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# MOISTURE TRANSPORT PROCESSES AND CONTROL OF RELATIVE HUMIDITY IN REFRIGERATED FACILITIES

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## ABSTRACT

Increasingly air relative humidity (RH) is becoming an important design and operational variable for refrigerated facilities. An integrated dynamic model of the main heat and moisture transfer mechanism in a refrigerated facility was developed. Specific features of the model that enabled RH to be predicted were:

- Multiple air zones to represent variation of temperature and RH with position.
- A single zone evaporator model with dehumidification based on a straight line approach to the saturation condition at the surface temperature.
- Condensation and evaporation of water from surfaces and structures in the facilities.
- Evaporator defrost assuming that a fraction of the defrost heat melts frost and the rest heats the evaporator and refrigerant mass.
- Hot gas bypass with liquid refrigerant desuperheating to prevent the compressor operating into vacuum.
- Moisture sorption by packaging associated with the product.

The model was validated against data collected from a walk-in cool store 3.3m wide by 4.4m long by 3.0m high. The cool-store was cooled by an air cooled direct expansion HFC-134a refrigeration system with electric defrost, a suction line heat exchanger and electronic evaporation pressure regulating (EPR) valve for temperature control. To mimic the different design and operating conditions extra sensible and latent heat loads were provided by the cool store lights, up to 5 kW of electric heaters, and an ultrasonic humidifier.

For the validation room trials fan speed, coil size, sensible load, latent loads and temperature set point were varied. Other conditions were held constant as far as possible and the room was operated for at least two defrost cycles.

For the coolstore the model computed about 70 ordinary differential equations and more than 160 algebraic equations which were solved using Matlab 6.5, with the ODE45 solver.

The measured and predicted store air temperature, RH, refrigerant suction and discharge temperatures and pressures showed good agreement for most of the trials during both pull-down and the mainly steady-state operation between defrosts. Differences in measured and predicted RH and refrigeration system operating conditions were largely explained by uncertainty in model input data, measurements and calibration; and imprecision of the actual refrigeration control system and particularly the hot gas bypass capacity control and the expansion valves. This suggests that the model is a useful tool for the design and optimisation of passive or active RH control strategies for refrigerated stores.

Trials were also undertaken to quantify the effect of defrost frequency on the coolstore performance. Defrost efficiency and defrost duration were both proportional to defrost interval and doubled as defrost interval increased from 6 hours to 30 hours. For short defrost intervals; temperature control was poorer due to the frequent pull-downs. For longer defrost interval the room RH was lower and temperature control was poorer due to frost induced decline of evaporator performance. The optimal defrost interval for the particular cool store was 8 to 12 hours. Overall energy use did not change significantly due to the use of EPR temperature control and the low latent heat loads used.

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## 1 INTRODUCTION

Refrigeration is a widely accepted technology worldwide; historically it played an important role in the food industry as a preservation technology. The other areas of interest include comfort air-conditioning, industrial processes and heat pump technology with air-conditioning being the leading area of application due to demand for improved quality of living worldwide. Food refrigeration processes include chilling and freezing under controlled conditions and cool ( $>0^{\circ}\text{C}$ ) and cold ( $<-10^{\circ}\text{C}$ ) storage. There are alternative preservation technologies in the food industry but these technologies tend to change the product characteristics so refrigeration is likely to remain a key technology for a long time.

Temperature control has the highest priority in the operation of a food storage facility but increasingly improved control of air relative humidity (RH) and free moisture is being demanded. In particular, relative humidity affects the rate of evaporative water loss from unpackaged foods, and the strength of paper base packaging. Free moisture (condensation or ice) in an integrated facility is a concern from quality, food safety and operational safety perspectives. Air RH also influences the performance of evaporators due to frosting and the need for defrosting.

The overall objective of this research is to quantify the mechanisms for moisture transport in refrigerated facilities as the first stage of optimum design and control of facilities from an air RH perspective. The main focus will be refrigerated storage facilities (cool stores and cold stores) using air as the heat transfer medium.