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# Efficiency test of solar collectors: uncertainty in the estimation of regression parameters and sensitivity analysis

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## Abstract

The results obtained from efficiency tests conducted on a flat plate solar collector, according to the ISO 9806/1 test procedure, have been used to determine the uncertainty in the curve fitting parameters. The said standard, though requiring certain levels of accuracy in the measuring process, does not provide any method to determine the uncertainty of the efficiency curve parameters. The methodology used in the present paper (not provided by the ISO standard) allows solving the above mentioned problem and evaluating not only the parameters and their uncertainties but also the reliability of the test procedure and its goodness toward fitness. In order to evaluate the effects of measurement errors on the values of the uncertainty in estimated parameters, a sensitivity analysis has also been conducted. Strong dependence of some uncertainties, involving a larger accuracy level in the estimation of the measured parameters, is a clear indication of the present investigations. © 2002 Elsevier Science Ltd. All rights reserved.

*Keywords:* Collector efficiency test; Chi-square fitting; Uncertainty in estimated parameters; Sensitivity analysis

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## 1. Introduction

ISO standards are mainly used for determination of the collector efficiency by means of a least squares fit performed on the measured data. It is, however, to be noted that to use such standard, it is essential to have a certain level of accuracy, especially for the sensors and instrumentation, but the fact remains that no prescribed methodology is available to determine the uncertainty of the efficiency curve parameters.

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### Nomenclature

$A$	collector aperture ( $\text{m}^2$ )
$T_{\text{in}}$	inlet temperature ( $^{\circ}\text{C}$ )
$T_{\text{out}}$	outlet temperature ( $^{\circ}\text{C}$ )
$\Delta T$	temperature difference ( $^{\circ}\text{C}$ ) $\Delta T = T_{\text{out}} - T_{\text{in}}$
$\Gamma$	mass flow rate ( $\text{kg s}^{-1}$ )
$G$	global solar irradiance ( $\text{W m}^{-2}$ )
$T_{\text{a}}$	ambient temperature ( $^{\circ}\text{C}$ )
$T_{\text{m}}$	mean temperature ( $^{\circ}\text{C}$ ), equal to $(T_{\text{in}} + T_{\text{out}})/2$
$T^*$	reduced temperature ( $\text{m}^2 \text{W}^{-1} \text{K}$ ), equal to $(T_{\text{m}} - T_{\text{a}})/G$
$\sigma_{\text{A},X}$	Type A standard uncertainty
$u_{\text{B}}$	Type B standard uncertainty

In order to solve the above mentioned problem, an attempt has been made to deal with the problem using both the results available in the literature [1,2] and experimental data collected in our laboratory. A detailed sensitivity analysis has been conducted to determine the influence of the uncertainties in the measured parameters on the uncertainty level that can be assigned to coefficients of the efficiency curve.

The present work has been done by a group of researchers from the Solar Collector and Overall System Test Laboratory at the ENEA (Agency for New Technology, Energy and Environment) Research Centre, Trisaia, in Southern Italy. The laboratory performs efficiency tests both on glazed and unglazed solar collectors, according to ISO standards 9806/1 and 3. Systems performance tests are conducted using ISO standard 9459/2 [3–5]. The experimental data collected over a period of nearly two years has been used. Over this period, about 30 collectors, made in Italy and/or abroad, have been tested. The sensors, instrumentation and control system used permits an accuracy level much higher than the one requested by the ISO standards.

At present, though the test facilities are available to work with collectors in a fixed position (facing the equator) in a semi-automatic way, steps have already been taken to make the system fully automatic while working with sun following solar collectors.

The sensors and instrumentation employed, along with their accuracy, a brief resume of uncertainty theory and curve fitting and, finally, a sensitivity analysis performed and the results obtained, are discussed in the present paper.

## 2. Sensors and instrumentation used in the laboratory

A brief description of the solar collector test facilities, accuracy of the sensors and instrumentation employed and their comparison with recommended ISO standard values is presented in this section.

The entire necessary infrastructure for implementation of solar collector efficiency tests, as per ISO standard, is available in the laboratory. The solar collector test facilities, a closed loop with

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