# DEVELOPMENT AND APPLICATION OF A MODEL FOR ESTIMATING THE EFFICIENCY AND CARBON FOOTPRINT OF REFRIGERATION SYSTEMS BY CONSIDERING THE IMPACT OF FOULING ON CONDENSER PERFORMANCE.

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## Abstract

Refrigeration systems on industrial plants such as dairy processing facilities are major consumers of energy. The higher the efficiency of these systems the lower the cost of electricity and subsequent carbon emissions from electricity produced from fossil fuels.

Traditionally chemical treatment of cooling loops for refrigeration systems has been undertaken in a reactive manner. The treatment regime is only changed when there is a detrimental effect on the system such as the development of corrosion, scale or biofilm. Often this results in medium to long term losses in efficiency before the situation is rectified.

A predictive model has been developed that has the potential to allow real time control of chemical treatment for cooling loops. The model predicts the film thickness for common fouling materials found in cooling systems and the heat transfer efficiency losses associated with this fouling. Such a predictive model can be used in conjunction with monitoring of the apparent heat transfer efficiency to infer the film thickness and therefore guide chemical treatment programmes.

The model was tested against foulant efficiency relationships published by Qureshi and Zubair, Macleod - Smith and The Carrier Refrigeration Handbook. In all three cases the predictive model produced results that agreed with the results for each of these sources.

The model was also tested using the reticulated ammonia refrigeration system at Fonterra Whareroa. Psychrometric, climatic, data logged temperatures and sensor data from the Whareroa system database were used to calculate the efficiency of one of the refrigeration system's condensers (EC1). Resulting heat of rejection values and an estimated thermal conduction constant (k) based on a deposit analysis were used as inputs for the model to calculate the predicted foulant film thickness. Inspection of the evaporative condenser during the June

2010 shut determined the model had predicted the foulant film thickness to within 6% of the measured 1.62mm.

An energy balance was completed on the reticulated ammonia refrigeration system at Whareroa to provide a better understanding of the system dynamics. Unfortunately it was not possible to obtain complete agreement between heat load and heat of rejection for the ammonia system – the level of agreement ranged from 8.9 to 30.2%. This variability seems to be explained by incomplete monitoring of the condenser fan speed.

Although the predictive model produced results that agreed with three other researchers the level of efficiency determined by the model is dependent on the accuracy of a number of variables including the thermal conductivity value (k-value) chosen for the foulant material creating the insulating film on the evaporative condenser coils. This is easy to determine for a pure compound but there is no model available to predict the thermal conductivity of a composite fouling material. Consequently this would be one improvement that could be made to the model in the future.

Model capabilities would also be enhanced by incorporating the commercial version of EES. This would allow the model to be automated for 'on-line' real time system monitoring.

The evaporative condensers at Fonterra Whareroa that were used for this study are 'base load' heat of rejection units, i.e. they are always fully loaded or turned off. Consequently it is recommended that the model is further tested on refrigeration systems with variable loads to determine the accuracy for partial load situations, and also on systems with a range of fouling materials.

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