INTERNATIONAL STANDARD

ISO 9459-3

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Solar heating — Domestic water heating systems —

Part 3:
Performance test for solar plus supplementary systems

Chauffage solaire — Systèmes de chauffage de l'eau sanitaire —

Partie 3: Essai de performance pour systèmes solaires comportant des systèmes d'appoint

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 9459-3 was prepared by Technical Committee ISO/TC 180, *Solar energy*, Subcommittee SC 4, *Systems — Thermal performance, reliability and durability*.

ISO 9459 consists of the following parts, under the general title *Solar heating — Domestic water heating*:

— *Part 1: Performance rating procedure using indoor test methods*

— *Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems*

— *Part 3: Performance test for solar plus supplementary systems*

— *Part 4: System performance characterization by means of component tests and computer simulation*

— *Part 5: System performance characterization by means of whole-system tests and computer simulation*

Annexes A and B form an integral part of this part of ISO 9459. Annexes C to E are for information only.

Introduction

International Standard ISO 9459 has been developed to help facilitate the international comparison of solar domestic water heating systems. Because a generalized performance model which is applicable to all systems has not yet been developed, it has not been possible to obtain an international consensus for one test method and one standard set of test conditions. It has therefore been decided to promulgate the currently available simple methods while work continues to finalize the more broadly applicable procedures. The advantage of this approach is that each part can proceed on its own.

ISO 9459 is divided into five parts within three broad categories, as described below.

Rating test

ISO 9459-1 involves testing for periods of one day for a standardized set of reference conditions. The results, therefore, allow systems to be compared under identical solar, ambient and load conditions.

Black box correlation procedure

ISO 9459-2 is applicable to solar-only systems and solar-preheat systems. The performance test for solar-only systems is a "black box" procedure which produces a family of "input-output" characteristics for a system. The test results may be used directly with daily mean values of local solar irradiation, ambient air temperature and cold water temperature data to predict annual system performance.

ISO 9459-3 applies to solar plus supplementary systems. The performance test is a "black box" system test procedure which produces coefficients in a correlation equation that can be used with daily mean values of local solar irradiation, ambient air temperature and cold water temperature data to predict annual system performance. The test is limited to predicting annual performance for one load pattern.

Testing and computer simulation

ISO 9459-4, a procedure for characterizing annual system performance, uses measured component characteristics in the computer simulation program "TRNSYS". Procedures for characterizing the performance of system components other than collectors are also presented in this part of ISO 9459. Procedures for characterizing the performance of collectors are given in ISO 9806-1, ISO 9806-2 and ISO 9806-3.

ISO 9459-5 presents a procedure for dynamic testing of complete systems to determine system parameters for use in a computer model. This model may be used with hourly values of local solar irradiation, ambient air temperature and cold water temperature data to predict annual system performance.

The procedures defined in ISO 9459-2, ISO 9459-3, ISO 9459-4 and ISO 9459-5 for predicting yearly performance allow the output of a system to be determined for a range of climatic conditions.

The results of tests performed in accordance with ISO 9459-1 provide a rating for a standard day.

The results of tests performed in accordance with ISO 9459-2 permit performance predictions for a range of system loads and operating conditions, but only for an evening draw-off.

The results of tests performed in accordance with ISO 9459-4 or 9459-5 are directly comparable. These procedures permit performance predictions for a range of system loads and operating conditions.

System reliability and safety will be dealt with in ISO 11924.

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Solar heating — Domestic water heating systems —

Part 3:
Performance test for solar plus supplementary systems

1 Scope

This part of ISO 9459 establishes test procedures for characterizing the performance of solar domestic water heating systems with in-tank auxiliary boosting, and for predicting annual performance in any given climatic conditions. A "black box" approach is adopted which involves no assumptions about the type of system under test, and the procedures are therefore suitable for testing all types of systems, including forced circulation, thermosiphon, freon-charged and integrated collector-storage systems.

This part of ISO 9459 applies to solar domestic water heating systems designed to heat potable water to be supplied solely for domestic water usage and is not intended to be applied to other systems. It is not generally applicable to concentrating systems.

The solar-plus-auxiliary test procedures in clause 7 are carried out in typical operational conditions, the only restriction on the nature of systems that can be tested is that there shall be no long-term energy storage, and the storage capacity in the solar preheat section of the tank shall be less than twice the specified daily total load (7.2.4).

The test procedures in this part of ISO 9459 do not require the solar water heating system to be subjected to freezing conditions. Consequently, the energy consumed or lost by a system while operating in the freeze-protection mode will not be determined.

This part of ISO 9459 is limited to systems in which the solar collector and the storage tank are exposed to the same ambient conditions, and to systems in which the auxiliary energy (thermal or electric) can be monitored separately from the solar energy input.

It is not intended to be used for testing the individual components of the system, nor is it intended to abridge any safety or health requirements.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 9459. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9459 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 9459-1:1993, *Solar heating — Domestic water heating systems — Part 1: Performance rating procedure using indoor test methods.*

ISO 9059:1996, *Solar energy — Calibration of field pyrheliometers by comparison to a reference pyrheliometer.*

ISO 9060:1990, *Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation.*

ISO 9846:1993, *Solar energy — Calibration of pyranometer using pyrheliometer.*

ISO 9806-1:1994, *Test methods for solar collectors — Part 1: Thermal performance of glazed liquid heating collectors including pressure drop.*

ISO 9845-1:1992, *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5.*

ISO 9488:—[1], *Solar energy — Vocabulary.*

Guide to Meteorological Instruments and Methods of Observation[2], 5th edition, WMO-8, World Meteorological Organization, Geneva, 1983, Chapter 9.

3 Definitions

For the purposes of this part of ISO 9459, the definitions given in ISO 9488 apply.

4 Symbols

The symbols given in ISO 9459-1 and the following symbols apply.

a_1, a_2, a_3	coefficients used in performance characteristic equations
f	fraction of hot water load supplied by solar energy = $(Q_L - Q_{AUX})/Q_L$, dimensionless
fr	fractional energy savings relative to a conventional water heater = $(Q_{AUX,NS} - Q_{AUX,S})/Q_{AUX,NS}$, dimensionless
H	daily solar irradiation on the collector aperture plane, in megajoules per square metre
$Q_{AUX,S}$	auxiliary energy used by solar water heater, in megajoules per day
$Q_{AUX,NS}$	auxiliary energy used by conventional water heater = load + Q_{LOS}, in megajoules per day
Q_B	gas burner capacity (primary energy input), in watts
Q_F	fossil fuel primary energy consumption, in megajoules per day
Q_L	useful energy extracted from the system under load cycle operation, in megajoules per day
Q_M	heat loss and pilot maintenance rate for a gas storage water heater, in watts
t_a	ambient or surrounding air temperature, in degrees Celsius
t_{main}	cold water supply temperature, in degrees Celsius
t_d	mean water temperature of load drawn off, in degrees Celsius
t_e	effective heat sink temperature = $t_a + (t_a - t_{main})/2$, in degrees Celsius
u	surrounding air speed, in metres per second
UA	product of heat loss coefficient x area for a conventional water heater tank, in watts per kelvin

1) To be published.

2) The World Radiometric Reference Scale, known as the WRR Scale, is related to the International Pyrheliometric Scale 1956 (IPS 1956) by the identity WRR = 1.022 (IPS 1956).

V_c volume of daily hot water consumption, in litres

ρ_w density of water, in kilograms per cubic metre

η_f efficiency of fossil fuel auxiliary source

Subscript

NS no solar energy input

5 System classifications

Solar domestic hot water systems are classified by seven attributes, each divided into two or three categories. The categories of each attribute are defined as shown in table 1.

Table 1 — Classification of solar domestic hot water systems

Attribute	Category		
	a	b	c
1	Solar only	Solar preheat	Solar plus supplementary
2	Direct	Indirect	
3	Open	Vented	Closed
4	Filled	Drainback	Draindown
5	Thermosiphon	Forced	
6	Circulating	Series-connected	
7	Remote storage	Close-coupled collector storage	Integral collector storage

5.1 Attribute 1

a) **Solar only** — system designed to provide solar heated domestic water without use of supplementary energy other than that required for fluid transport and control purposes.

b) **Solar preheat** — system not incorporating any form of supplementary heating and installed to preheat cold water prior to its entry into any other type of household water heater.

c) **Solar plus supplementary** — system which utilizes both solar and auxiliary energy sources in an integrated way and is able to provide a specified hot water service independently of solar energy availability.

5.2 Attribute 2

a) **Direct** — system in which the heated water that will ultimately be consumed passes through the collector.

b) **Indirect** (heat exchange) — system in which a heat transfer fluid other than the heated water ultimately consumed passes through the collector.

5.3 Attribute 3

a) **Open** — system in which the heat transfer fluid is in extensive contact with the atmosphere.

NOTE — In the USA the term "open system" encompasses both open and vented systems as herein defined.

b) **Vented** — system in which contact between the heat transfer fluid and the atmosphere is restricted either to the free surface of a feed and expansion cistern or to an open vent pipe only.

c) **Closed** (sealed or unvented) — system in which the heat transfer fluid is completely sealed from the atmosphere.

5.4 Attribute 4

a) **Filled** — system in which the collector remains filled with the heat transfer fluid.

b) **Drainback** — system in which, as part of the normal working cycle, the heat transfer fluid is drained from the collector into a storage vessel for subsequent reuse.

c) **Draindown** — system in which the heat transfer fluid can be drained from the collector and run to waste.

5.5 Attribute 5

a) **Thermosiphon** — system which utilizes only density changes of the heat transfer fluid to achieve circulation between collector and storage.

b) **Forced** — system in which heat transfer fluid is forced through the collector either by mechanical means or by externally generated pressure.

5.6 Attribute 6

a) **Circulating** — system in which heat transfer fluid circulates between the collector and a storage vessel or heat exchanger during operating periods.

b) **Series-connected** — system in which the water to be heated passes directly from a supply point through the collector to a storage vessel or to a point of use.

5.7 Attribute 7

a) **Remote storage** — system in which the storage vessel is separate from the collector and is located at some distance from it.

b) **Close-coupled collector storage** — system in which storage vessel abuts the collector, and is mounted on a common support frame.

c) **Integral collector storage** — system in which the functions of collection and storage of solar energy are performed within the same device.

6 Requirements

6.1 System requirements

6.1.1 System type

Before applying the test procedure to a system with an auxiliary heater the following must be considered.

6.1.1.1 Systems with separate auxiliary heating

The solar performance of systems which have the auxiliary heater separated from the solar-heated storage tank will not be influenced by the auxiliary heater. However the maximum load size will be influenced by the presence of the auxiliary heater. Therefore these types of systems shall be tested with both the solar preheater and separate auxiliary heater considered as part of the same system.

6.1.1.2 Systems with manual auxiliary heater control

Systems which have the auxiliary heater integrated in the solar-heated storage tank, and in which the auxiliary heater is provided only for irregular intermittent operation (manually operated switch) shall not be tested using the procedure given in this part of ISO 9459. In order to achieve reproducible test results, such systems should be tested with the auxiliary heater switched off using the test procedure given in ISO 9459-2.

6.1.1.3 Systems with integrated auxiliary boosting

Systems which have a continuous or nighttime-use auxiliary heater integrated in the solar-heated storage tank shall be assessed using the test procedure specified in this part of ISO 9459.

6.1.2 Test system installation

Tests shall be performed with the system components installed in accordance with manufacturer's installation instructions. Any controller included in the system shall be set in accordance with the manufacturer's instructions. In the absence of specific instructions from the manufacturer, the system shall be installed as follows.

The system shall be mounted in a manner such as to ensure safety to personnel. Due consideration shall be paid to the likelihood of glass failure and the leakage of hot liquids. Mountings shall be able to withstand the effects of wind gusts.

Whenever possible the system shall be mounted on a structure provided by the manufacturer. If no mounting is provided then, unless otherwise specified (for example when the system is part of an integrated roof array), an open mounting system shall be used. The system mounting shall in no way obstruct the aperture of the collectors and the mounting structure shall not significantly affect the back or side insulation of the collectors or storage vessel.

Except for systems where the storage vessel is fixed to the collectors in some way (for example integral collector-storage systems and close-coupled thermosiphon systems) the store shall be installed in the lowest position allowed in the manufacturer's installation instructions, or with the bottom of the store located 5 m below the bottom of the collector if no specification is supplied by the manufacturer.

For systems where the hot water store is separate from the collectors, the total length of the connecting pipes between the collector and store shall be 15 m (i.e. 2 × 7,5 m). The diameter and insulation of the pipes shall be in accordance with the manufacturer's installation instructions.

6.1.3 Collector installation

Systems shall be tested at tilt angles recommended by manufacturers or specified for actual installations, provided that the angle used is specified with the test results. The specified tilt angle shall remain constant throughout the test. The collector shall be mounted in a fixed position facing the equator to within ± 10°.

The collector shall be mounted in a fixed position facing the equator to within ± 10°.

The collector shall be located such that a shadow will not be cast onto the collector at any time during the test period.

The collector shall be located where there will be no significant solar radiation reflected onto it from surrounding buildings or surfaces during the tests, and where there will be no significant obstructions in the field of view.

The temperature of surfaces adjacent to the system shall be as close as possible to that of the ambient air. For example, the field of view of the system shall not include chimneys, cooling towers or hot exhausts.

6.1.4 Liquid flow system

A test loop of the type shown in figure 1 shall be used. The piping used in the loop shall be suitable for operation at temperatures up to 95 °C. Pipe lengths should be kept short. In particular, the piping between the outlet of the cold water temperature regulator and the inlet to the storage vessel shall be minimized, to reduce the effects of the environment on the inlet temperature of the water. This section of pipe shall be insulated to ensure a rate of heat loss of less than 0,2 W/K and be protected by a reflective weatherproof coating.

Pipework between the temperature-sensing points and the store (inlet and outlet) shall be protected with insulation and reflective weatherproof covers extending beyond the positions of the temperature sensors, such that the calculated temperature gain or loss along either pipe does not exceed 0,01 K under test conditions. Flow mixing devices such as pipe bends are required immediately upstream of temperature sensors.

The flow control device and flow meter shall be installed on the cold water inlet pipe, so that readings are not affected by temperature changes. The flowrate during the draw-off of hot water from the store is important, as it may influence the draw-off temperature profile. The flow controller shall maintain a constant flowrate through the storage vessel of (600 ± 50) l/h.

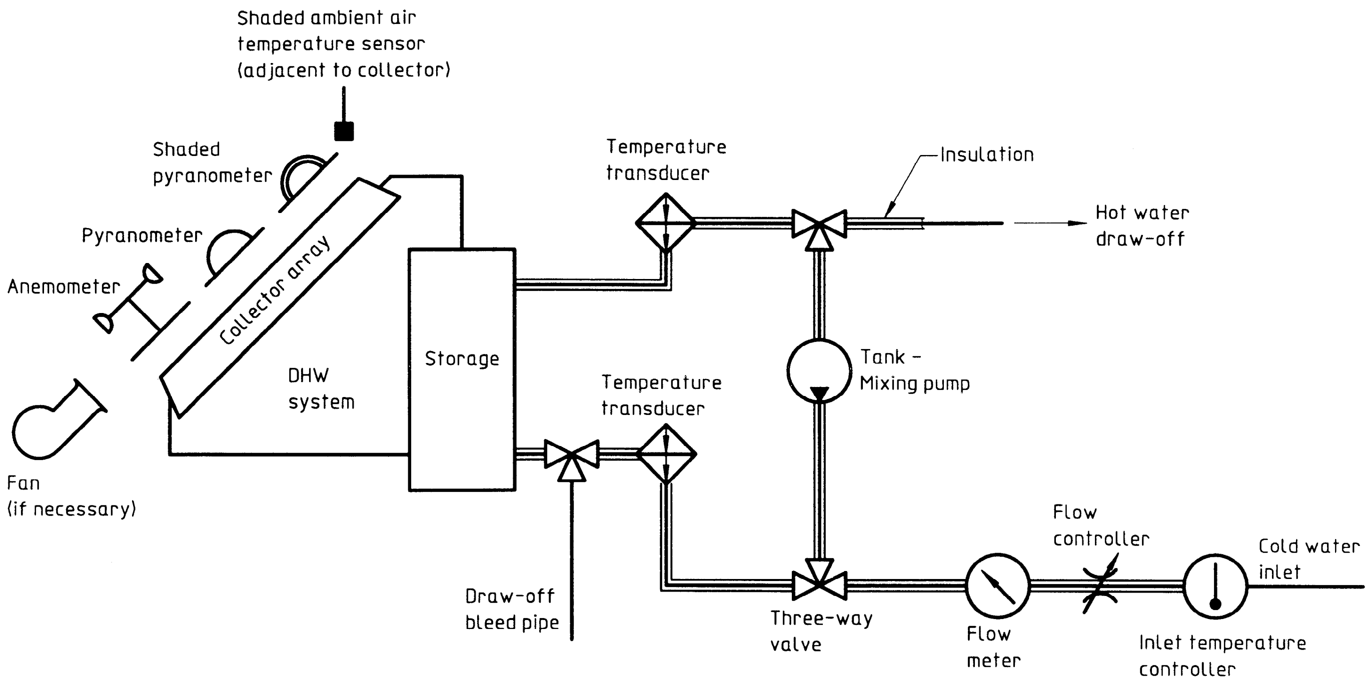

Figure 1 — Schematic representation of experimental apparatus for system performance test

When testing systems with pumped circulation, a flow meter shall be installed to measure the fluid flowrate in the collector loop to an accuracy of ± 5 %.

NOTE — This measurement is excluded from the requirements of 6.2.3 which require flow measurements to have an accuracy of ± 1 %.

The heat transfer fluid used in the system during testing shall be the fluid recommended by the manufacturer. When testing forced-circulation systems, the fluid flowrate recommended by the manufacturer shall be used. If the solar collector loop is designed to be used with non-freezing fluids, the test procedures in this standard shall be carried out with these fluids, according to the manufacturer's requirements.

6.2 Measurement requirements

6.2.1 Solar radiation

Solar radiation measurement shall be carried out in accordance with ISO 9060 and WMO No. 8.

A pyranometer shall be used to measure the solar radiation on the collector aperture plane. The pyranometer shall be a first class (or better) pyranometer as specified in ISO 9060. The recommended practice described in ISO/TR 9901 should be observed.

The pyranometer shall be calibrated using a standard pyrheliometer in accordance with ISO 9846 and ISO 9059. Any change in the responsivity of more than ± 1% over a year period shall warrant the use of more frequent calibration or replacement of the instrument if the instability is permanent. If an instrument is damaged in any significant manner, it shall be recalibrated to check the stability of the calibration factor and the time constant. In case of replacement of one of the domes, the cosine response should also be checked.

6.2.2 Temperature

6.2.2.1 Accuracy, precision and response time

The accuracy and precision of the instruments including their associated readout devices shall be within the limits given in table 2. The response time shall be less than 5 s.