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# A novel Temperature–Humidity–Time defrosting control method based on a frosting map for air-source heat pumps

*Jiahe Zhu, Yuying Sun, Wei Wang*, Yijing Ge, Lintao Li, Jingdong Liu*

*Department of Building Environment and Facility Engineering, College of Architecture and Civil Engineering, Beijing University of Technology, No.100 Pingleyuan Road, Chaoyang District, Beijing, 100124, China*

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ABSTRACT

To improve the defrosting accuracy and the energy efficiency of the air-source heat pump (ASHP) under frosting and defrosting conditions, a novel Temperature–Humidity–Time (T–H–T) defrosting control method, based on a frosting map for the ASHP unit, is proposed in this paper. A field test was conducted for two heating seasons, to verify the feasibility and applicability of the T–H–T method. The advantages of the T–H–T method, compared to the conventional Temperature–Time (T–T) defrosting control method, are presented. In total, eight cases are shown in this paper. Cases 1 to 4 were chosen to reveal the T–H–T performance under different frosting conditions. It was found that no matter what kind of frosting conditions, defrosting was always initiated in a similar situation: ~90% of the outdoor coil surface was covered by frost; the temperature difference between the compressor suction and discharge increased by ~20%; and the heating capacity decreased by ~30%. These results indicate that the T–H–T method can make an accurate decision under different frosting conditions. Cases 5a, 5b and Cases 6a, 6b were two groups of cases to compare the advantages of the T–H–T method against the conventional T–T method. Cases 5a and 5b were chosen for the non-frosting condition. It was found that the T–T method initiated the defrosting operation 31 times within 24 h. However, none of the defrosting operations was conducted for the T–H–T method. Cases 6a and 6b were chosen to compare these two methods under consecutive and variable frosting conditions. For the T–T method, 63% of the defrosting processes were found to be executed under conditions where defrosting was not necessary. However, for the T–H–T method, all the defrosting controls were found to be accurate and reasonable. These results indicated that the novel T–H–T method is suitable for the defrosting control of the ASHP, and has a more competitive performance than the conventional T–T method.



* *Corresponding author*. Tel./fax: +86 010 67391608 804.
E-mail address: mrwangwei@bjut.edu.cn (W. Wang).

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# Une nouvelle méthode de régulation de la température, de l'humidité et de la durée du dégivrage basée sur une cartographie du givrage pour des pompes à chaleur aérothermiques

*Mots clés :* Pompes à chaleur aérothermiques ; La méthode de régulation du dégivrage ; Carte du givrage ; Vitesse de givrage ; Périodicité du dégivrage ; Essaie sur le terrain

**Nomenclatures**

| | |
|---|---|
| $D_{ar}$ | Defrosting accuracy rate (%) |
| $k$ | Constant |
| $M_{dfw}$ | Defrosting water mass (g) |
| Q | Heating capacity (kW) |
| RH | Ambient relative humidity (%) |
| $t_{def}$ | Defrosting interval (min) |
| $t_{sdef}$ | Standard defrosting interval (min) |
| $t_{tot}$ | Total operation time (min) |
| $T_a$ | Ambient temperature (°C) |
| $T_{dis}$ | Discharge temperature (°C) |
| $T_{suc}$ | Suction temperature (°C) |
| $T_w$ | Outdoor coil surface temperature (°C) |
| P | Input electrical power (kW) |
| $W_{def}$ | Wasted work for defrosting (MJ) |
| X | Constant |

## 1. Introduction

Air-source heat pumps (ASHPs) have been used widely for space heating and cooling in many parts of the world, owing to the merits of energy-saving and environmental protection (Wang et al., 2005; Mohanraj et al., 2012). Frosting is one of the main problems with ASHPs when they work in winter. The other is the inefficient operation at low outdoor temperature. Some disadvantages created by the frosting process are as follows (Rafati Nasr et al., 2014):

- Blocked air-flow passage.
- Increase in the air-side pressure drop, the electric current and electric power to compressor and fan, and the compressor discharge temperature.
- Decrease in the air-flow rate, the compressor suction temperature and pressure, the heat transfer rate, and the heating capacity.

These disadvantages can result in the performance reduction of an ASHP unit over a short time period, or even physical damage to an ASHP unit over a long time (Yang et al., 2006; Kondepudi et al., 1990). It was found that the COP of an ASHP unit can be decreased by 35–60 %, and the heating capacity can be decreased by 30–57 % (Brian et al., 1970; Sanders, 1974; Wang et al., 2013), when most of the area of its outdoor coil was covered by frost.

Therefore, to maintain a high performance, frost must be removed from the outdoor coil surface. The ideal way is to conduct the defrosting operation based on demand. However, in practical applications, defrosting is often initiated improperly, sometimes when a 'critical' level of frosting has been reached for a long time, sometimes when no frost has occurred in the outdoor coil surface. These phenomena are defined as mal-defrosting (Wang et al., 2011), which may cause several undesirable effects for the ASHP unit, such as a large decrease in the heating capacity, a large amount of energy consumption, and uncomfortable heating conditions.

The origin of the mal-defrosting can be attributed to the current defrosting control method. Although there are many defrosting control methods for the ASHP unit, which have been investigated based on different parameters — such as Temperature–Time (T–T) (Buick et al., 1978), air pressure