

Modeling and Testing of Water-Coupled Microchannel Gas Coolers for Natural Refrigerant Heat Pumps

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An experimental and analytical study on the performance of a compact, microchannel water-carbon dioxide gas cooler was conducted. The gas cooler design under investigation used an array of serpentine microchannel tubes to carry refrigerant. The serpentine tubes were wrapped around water passages containing offset strip fins. The geometry led to a generally counterflow configuration between the two fluids. The test facility consisted of one or two CO₂ compressors, a water-coupled evaporator, and the test gas coolers, together with the requisite data acquisition and control systems. Data were obtained for three gas coolers of the same design, but different sizes. The gas coolers were tested for a wide range of refrigerant and water inlet conditions using the carbon dioxide heat pump test facility. Measured heating capacity for the three different gas coolers ranged from 2.0 to 6.5 kW. An analytical model was developed to predict the heat transfer and pressure drop performance of the gas cooler under varying inlet conditions. A segmented approach was used to account for the steep gradients in the thermodynamic and transport properties of the supercritical carbon dioxide through the gas cooler. The model predicted heating capacity with an average absolute error of 7.0 % for all data points obtained using the three different gas cooler sizes. Refrigerant- and water-side pressure drops were under predicted by the model. In general, the refrigerant-side resistance was the limiting factor in heat transfer for all cases. The results of this study can be used to optimize gas cooler design for a variety of CO₂ heat pump applications over a wide range of operating conditions. The effect of changing physical heat exchanger parameters such as fin dimensions, microchannel size or number of water passes can be predicted without the need for costly prototype development and testing.