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A virtual supply airflow rate meter for rooftop air-conditioning units

Daihong Yu*, Haorong Li, Mo Yang

Department of Architectural Engineering, University of Nebraska-Lincoln, PKI Room 245 1110 S, 67th Street, Omaha, NE 68182, United States

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A B S T R A C T

A proper amount of supply airflow is critical in all kinds of air-based HVAC systems to maintain desired control effectiveness, energy efficiency and indoor air quality (IAQ). Although knowledge of supply airflow rate (SCFM) is certainly very important, measuring and monitoring SCFM in rooftop air-conditioning units (RTUs) by using the conventional SCFM metering devices are very costly and more than often problematic. This paper proposes a low-cost but accurate virtual SCFM meter to solve the dilemma for RTUs. The SCFM values are indirectly derived from a first-principle model in combination with accurate measurements of low-cost virtual or virtually calibrated temperature sensors. Modeling, uncertainty analysis and experimental evaluation through a wide range of laboratory testing for both cooling- and heating-based approaches are performed respectively in the development. The study reveals that the heating-based method surpasses the other in terms of its simplicity, accuracy (uncertainty is ±6.9% vs ±13.8%) and reliability and is chosen to be the virtual SCFM meter in RTUs. This cost-effective application is promising with a number of merits, such as easy to implement, economical for use, and generic in RTUs with the same constructed gas furnaces. For applications, it could be applied as a permanently installed monitoring tool to indicate the SCFM and/or to automatically detect and diagnose improper quantity of SCFM for RTUs.

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1. Introduction

RTUs are widely used for air-conditioning retail, residential and industrial premises, covering from small to medium sizes of spaces. The U.S. Department of Energy estimates that RTUs including unitary air-conditioning equipments account for about 1.66 quads of total energy consumption for commercial buildings in the United States [1]. Knowledge of SCFM through RTUs is certainly of great importance for a number of reasons. For instance, low SCFM directly impairs temperature distribution and causes poor IAQ. ASHRAE standard 62.1-2007 [2] specifies ventilation and circulation airflow rate based on the occupancy and floor area. In some cases, low SCFM across the RTUs makes the heating equipment to run on the high temperature limit, leading to intensive heating cycling and energy losses.

In the last two decades, a number of studies have focused on finding good solutions for measuring SCFM [3–10]. In terms of physical airflow measuring and monitoring devices, the most popular techniques are based on air dynamic pressure measurements by using a pitot traverse or on air velocity by vane anemometer. However, in general

- *A physical airflow monitoring meter (PAFM) is fragile*

The main disadvantage of PAFM is its flimsy reliability. Periodical calibration is required but rarely followed in real applications. Credibility of measurements would be compromised dramatically after long-term use in adverse duct work surroundings.

- *Implementing and maintaining a PAFM are expensive*

PAFMs are costly in the regards of procurement and installation, ranging from hundreds to thousands dollars. Much more expenses emerge along for maintenance, repair or rebuild, due to the hostile operating environment.

- *Additional pressure loss is incurred*

In order to get accurate measurement, a high air velocity across the instrument is desired for a spread of different airflow rate. To achieve this, a piece of duct work is throttled and it causes additional pressure loss to the fan.

Besides, installing PAFMs in RTUs is even more unrealistic,

- *It is hard to install a PAFM in RTUs.*

RTUs usually have compact structure and duct work. The originally efficient configuration leaves barely any space for a physical

* Corresponding author. Tel.: +1 402 554 2074.
E-mail addresses: dyu@mail.unomaha.edu, daisy.yu926@gmail.com (D. Yu).

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