A model for Improvement of Water Heating Heat Exchanger Designs for Residential Heat Pump Water Heaters

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ABSTRACT

Heat pump water heaters are a promising technology to reduce energy use and greenhouse gas emissions. A key component is the water heating heat exchanger. Two multi-zone models of the double-wall counter-current flow heat exchanger (condenser and gas cooler models) for residential air-source heat pump water heaters were developed. These models were validated against available data in the open literature. They predicted heat exchanger size within -0.8% for a HFC-134a (with oil) condenser and within -14% for a CO_2 gas cooler. The multi-zone model was significantly more accurate than one and three zone models. The models for a R410A subcritical heat pump and a CO_2 transcritical heat pump were used to investigate the effect of key design parameters by varying water or refrigerant flow channel size for three water heating heat exchanger configurations: circular tube-in-tube, flat tube-on-tube, and twisted tube-in-tube. For the circular tube-in-tube configuration, refrigerant flow in the annulus (case *B*) performed better than refrigerant flow in the inner tube. The optimal flow channels for the circular tube-in-tube configuration case *B* with 0.1 mm thick air gap in the double wall were found to be d_i (inside diameter of the 1st tube) of 8 mm and annulus [D_i (inside diameter of the 3rd tube) $-d_2$ (outside diameter of the 2nd tube)] of 1.5 mm for R410A and d_i of 7 mm and $D_i - d_2$ of 1.0 mm for R744. The optimal flow channels for the flat tube-on-tube configuration with b_{1i} (major length of the refrigerant flow channel) and b_{2i} (major length of the water flow channel) both of 9 mm were found to be a_{1i} (minor length of the refrigerant flow channel) and a_{2i} (minor length of the water flow channel) of 1.5 mm for R410A and a_{1i} of 1 mm and a_{2i} of 1.5 mm for R744. The optimal flow channels for the twisted tube-in-tube configuration were found to be d_i of 7.94 mm and d_1 (original inside diameter of twisted tube) of 12.7 mm for R410A and d_i of 6.35 mm and d_1 of 9.525 mm for R744. At the optimal flow channel size in each configuration, heat exchanger weight of the flat tube-on-tube was lower than the circular tube-in-tube by about 34.4% for R410A and by about 66.6% for R744. This was mainly due to elimination of the air gap resistance with the tube-on-tube configuration. Heat exchanger length, weight, and pumping power of the twisted tube-in-tube with 94% contact were significantly lower than the flat tube-on-tube by about 85%, 62%, and 97% respectively for R410A and by about 65%, 35.7%, and 98% respectively for R744. Overall, the flat tube-on-tube and the twisted tube-in-tube configurations are most promising for the water heating heat exchanger in terms of the lowest investment and running costs respectively.

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