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Simplifying manufacturers' data in unitary HVAC equipment through a DX cooling coil modeling

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ABSTRACT

This paper studies the current practice of manufacturers' data in unitary HVAC equipment in terms of data structure, simplification, and approximation. Both an improved DX cooling coil modeling in split systems and a self-validation validation by manufacturers' data are used in this study. It shows that the current approximations of dependent variables with their independent variables in manufacturers' data cause an unacceptable level of error, while all dependent variable estimation functions have valid partial derivatives with respect to outside air temperature (*OAT*). Therefore, a generic equation about the total cooling capacity difference between the base *OAT* (35 °C) and any other *OAT* is developed to accurately simplify a manufacturer's data, and accordingly a simplified table of this manufacturer's data is also presented here. However, the non-additivity of sensible heat ratio (*SHR*) requires another method to accurately simplify *SHR* with its independent variables. These accurate simplifications and approximations allow manufacturers to post less performance data, facilitate calculations for manufacturer's data-based models, and validate data from field or laboratory experiments.

1. Introduction

Manufacturers' data play an essential role in equipment design, selection, operation, maintenance, modeling, and analysis. Manufacturers' data are not only freely and widely available, but also commonly used as the performance reference for comparison of one system with another; therefore, they are used to address the problem of scarce or expensive laboratory test validation data.

However, there is no industry standard methodology to define product specifications for some HVAC equipment, e.g., split systems. Without such a standard, manufacturers have the flexibility to present performance data of their products using different assumptions and data structures. As shown below (Comparison between Unitary Rooftop Units and Split Systems), some manufacturers neglect (or approximate using simple equations) the airflow rate $\dot{V}$ through the evaporator, or the drybulb and wetbulb temperature (ET_{db} and ET_{wb}) of air entering the evaporator for split systems. These differences cause difficulty in regards to performance comparison among different manufacturers' HVAC equipment due to the lack of a comparison reference. They may also portray a technically inferior product to be technically superior, leading to erroneous conclusions in product selection, and even convey that any input variable can be negligible in a specific manufacturer's product. However, the neglect or approximations in terms of an input variable can lead to unacceptable errors during the implementation of a generic rating-data-based (GRDB) DX coil modeling developed by Yang and Li [1]. Therefore, it is very important to study a standard methodology about posting manufacturers' performance data, so that engineering information is expressed by the simple, clear, and exact data, without the superfluous or missing data.

Based on the publicly free manufacturer's data, the GRDB DX coil modeling was developed and validated through packaged rooftop units, and mainly implemented in commercial buildings. Thus, it is necessary to extend the GRDB method to split systems commonly used in residential buildings, and the difference of split systems from rooftop units will determine the performance of GRDB in such systems. A unitary air conditioner or heat pump having more than one factory-made assembly (e.g., indoor and outdoor units) is commonly called a split system [2], while indoor and outdoor units are often put together in one factory-made assembly in packaged

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Nomenclature

Q_T	total cooling capacity (kw, kBtuh)
Q_{sens}, Q_s	sensible cooling capacity (kw, kBtuh)
SHR	sensible heat ratio
$\dot{V}$	volumetric flow rate of air entering evaporator (m^3/s, ft^3/min)
OAT	outside air temperature (°C, °F)
ET	temperature of air entering evaporator (°C, °F)
$RErr\_Q_S$	relative error of sensible cooling capacity between model calculation and real value
Rel_{SHR_i}	relative error of SHR between ith iteration calculation and real value ($i \geq 0$)
$AbS(\cdot)$	the absolute value
$E(\cdot)$	the mean equation or expectation
$E(Y\|X)$	the mean equation or expectation of Y under the X
Ω	the real domain for variables

Subscripts and superscripts

rated	rated condition
wb	wet bulb
db	dry bulb
0	critical point
i	*i*th iteration calculation
ˆ	the estimated
′	the derivative
+	by the increasing direction of an independent variable, i.e., the maximum of independent variable as validation part
−	by the decreasing direction of an independent variable, i.e., the minimum of independent variable as validation part
v	validation part

rooftop units. This structural difference does not make split systems' physical principles different from those of packaged rooftop units, and the performance of GRDB modeling in split systems will be determined by the availability and accuracy of manufacturers' data.

Unfortunately, manufacturers' data are neither available nor accurate in split systems in many cases. On the one hand, there are various matches of indoor coils and outdoor condensers in the same series of machines, and a manufacturer posts the detailed performance data for one typical match but only with inaccurate coefficients for other matches. On the other hand, the real field machine may not be the same one with its performance data posted in the manual due to field design and installation, e.g., the fence, overhangs or bushes outside the outdoor units, the refrigerant charge, the installation location, and the interconnecting tubing work. Although some simple approximation functions are provided for the situations other than that of the posted ratings, they often cause unacceptable errors. Furthermore, these data uncertainties and disturbances may make a regression model (such as GRDB models) unreliable.

This paper, therefore, attempts to tackle the shortcomings of the GRDB's implementation in split systems. Firstly, the manufacturers' data are adjusted and/or expanded in order to minimize or avoid the effects from above issues before the implementation of GRDB model. Secondly, the GRDB model is tuned to be more robust against data concerns (uncertainties and disturbances) in split systems after a regression analysis. Thirdly, a self-validation method [3] by manufacturers' data based on the Fundamental Theorem of Calculus was used to tackle the scarcity of laboratory validation data. After the implementation of the improved GRDB modeling in split systems, the self-validation analysis shows that partial derivatives of the estimated functions with respect to the independent variable, OAT, always exist. On the other hand, the current practice of approximations regarding the independent variables, such as $\dot{V}$, ET_{db} and ET_{wb}, will bring unacceptable errors. Finally, this paper further analyzes manufacturers' data, suggests a generic approximation equation to accurately simplify these data, and provides evidence to develop a standard methodology about posting manufacturers' data for HVAC equipment.

2. A GRDB DX coil modeling method

The GRDB modeling method is summarized in Eq. (1) and Fig. 1. Eq. (1) shows the outputs' relationship of a cooling system with its inputs for any operating driving input (ET_{db}, ET_{wb}, $\dot{V}$, OAT).

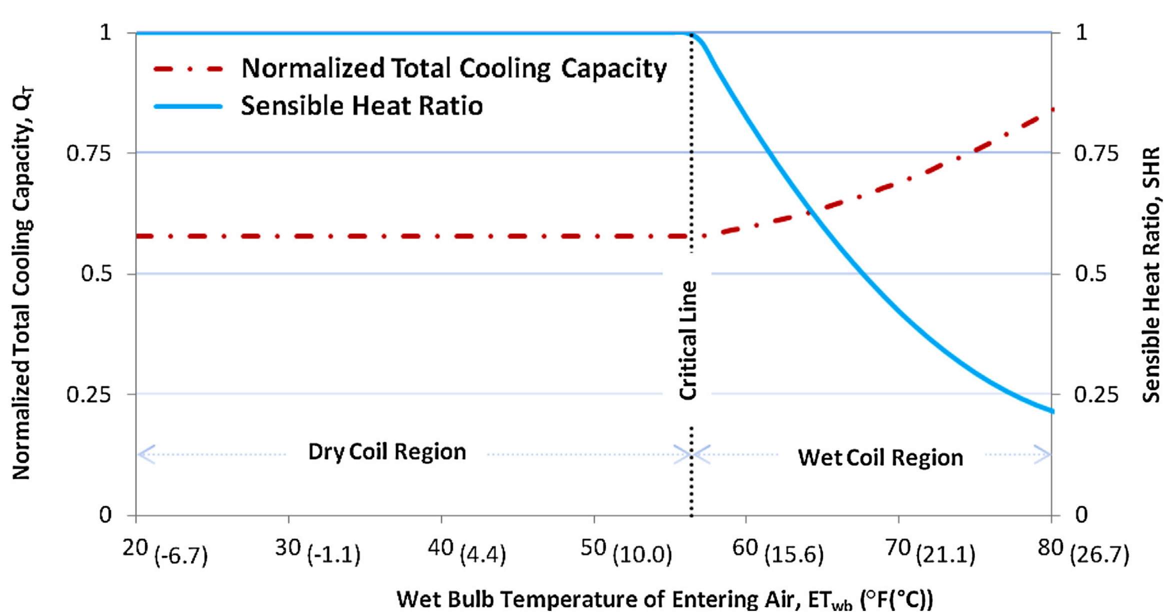

Fig. 1. The relationship of total cooling capacity, Q_T, and sensible heat ratio, SHR, to entering air wet-bulb temperature, ET_{wb}, at a fixed entering air dry-bulb, flow rate, and outdoor air temperature (ET_{db}, $\dot{V}$, OAT).