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A Component Testing System Simulation (CTSS) method for characterising solar air-conditioner performance

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ABSTRACT

Solar desiccant air-conditioning is an emerging technology that offers the promise of reducing reliance on grid connected electricity for providing comfort air-conditioning. Development of a method of assessing the seasonal energy savings of these devices would enable a fair comparison with alternative devices. This could be used in policy support mechanisms to assist industry growth. Here we describe the application of the Component Testing System Simulation method to predict the energy savings of solar air-conditioners using the same approach as that applied successfully in the Australian solar hot water industry. The CTSS approach is made possible by the development of a new simplified generic model of the desiccant air-conditioner component. The performance of the generic model is evaluated for five different air-conditioner designs. The results suggest that the approach is valid for estimating the annual energy savings. The method will be documented in a provisional Australian Standard to be released in 2013.

Une méthode de simulation système pour l'évaluation des composants (CTSS) pour la caractèrisation de la performance d'un conditionneur d'air solaire

Mots clés : Conditionnement d'air solaire ; Norme, Evaluation ; CTSS (simulation système pour l'évaluation des composants) ; Programmes de soutien pour l'industrie

1. Introduction

Solar space heating and cooling is an emerging technology that offers the promise of reducing greenhouse gas emissions and reducing the reliance on grid connected electricity for the provision of comfort space conditioning. Presently, there are a number of solar air-conditioning technologies that could be readily deployed. These include; i) solar thermal systems with

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Nomenclature

M_c	kg s^{-1}, Evaporator/spray cooling water flow-rate
M_h	kg s^{-1}, Hot water flow-rate
M_s	kg s^{-1}, outlet (supply) air flow rate
P	W, Electrical power consumption
T_s	°C, outlet (supply) air temperature
T_{s_wb}	°C, outlet (supply) air wet bulb temperature
HR_s	kg kg^{-1}, outlet (supply) air humidity ratio
T_a	°C, inlet (ambient) air temperature
T_{a_wb}	°C, Inlet (ambient) air wet bulb temperature
HR_a	kg kg^{-1}, inlet (ambient) air humidity ratio
T_b	°C, building return (indoor) air temperature
T_{b_wb}	°C, Building return (indoor) air wet bulb temperature
HR_b	kg kg^{-1}, building return (indoor) air humidity ratio
T_c	°C, Evaporator/spray cooling water inlet temperature
T_e	°C, Exhaust (to ambient) air temperature
HR_e	kg kg^{-1}, Exhaust (to ambient) air humidity ratio
T_{hi}	°C, Hot water inlet temperature
T_{ho}	°C, Hot water outlet temperature
T_{A_k}	°C, inlet (ambient) air temperature in the kth experimental Test Point
T_{B_k}	°C, building return (indoor) air temperature in the kth experimental Test Point
T_{ref}	°C, constant reference temperature used to normalise the equations
HR_{A_k}	kg kg^{-1}, inlet (ambient) air humidity ratio in the kth experimental Test Point
HR_{B_k}	kg kg^{-1}, building return (indoor) air humidity ratio in the kth experimental Test Point
HR_{ref}	kg kg^{-1}, constant reference humidity ratio used to normalise the equations
w_k	–, weighting factor to the distance from the kth experimental Test Point in the ambient condition space
x_k	–, weighting factor to the distance from the kth experimental Test Point in the indoor condition space
r_o	–, a constant specified in the model

either adsorption, absorption or desiccant cooling, and ii) vapour compression systems with PV panels. While a number of commercial installations are in operation around the world (White et al., 2012) (Kohlenbach and Dennis, 2010), they have made no measurable penetration into the residential air-conditioner market. This is largely due to the capital cost of the solar systems.

Unfortunately, at these early stages in the development of the industry, it is difficult to achieve cost effective volume manufacturing compared with the incumbent fossil fuel powered technology. Successful growth of the industry will require policies that help to address this capital cost disadvantage. Amongst other things, the International Energy Agency SHC Task 48 “Quality Assurance and Support Mechanisms for Solar Cooling” aims to develop rating tools that could be used by policy makers to award performance-based incentives to solar heating and cooling systems (Mugnier and Jakob, 2012). Such tools would ideally provide an evidence-based framework for awarding industry development incentives that reflect the greenhouse gas benefit of using solar technology over the fossil fuel based alternatives.

A number of separate and unconnected rating methodologies exist in the air-conditioning and solar industries. On the one hand, in the air-conditioning industry, standards exist for testing the performance of vapour compression air-conditioners at rated conditions (e.g. ISO5151 (ISO, 2010), AS/NZS 3822 (Standards Australia, 2012)). These have been further adapted to partially reflect annual performance in target climates through the development of seasonal (SEER) ratings (AHRI, 2008). Results from testing to these standards can be used to benchmark the performance of an air-conditioning product against reference performance levels in some form of star rating scheme (see for example (Standards Australia, 2011)).

On the other hand, in the solar industry standards exist for testing the performance of solar collectors (Standards Australia, 2007) at rated conditions. The performance of the collector can then be converted into an annual energy production or saving for a given climate using either the “Bin” method (similar to the seasonal performance rating method for air-conditioners), or using a “Component Testing System Simulation” (CTSS) method (Standards Australia, 2008) (ISO, 2013). An alternative is to test the performance of the complete solar cooling system as a package such as is described in the ASHRAE 174 desiccant air-conditioning test method (ASHRAE, 2009).

At this point, there is no clearly established method for comparing the performance of solar heating and cooling systems with that of a conventional fossil fuel based alternative. This is a significant barrier to the development of the solar heating and cooling industry because, without this methodology, consumers cannot easily compare the benefits of the new technology and policy makers do not have a basis for awarding performance-based industry support incentives.

This paper proposes use of the CTSS approach for rating individual solar heating and cooling products. It reviews the role of technical standards in the development of the solar hot water market in Australia and the successful application of the CTSS method for solar hot water in the existing Australian Renewable Energy Target certificate trading market. The paper then shows how the CTSS method could be extended for use in solar air-conditioning applications and discusses a new technical standard for rating solar air-conditioners. The development of a generic desiccant air-conditioner component model for the CTSS method is described and results are presented comparing the generic model with the exact performance for a number of example desiccant air-conditioner designs.

2. The CTSS method for characterising solar hot water system performance in Australia

2.1. A brief history of the Australian solar hot water industry

It is natural to seek parallels between solar cooling and the development of the solar hot water industry. In Australia, the