production Rating
 - 9.5 Daily Thermal Energy Generation
 - 9.5.1 Calculation
 - 9.5.2 Thermal Energy Output
 - 9.5.3 Equation Simplification
 - 9.5.4 Heating Categories
 - 9.5.5 Output Values
- 10 Presentation of Results**
 - 10.1 General
 - 10.1 Energy Production Ratings by Unit Area
 - 10.2 Energy Production Ratings in I-P Units

Tables

1	(Section 5.2)	Total Daily Solar Irradiation
2	(Section 6.1.2)	Typical Heating Categories
3	(Section 8.2.1)	Incidence Angle Modifier — Isotropic Presentation Format
4	(Section 8.4.2.1)	Longitudinal Angle of Incidence Modifier Values — Biaxial
5	(Section 8.4.2.1)	Transversal Angle of Incidence Modifier Values — Biaxial
6	(Section 10.1.1)	Format for Reporting Collector Performance

Figures

1	(Section 8.4.1)	Symmetry Planes and Angles Relevant for the Determination of Biaxial or Multi-Axial Incidence Angle Modifier
---	-----------------	--

Annexes

A (Normative)	Hourly Irradiance, Incidence Angles, and Air Speed for Rating Days
B (Normative)	Energy Production Rating Calculation Procedure for Collectors with Reported Efficiency Equation Based on Mean Collector Temperature
C (Normative)	Procedures for Calculating Unreported Isotropic and Biaxial Incidence Angle Modifier Values
D (Informative)	Symbols
E (Informative)	Ratings Calculator

Preface

This is the first edition of IAPMO S1001.4, *Energy Production Rating of Solar Heating Collectors*.

This Standard was developed by the IAPMO S1001 Technical Subcommittee and approved by the IAPMO Solar Standards Committee in accordance with the *ANSI Essential Requirements: Due process requirements for American National Standards* and the *IAPMO Policies and Procedures for Consensus Development of American National Standards*. This Standard was approved as an American National Standard on June 17, 2015.

Notes:

- (1) *The use of the singular does not exclude the plural (and vice versa) when the sense allows.*
- (2) *This standard was developed in accordance with the IAPMO procedures accredited as meeting the criteria for American National Standards and it is an American National Standard. The IAPMO Standards Committee that approved this Standard was balanced to assure that individuals from competent and concerned interests had an opportunity to participate. During its development, this Standard was made available for public review, thus providing an opportunity for additional input from industry, academia, regulatory agencies, and the public at large.*
- (3) *This Standard was developed by consensus, which is defined as substantial agreement; consensus implies much more than a simple majority, but not necessarily unanimity. It is consistent with this definition that a member of the relevant IAPMO Standards Committee can be included in the committee roster and yet not be in full agreement with all sections of this Standard.*
- (4) *Although the intended primary application of this Standard is stated in its scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*
- (5) *IAPMO Standards are subject to periodic review and suggestions for their improvement will be referred to the relevant IAPMO Standards Committee. To submit a proposal for change to this Standard, you may send the following information to the International Association of Plumbing and Mechanical Officials, Attention Standards Department, at standards@IAPMOstandards.org or, alternatively, at 5001 East Philadelphia Street, Ontario, California, 91761, and include "Proposal for change" in the subject line:*
 - (a) *standard designation (number);*
 - (b) *relevant section, table, or figure number, as applicable;*
 - (c) *wording of the proposed change, tracking the changes between the original and the proposed wording; and*
 - (d) *rationale for the change.*
- (6) *Requests for interpretation should be clear and unambiguous. To submit a request for interpretation of this Standard, you may send the following information to the International Association of Plumbing and Mechanical Officials, Attention Standards Department, at standards@IAPMOstandards.org or, alternatively, at 5001 East Philadelphia Street, Ontario, California, 91761, and include "Request for interpretation" in the subject line:*
 - (a) *the edition of the standard for which the interpretation is being requested;*
 - (b) *the definition of the problem, making reference to the specific section and, when appropriate, an illustrative sketch explaining the question;*
 - (c) *an explanation of circumstances surrounding the actual field conditions; and*
 - (d) *the request for interpretation phrased in such a way that a "yes" or "no" answer will address the issue.*
- (7) *Interpretations are processed in accordance with IAPMO's accredited standards development procedures. IAPMO issues written replies to inquiries concerning interpretation of technical aspects of this Standard.*
- (8) *IAPMO accepts responsibility only for those interpretations of this Standard issued in accordance with the accredited IAPMO policies and procedures, which precludes the issuance of interpretations by individuals.*
- (9) *IAPMO does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.*

- (10) Attention is drawn to the possibility that some of the elements of this Standard may be the subject of patent rights. IAPMO is not to be held responsible for identifying any or all such patent rights. Users of this Standard are expressly advised that determination of the validity of any such patent rights is entirely their responsibility.
- (11) IAPMO does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this Standard, and does not undertake to insure anyone utilizing this Standard against liability for infringement of any applicable patents, nor assumes any such liability. Users of this Standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their responsibility.
- (12) Participation by federal or state agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this Standard.

IAPMO Solar Standards Committee

L. Nelson	IAPMO Ontario, California, USA	<i>Chair (Non-Voting)</i>
A. Chrisman	SunEarth Inc. Fontana, California, USA	
J. Critchfield	United States Environmental Protection Agency Washington, DC, USA	
M. Dunlop	Florida Solar Energy Center Cocoa, Florida, USA	
R. Gillespie	Caleffi North America Milwaukee, Wisconsin, USA	
W. Guiney	Artic Solar, Inc. Middleburg, Florida, USA	
E. Murray	Aztec Solar Sacramento, California, USA	
P. Outram	Lite Energy Engineering Alta Loma, California, USA	
P. Redgate	Ameco Solar Inc. Paramount, California, USA	
V. Woodruff	Insource Renewables Pittsfield, Maine, USA	
A.I. Murra	IAPMO Ontario, California, USA	<i>Secretary</i>
K.C. Thompson	IAPMO Ontario, California, USA	<i>Staff Liaison</i>

IAPMO S1001 Technical Subcommittee

L. Nelson	IAPMO Ontario, California, USA	<i>Chair</i>
J. Alger	Alternate Energy Technologies, LLC Green Cove Springs, Florida, USA	
A. Chrisman	SunEarth Inc. Fontana, California, USA	
M. Dunlop	Florida Solar Energy Center Cocoa, Florida, USA	
R. Gillespie	Caleffi North America Milwaukee, Wisconsin, USA	
B. Gravely	Holocene Technologies Raleigh, North Carolina, USA	
A. Mauchlen	Enerworks Inc. Woodstock Ontario, Canada	
S. Morner	Sustainable Engineering Group LLC Madison, Wisconsin, USA	
E. Murray	Aztec Solar Sacramento, California, USA	
P. Outram	Lite Energy Engineering Alta Loma, California, USA	
D. Sizelove	Aquatherm Industries, Inc. Lakewood, New Jersey, USA	
J. Thornton	Thermal Energy System Specialists Madison, Wisconsin, USA	
C. DeJong	ASTM International West Conshohocken, Pennsylvania, USA	<i>Liaison</i>
A.I. Murra	IAPMO Ontario, California, USA	<i>Staff Liaison</i>
K.C. Thompson	IAPMO Ontario, California, USA	<i>Secretary</i>

IAPMO/ANSI S1001.4-2015

Energy Production Rating of Solar Heating Collectors

1 Scope

1.1

This Standard specifies the procedures used to determine the energy production rating of solar heating collectors.

Notes:

- 1) *The purpose of energy production ratings is to*
 - (a) *provide a basis for comparing the relative thermal performance of various solar collector technologies when evaluated under the same rating conditions; and*
 - (b) *help users of solar heating collectors make an informed decision regarding the choice of technology with respect to thermal performance.*
- 2) *In this Standard, "solar heating collectors" are referred to as "collectors".*

1.2

The procedures in this Standard are a set of calculations used to evaluate the daily energy production of a collector under a specific set of climatic conditions using existing test results.

1.3

The calculated energy production rating values are valid when the collectors are operating with the fluid type and flow rate used during thermal performance testing.

1.4

The procedures in this Standard are applicable to the following types of collectors:

- (a) glazed tubular collectors;
- (b) glazed flat-plate collectors; and
- (c) unglazed flat-plate collectors.

1.5

The procedures in this Standard can also be used to calculate the energy production rating for other types of collectors tested in accordance with Section 4.1, including

- (a) concentrating collectors (i.e., heat generation only);
- (b) transpired air collectors;
- (c) glazed integral collector storage (ICS);
- (d) unglazed ICS; and
- (e) thermosyphon collectors.

1.6

This Standard does not cover

- (a) collector performance metrics other than thermal output (e.g., fitness for purpose, quality of construction, durability, and safety);