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Performance curves of room air conditioners for building energy simulation tools

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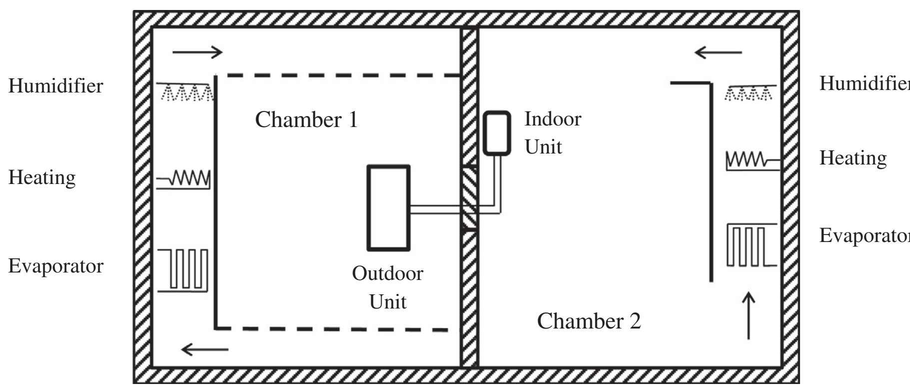
HIGHLIGHTS

- Experimental characteristic curves for two room air conditioners are presented.
- These results can be implemented in building simulation codes.
- The energy consumption under different conditions can numerically determine.
- The labeled higher energy efficiency product not always provides the best result.

GRAPHICAL ABSTRACT



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ABSTRACT

In order to improve the modeling of air conditioners in building simulation tools, the characteristic curves for total cooling capacity, sensible cooling capacity and energy efficiency ratio of two room units were determined. They were obtained by means of standard capacity tests on climatic chambers in a set of environmental conditions described by external dry- and internal wet bulb temperatures. Afterward, the performance of these two units and that of four other units, with and without taking into to account the thermodynamic variations of the surrounding environments on it, were compared using a whole building simulation program for simulating a conditioned space. The comparative analysis showed that the air conditioner with the higher energy efficiency rating not always provides the lowest power consumption in real conditions of use.

1. Introduction

Since 1970's energy consumption is a topic of main concern worldwide and, according to the World Energy Council [1], the global energy demand is expected to double by 2050 and, during the same period, the global greenhouse gas emissions has to be reduced by half to keep a global temperature increase below two degrees Celsius. In order to obtain fast improvements worldwide, labeling and minimum energy efficiency criteria are top-performing options [1].

In Brazil, with the energy crisis that took place in 2001, a national concern about rational use and energy conservation was encouraged by the Law of Energy Efficiency, Law 10295/2001 [2], due to the risks of energy shortages and due to the high cost of implementation of new hydro power plants in the country. In order

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to promote the energy conservation in buildings, the Brazilian Government developed a regulation to classify such buildings by their energy efficiency level.

The labeling process in Brazil is non-mandatory and can be determined either by prescriptive method or by simulation method. The classification of the building is determined considering the relative weighting that counts 30% for the building envelope, 30% for lighting system and 40% for the air conditioning system. Also, there are bonuses that can raise the building overall energy efficiency level. In the prescriptive method, equations and tables are used and, for the case of room air conditioners, the energy efficiency ratio of the equipment can be directly used. The simulation method compares the energy consumption with references buildings. More detailed information on the Brazilian Regulation code can be found in [3–5].

Both prescriptive and simulation methods require the energy efficiency of room air conditioners (RAC) which are obtained worldwide from standards for performance evaluation. In the United States, the national standard is ANSI/AHAM RAC-1 [6], which test procedures and conditions are based on ASHRAE 16-1983 [7]. In Brazil, the national standard regarding the test procedures to be used when determining the characteristics of the air conditioners is NBR 5882 [8] and they are very similar to the ones described on ISO 5151 [9].

In addition, the use of RACs has been progressively increased especially in countries at a newly advanced economic development such as China, India, Russia, Mexico and Brazil [10]. In this way, the energy efficiency of air conditioners is a crucial issue for the social and economical development of those countries, which markets are far away from becoming saturated.

Many simulation programs employ empirical modeling of direct-expansion air conditioners, using only test data and can be simple and accurate. This kind of modeling let users spend much less efforts for predicting air conditioners performance. The models are based on experimental data obtained from tests carried out in calorimeters according to ISO standard [9].

However, performance data from standard procedures available from manufacturers usually refer only to nominal conditions, which may lead to wrong evaluation of energy efficiency of air conditioners and buildings as shown in the present paper.

Literature is strict on performance testing of residential direct-expansion air conditioners [10–12]. Some are related to the application of inverter technologies for performance optimization, variable refrigerant flow and central systems [13–23]. On the other hand, the issue on the fact that a higher energy efficiency rating not always provides lower power consumption in real conditions of use has not been paid enough attention by energy regulators or manufacturers.

Therefore, the main goal of this work is to compare the performance of room air conditioners modeled by characteristic curves and by nominal performance data. At first, the characteristic curves for total cooling capacity, sensible cooling capacity and energy efficiency ratio of two room units were determined based on the dry-bulb and wet-bulb temperatures of external and internal environments, respectively, by means of standard capacity tests on climatic chambers and polynomial regression. Then, those curves have been used to evaluate the thermal comfort and the energy consumption of a conditioned space in simulations performed with the building energy simulation program Domus [13].

2. Experimental facility

2.1. Set-up description

The experimental apparatus, a calibrated calorimeter, was developed to test non-ducted air conditioners up to 3 tons of refrigeration (10,550 W) according to ISO 5151[9]. Basically, it consists of two dynamic climatic chambers, Fig. 1, that are connected to each other by a window where the unit to be tested is mounted. Their function is to simulate indoor and outdoor environments for the air conditioner, while the energy consumption of the unit is measured and its cooling capacity is indirectly determined by measuring the heat and water inputs for balancing the cooling and dehumidifying effects in the indoor-side compartment.

The internal volume of the chamber representing the external environment (chamber 1) is 25.11 m^3 and the operating ranges for the temperature and relativity humidity are: 0 to 60 °C ±0.1 K and 30–70% RH ±5% RH, respectively. Concerning the chamber representing the internal environment (chamber 2), its internal volume is 40.66 m^3 and the operating ranges for temperature and relativity humidity are: 25 to 70 °C ± 0.1 K and 30–99% RH ±1% RH, respectively.

2.2. Test protocol

The experiments to obtain the characteristic curves for room air conditioners were based on the protocol of refrigeration capacity tests given by Brazilian Standard NBR5882 [8].

Since the performance of air conditioners is mainly influenced by the dry-bulb temperature of outdoor air (DBT_{ext}) and the wet-bulb temperature of indoor air (WBT_{int}), environmental conditions are defined by these two temperatures. Therefore, in this protocol, once the equipment to be tested is installed between the two climatic chambers, the internal and external environmental conditions are settled in the corresponding chambers, this means, the dry-bulb temperature of air in the outdoor-side (chamber 1) is maintained at 35 °C and the wet-bulb temperature of air in the indoor-side (chamber 2) is maintained at 19 °C. Next, the air

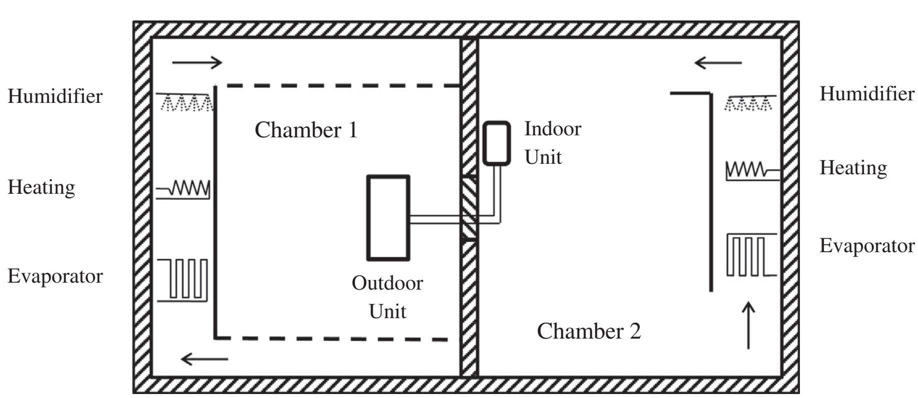

Fig. 1. Sketch of the experimental set-up.