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# Experimental investigation of geared domestic refrigerative dehumidifier performance in New Zealand household climates

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ABSTRACT

Small refrigerative dehumidifiers, which are commonly used in New Zealand to reduce household moisture, typically operate in relatively cool environments, outside their optimum performance envelope. This study investigates the potential for improving the low-temperature dehumidification capacity of a domestic dehumidifier using an evaporator economiser, with particular emphasis on the limitations caused by evaporator frosting. The paper reports performance measurements on a modified domestic dehumidifier which can be operated either geared with an evaporator economiser, or ungeared. An empirical heat pump model, which was calibrated using the ungeared performance data, was also used to compare the two modes. The measured results show a clear improvement in the dehumidification capacity in the geared mode at the higher temperatures tested. The performance improvement in the lower temperature tests was less than that predicted by the model due to increased evaporator frosting under gearing and to limitations in the economiser model relating to latent cooling.


# Etude expérimentale sur la performance des déshumidificateurs à engrenages des réfrigérateurs domestiques dans les zones climatiques néo-zélandaises

*Mots clés :* Déshumidificateur ; Déshumidification ; Conditionnement d'air ; Nouvelle-Zélande

## 1. Introduction

High indoor relative humidity is a major problem in many New Zealand (NZ) homes. Relative humidity values above 50% can result in the peeling of wallpaper and paint and mould can form when the relative humidity is above 80% (Cunningham, 2007). Dampness issues account for almost two thirds of all building failures in NZ (Fortes et al., 2003). Galvin (2010) identified similar problems due to high indoor humidity in UK housing, and noted falling over-night temperatures as

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**Nomenclature**

| | |
|---|---|
| $\Delta T_{DIFF}$ | quantity defined as $\Delta T_{COLD} - \Delta T_{HOT}$ [°C] |
| *MER* | moisture extraction rate [kg $h^{-1}$] |
| *SMER* | specific moisture extraction rate [kg $kW^{-1}$ $h^{-1}$] |
| *T* | temperature [°C] |
| *Greek* | |
| Δ | denotes a change in the following physical quantity |
| ε | effectiveness [–] |
| *Subscripts* | |
| A2 | economiser cold side entry position |
| A3 | economiser cold side exit position |
| COLD | cold side |
| d | dry side |
| db | dry bulb |
| EC | economiser |
| EV | evaporator |
| HOT | hot side |
| SSH | suction super-heat |
| T | total |
| *Abbreviations* | |
| CD | condenser |
| EV | evaporator |
| PHE | plate heat exchanger |

a particular cause. In addition to building problems, high indoor humidity is linked with occupant health issues. For example, dust-mites, which thrive in high humidity conditions (Cunningham, 2007), are linked with increased asthma attacks (Hyndman et al., 1994) and Howden-Chapman et al. (1999) have suggested that a number of diseases in the elderly are due to household dampness. Refrigerative dehumidifiers are used to alleviate these problems in 25% of NZ homes (Isaacs et al., 2004; Howden-Chapman et al., 1999). In June of 2005, the stock of dehumidifiers in NZ was 244,000, with 45,000 sold annually (Energy Consult Ltd, 2005).

Domestic dehumidifiers used in NZ are imported from overseas where they are normally tested at conditions quite different from those in which they operate in this country. Dehumidifier capacity is tested by the Association of Home Appliance Manufacturers (AHAM) in the range 18.3 °C–32.2 °C with a central test at 26.7 °C (Cunningham and Carrington, 2005). But dehumidifiers are typically operated at low temperatures in NZ, sometimes as low as 10 °C (Cunningham and Carrington, 2005). The NZ household energy end-use survey of 400 houses found that the average evening living room temperature was 17.9 °C (French et al., 2007) and a study of 100 Dunedin NZ homes (Lloyd et al., 2008) found that the average temperature of living areas was 14.9 °C.

This mismatch between the conditions in which the AHAM tests dehumidifier capacity and those in which these systems operate also occurs in the UK (Galbraith et al., 1986). The dehumidifiers were designed for use in a warm environment and performed poorly in the UK home environment, with ice often forming on the evaporator (Galbraith et al., 1986). Imported dehumidifiers in NZ normally have a defrost mechanism, suggesting that they also may be operating ineffectively in NZ homes.

One of the options for improving the performance of dehumidifiers is to use an evaporator economiser, or gearing, as suggested by Blundell (1979). The purpose of the economiser is to reduce the sensible load of the refrigerant evaporator in order to increase the efficiency of the dehumidifier (Doderer and Clower, 1981; Dieckmann et al., 2009). These benefits have been established for industrial scale equipment at higher temperatures (Yau and Tucker, 2003; Bannister et al., 1995; Pereira et al., 2004), but there is little published evidence for them in domestic scale equipment at household temperatures. One might expect an evaporator economiser to provide significant performance gains at lower air temperatures, because, as the temperature decreases at a fixed relative humidity, the absolute humidity falls and the fraction of sensible cooling increases. An economiser has the potential to carry some of this additional sensible cooling. On the other hand, evaporator frosting is a potential complication for a dehumidifier operating at air temperatures below 20 °C, because the dew-point is so close to the freezing point. For example, at 50% relative humidity the dew-point is approximately 10 °C below the air temperature. It is expected that gearing will exacerbate this issue because it lowers the evaporating temperature due to pre-cooling of the air entering the evaporator by the economizer. As a consequence, a geared system is likely to operate in the frosting region at a higher ambient temperature and humidity than an ungeared one.

One of the purposes of this paper is to better understand these competing effects in practice. In particular, the aim is to assess how retro-fitting an economiser to a dehumidifier affects its performance under low temperature conditions by presenting operating data for a domestic dehumidifier, adapted so that an evaporator economizer can be fitted. This allows the system to operate either as an ungeared or as a geared (i.e. with economiser) dehumidifier. We present measurements of the moisture extraction rate (*MER*) and the specific moisture extraction rate (*SMER*) of the test system with and without gearing, but no other changes. The measurements cover the range of air temperatures that domestic dehumidifiers are typically used in New Zealand, 10–25 °C.

## 2. The test system and methods

### 2.1. *Description of the test system*

The test dehumidifier, shown schematically in Fig. 1, consists of the refrigeration system from a domestic dehumidifier, which has been adapted by means of additional air ducting.

#### 2.1.1. *Refrigeration system*

The primary refrigeration system (indicated by the bold line in Fig. 1) consists of the rotary compressor (item 5), the finned-tube evaporator (item 8) and condenser (item 6), a capillary