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Experimental study of a novel testing platform for the thermal performance of solar domestic water heating systems

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Abstract

Solar domestic water heating systems (SDWHS) are widely used in China, with an installed collector area of more than 330 million square meters by the end of 2014. Many relevant products keep on launching and upgrading in the market. To regulate the market, the performance of products, especially new products should be evaluated by the quality supervision agency. However, all the existing national standards of thermal performance tests for SDWHS require that the daily solar irradiation gain should be more than 16 MJ/m^2. Thus, only a small part of days in a year meet this criteria, which constrained quality supervision agencies to regulate the solar heater market. A new approach of testing platform for the thermal performance of SDWHS is also presented in this manuscript. The testing platform consists of a sun-tracking flat-mirror reflector which not only directs the sunlight to the collector to increase the daily solar irradiation gain but also produces a light spot of 2×2 m^2. A large number of experiments have been conducted to measure the performance of the testing platform. Results show that on one hand the platform can increase the daily gain of solar irradiation to 16 MJ/m^2 from 12 MJ/m^2, and on the other hand the light spot has a non-uniformity of less than 3%. Experiments on SDWHS have been performed on the platform as well as on the ground, respectively. It has been found that the relative difference of the daily thermal efficiency measured by the two methods is lower than 3%.

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Keywords: SDWHS (solar domestic water heating systems); Platform testing; Conventional testing; Daily thermal efficency

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1. Introduction

Solar domestic water heating systems (SDWHS) are widely used in China for remarkable energy saving. Usually, SDWHS can save energy as standard coal of 150 -180 kg per square meter per year. By the end of 2014, SDWHS have been installed more than 471 million square meters in the world.

The expected expanding market of SDWHS require that the standardized test method could be implemented easily and quickly. However, the current outdoor thermal performance test methods (ASHRAE Standard 95, 1987[1]; AS 2984, 1987[2]; International Standard ISO 9459, 1997[3]; GB/T 19141-2011[4]; GB/T 18708-2002[5]) can only be conducted in suitable weather conditions. The Solar Simulator has non-neglected drawbacks in form of high investment, huge usage cost, large irradiation non-uniformity and maintenance cost. Moreover, the actual proportion of far-infrared light spectrum of solar simulator is far more than the natural light. Furthermore, the lamp has a short life, a huge power consumption and high operation and maintenance costs. Scientists have already attempted to explore test methods or the performance enhancement with flat reflectors of SDWHS or solar collectors. O. García-Valladares et al. [6] proposed a simple and inexpensive test method for thermal performance test of SDWHS and compared it with standard test methods for SDWHS. D. Rojas et al. [7] comparatively analyzed the EN 12975-2 transient method and the ASHRAE 93 steady-state method. He concluded that only10 experimental data points strictly met the ASHRAE 93 Standard requirements. But there were 375 data points met the required conditions in the EN 12975-2 transient method in the same period due to the less restrictive solar irradiance requirements and shorter period to collect a data point. Additionally, differences in the efficiency curve between the two methods are always below 5%. H.P.Garg and D.S. Hrishikesan [8] presented a flat-plat collector augmented with two reflectors model which facilitates the prediction of the total energy absorbed by the collector at any hour of the day for any latitude for random tilt angles and azimuth angles of the collector and reflectors. D.K.McDaniels et al. [9] concluded that the enhancement in light gathering power for direct solar radiation is about a factor of 1.4~1.7 for a flat-plate collector combination with a reflector system.

From the foregoing discussion, the thermal performance test conditions of SDWHS are always limited to natural irradiation. In this paper, a platform to increase the available testing days by increasing the irradiation is presented. Which maintains a good irradiation uniformity as well as spectral consistency and is designed and studied based on GB/T19141-2011. By the aid of a reflector, the test platform increases solar irradiation on the test surface with the east-west single-axis tracking method. In addition, the reflector can be selected to be used or not according to the weather conditions.

Nomenclature

E_i	The irradiation of test point I (Wm^{-2})
$\bar{E}$	The average irradiation of test points (Wm^{-2})
δ_i	The irradiation deviation of test point I
E_1	solar irradiance on the platform ($MJm^{-2}day^{-1}$)
E_2	solar irradiance on the ground ($MJm^{-2}day^{-1}$)
C	concentration ratio of the platform
A	surface aperture (m^2)
G	total solar energy received by the collector ($Jm^{-2}day^{-1}$)
Q_u	useful energy gain (KJ)
Greek letters	
η	Daily efficiency of SDWHS (%)